File Ref.No.59902/GA - IV - J3/2019/Admn

UNIVERSITY OF CALICUT

Abstract

General and Academic IV- Faculty of Science- Scheme and Syllabus of B.Sc.Mathematics Honours Programme -in tune with the CUFYUGP Regulations 2024, with effect from 2024 admission - Approved-Subject to ratification by the Academic Council-Implemented- Orders Issued

G & A - IV - J

U.O.No. 10025/2024/Admn — Dated, Calicut University.P.O, 25.06.2024

Read:-1.U.O.No. 3103/2024/Admn dated 22.02.2024.
2.Revised minutes of the meeting of the Board of Studies in Mathematics (U G) held on 19.06.2024.
3.Remarks of the Dean, Faculty of Science dated 22.06.2024.
4. Orders of the Vice Chancellor in the file of even no dated 23.06.2024.

ORDER

1. The Regulations of Calicut University Four Year UG Programmes (CUFYUGP Regulations 2024) for Affiliated Colleges, has been implemented with effect from 2024 admission, vide paper read as (1) .
2. The Board of Studies in Mathematics (U G) in the meeting held on 19.06.2024 vide paper read as (2) , has approved the Scheme and Syllabus of B.Sc.Mathematics Honours Programme in tune with CUFYUGP Regulations 2024 ,with effect from 2024 admission .
3. The Dean, Faculty of Science vide paper read as (3) ,has approved the minutes of the meeting of the Board of Studies in Mathematics (U G) held on 19.06.2024.
4. Considering the urgency, the Vice Chancellor has approved the minutes of the meeting of the Board of Studies in Mathematics (U G) held on 19.06.2024 and accorded sanction to implement the Scheme and Syllabus of B.Sc.Mathematics Honours programme with effect from 2024 admission, subject to ratification by the Academic Council.
5. The Scheme and Syllabus of B.Sc.Mathematics Honours programme in tune with CUFYUGP Regulations 2024, is thus implemented with effect from 2024 admission,subject to ratification by the Academic Council. .
6. Orders are issued accordingly. (Syllabus appended)

Ajayakumar T.K

Assistant Registrar

To

1.Principals of all affiliated colleges 2.DR, CDOE
Copy to: PS to VC/PA to PVC/ PA to Registrar/PA to CE/DR, DOA/JCE I/JCE IV/DoA/EX and EG Sections/GA I F/CHMK Library/Information Centres/SF/DF/FC

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Section Officer

UNIVERSITY OF CALICUT

B.Sc. MATHEMATICS HONOURS

(MAJOR, MINOR AND GENERAL FOUNDATION COURSES)

SYLLABUS & MODEL QUESTION PAPERS

w.e.f. 2024 Admission Onwards

(CUFYUGP Regulations 2024)

B.Sc. MATHEMATICS HONOURS

(MAJOR, MINOR AND GENERAL FOUNDATION COURSES)

SYLLABUS

PROGRAMME OUTCOMES (PO):

At the end of the graduate programme at Calicut University, a student would:

PO1	**Knowledge Acquisition:** **Demonstrate a profound understanding of knowledge trends and their impact on the chosen discipline of study.**
PO2	**Communication, Collaboration, Inclusiveness, and Leadership:** **Become a team player who drives positive change through effective communication, collaborative acumen, transformative leadership, and a dedication to inclusivity.**
PO3	**Professional Skills:** **Demonstrate professional skills to navigate diverse career paths with confidence and adaptability.**
PO4	**Digital Intelligence:** **Demonstrate proficiency in varied digital and technological tools to understand and interact with the digital world, thus effectively processing complex information.**
PO5	**Scientific Awareness and Critical Thinking:** **Emerge as an innovative problem-solver and impactful mediator, applying scientific understanding and critical thinking to address challenges and advance sustainable solutions.**
PO6	**Human Values, Professional Ethics, and Societal and Environmental Responsibility:** **Become a responsible leader, characterized by an unwavering commitment to human values, ethical conduct, and a fervent dedication to the well-being of society and the environment.**
PO7	**Research, Innovation, and Entrepreneurship:** **Emerge as a researcher and entrepreneurial leader, forging collaborative partnerships with industry, academia, and communities to contribute enduring solutions for local, regional, and global development.**

PROGRAMME SPECIFIC OUTCOMES (PSO):

At the end of the B.Sc. Mathematics Honours Programme at Calicut University, a student would:

Programme Specific Outcome (Major)	
PSO1	**Advanced Mathematical Knowledge: Understand core mathematical abstract concepts/theories and demonstrate a high level of mathematical rigor and logical reasoning**
PSO2	**Modelling and Problem-Solving Skills: Apply mathematical techniques to solve complex problem situations across various domains and interpret the result, demonstrating critical thinking and analytical skills.**
PSO3	**Computational Proficiency: Apply mathematical understanding to solve problems and explicitly work out step by step either by self or by software based computational tools.**
PSO4	**Research Aptitude: Analyse mathematical abstract ideas effectively and present/communicate mathematical arguments and solutions in a clear and coherent manner leading to research in Mathematics**
Programme Specific Outcome (Minor)	
PSO5	**Mathematics Proficiency: Demonstrate a strong understanding of mathematical principles and problem solving**
PSO6	**Interdisciplinary Integration: Integrate Mathematics with relevant disciplines to develop more holistic approaches to solve problems, leading to innovative solutions and advancements in various fields.**

MINIMUM CREDIT REQUIREMENTS OF THE DIFFERENT PATHWAYS

IN THE THREE-YEAR PROGRAMME IN CUFYUGP

Sl. No.	Academic Pathway	Major	Minor/ Other Disciplines	Foundation Courses AEC: 4 MDC: 3 SEC: 3 VAC: 3	Intern-ship	Total Credits	Example
		Each course has 4 credits		Each course has 3 credits			
1	Single Major (A)	68 (17 courses)	24 (6 courses)	39 (13 courses)	2	133	Major: Mathematics + six courses in different disciplines in different combinations
2	Major (A) with Multiple Disciplines (B, C)	68 (17 courses)	12 + 12 (3 + 3 = 6 courses)	39 (13 courses)	2	133	Major: Mathematics + Statistics and Computer Science
3	Major (A) with Minor (B)	68 (17 courses)	24 (6 courses)	39 (13 courses)	2	133	Major: Mathematics Minor: Physics
4	Major (A) with Vocational Minor (B)	68 (17 courses)	24 (6 courses)	39 (13 courses)	2	133	Major: Mathematics Vocational Minor: Data Analysis
5	Double Major	A: 48	-	12 + 9+9 +9	2	133	

	(A, B)	(12 courses) B: 44 (11 courses)	The 24 credits in the Minor stream are distributed between the two Majors. 2 MDC, 2 SEC, 2 VAC and the Internship should be in Major A. Total credits in Major A should be 48 + 20 = 68 (nearly 50% of 133) 1 MDC, 1 SEC and 1 VAC should be in Major B. Total credits in Major B should be 44 + 9 = 53 (40% of 133)		Mathematics and Physics double major
Exit with UG Degree / Proceed to Fourth Year with 133 Credits					

B.Sc. MATHEMATICS HONOURS PROGRAMME

COURSE STRUCTURE FOR PATHWAYS 1 – 4

1. Single Major **2. Major with Multiple Disciplines**

3. Major with Minor **4. Major with Vocational Minor**

Semester	Course Code	Course Title	Total Hours	Hours/ Week	Credits	Marks		
						Internal	External	Total
1	MAT1CJ101/ MAT1MN100	Core Course 1 in Major – Differential Calculus	60	4	4	30	70	100
		Minor Course 1	60/ 75	4/ 5	4	30	70	100
		Minor Course 2	60/ 75	4/ 5	4	30	70	100
	ENG1FA101 (2)	Ability Enhancement Course 1– English (with Theory T & Practicum P)	30+30 (T+P)	2+2 (T+P)	2+1 (T+P)	25	50	75
		Ability Enhancement Course 2 – Additional Language	45	3	3	25	50	75
		Multi-Disciplinary Course 1 – Other than Major	45	3	3	25	50	75
		Total		22/ 24	21			525
2	MAT2CJ101/ MAT2MN100	Core Course 2 in Major – Integral Calculus	60	4	4	30	70	100
		Minor Course 3	60/ 75	4/ 5	4	30	70	100
		Minor Course 4	60/ 75	4/ 5	4	30	70	100
	ENG2FA103 (2)	Ability Enhancement Course 3– English	30+30	2+2	2+1	25	50	75

		Ability Enhancement Course 4 – Additional Language	45	3	3	25	50	75
		Multi-Disciplinary Course 2 – Other than Major	45	3	3	25	50	75
		Total		22/ 24	21			525
3	MAT3CJ201	Core Course 3 in Major– Multivariable Calculus (with Theory T & Practicum P)	45+30 (T+P)	3+2 (T+P)	3+1 (T+P)	30	70	100
	MAT3CJ202/ MAT3MN200	Core Course 4 in Major– Matrix Algebra	60	4	4	30	70	100
		Minor Course 5	60/ 75	4/ 5	4	30	70	100
		Minor Course 6	60/ 75	4/ 5	4	30	70	100
		Multi-Disciplinary Course 3 – Kerala Knowledge System	45	3	3	25	50	75
	ENG3FV108 (2)	Value-Added Course 1 – English	45	3	3	25	50	75
		Total		23/ 25	22			550
4	MAT4CJ203	Core Course 5 in Major –Real Analysis I	45+30	3+2	3+1	30	70	100
	MAT4CJ204	Core Course 6 in Major – Basic Linear Algebra	60	4	4	30	70	100
	MAT4CJ205	Core Course 7 in Major – Fundamentals of Python and SageMath (with Theory T & Practical P)	45+30 (T+P)	3+2 (T+P)	3+1 (T+P)	30	70	100

	ENG4FV109 (2)	Value-Added Course 2 – English	45	3	3	25	50	75
		Value-Added Course 3 – Additional Language	45	3	3	25	50	75
	ENG4FS111 (2)	Skill Enhancement Course 1 – English	30+30	2+2	2+1	25	50	75
		Total		24	21			525
5	MAT5CJ301	Core Course 8 in Major –Real Analysis II	45+30	3+2	3+1	30	70	100
	MAT5CJ302	Core Course 9 in Major –Abstract Algebra I	60	4	4	30	70	100
	MAT5CJ303	Core Course 10 in Major – Complex Analysis I	60	4	4	30	70	100
		Elective Course 1 in Major	60	4	4	30	70	100
		Elective Course 2 in Major	60	4	4	30	70	100
		Skill Enhancement Course 2	45	3	3	25	50	75
		Total		24	23			575
6	MAT6CJ304/ MAT8MN304	Core Course 11 in Major – Complex Analysis II (For choosing this course as minor from other departments, students must have acquainted themselves with necessary contents of MAT5CJ303, as prerequisites)	60	4	4	30	70	100
	MAT6CJ305/ MAT8MN305	Core Course 12 in Major – Elementary Number Theory	60	4	4	30	70	100

	MAT6CJ306/ MAT8MN306	Core Course 13 in Major – Methods of Differential Equations	60	4	4	30	70	100
		Elective Course 3 in Major	60	4	4	30	70	100
		Elective Course 4 in Major	60	4	4	30	70	100
	MAT6FS113	Skill Enhancement Course 3 – Data Science with Python	45	3	3	25	50	75
	MAT6CJ349	Internship in Major (Credit for internship to be awarded only at the end of Semester 6)	60		2	50	-	50
		Total		23	25			625
Total Credits for Three Years					133			3325
7	MAT7CJ401	Core Course 14 in Major – Mathematical Analysis	45+30	3+2	3+1	30	70	100
	MAT7CJ402	Core Course 15 in Major –General Topology	45+30	3+2	3+1	30	70	100
	MAT7CJ403	Core Course 16 in Major – Abstract Algebra II	45+30	3+2	3+1	30	70	100
	MAT7CJ404	Core Course 17 in Major – Linear Algebra	45+30	3+2	3+1	30	70	100
	MAT7CJ405	Core Course 18 in Major – Discrete Mathematics	45+30	3+2	3+1	30	70	100
		Total		25	20			500
8	MAT8CJ406 / MAT8MN406	Core Course 19 in Major – Basic Measure Theory	45+30	3+2	3+1	30	70	100

	MAT8CJ407 / MAT8MN407	Core Course 20 in Major – Number Theory	60	4	4	30	70	100
	MAT8CJ408 / MAT8MN408	Core Course 21 in Major – Differential Equations	60	4	4	30	70	100
	OR (instead of Core Courses 19 to 21 in Major)							
	MAT8CJ449	Project (in Honours programme)	360*	13*	12	90	210	300
	OR (instead of Core Courses 19 to 21 in Major)							
	MAT8CJ499	Project (in Honours with Research programme)	360*	13*	12	90	210	300
		Elective Course 5 in Major / Minor Course 7	60	4	4	30	70	100
		Elective Course 6 in Major / Minor Course 8	60	4	4	30	70	100
		Elective Course 7 in Major / Minor Course 9 / Major Course in any Other Discipline	60	4	4	30	70	100
	OR (instead of Elective Course 7 in Major, in the case of Honours with Research Programme)							
	MAT8CJ489	Research Methodology in Mathematics	60	4	4	30	70	100
		Total		25	24			600
Total Credits for Four Years					177			4425

* **The teacher should have 13 hrs/week of engagement (the hours corresponding to the three core courses) in the guidance of the Project(s) in Honours programme and Honours with Research programme, while each student should have 24 hrs/week of engagement in the Project work. Total hours are given based on the student's engagement.**

CREDIT DISTRIBUTION FOR PATHWAYS 1 – 4

1. Single Major **2. Major with Multiple Disciplines**

3. Major with Minor **4. Major with Vocational Minor**

Semester	Major Courses	Minor Courses	General Foundation Courses	Internship/ Project	Total
1	4	4 + 4	3 + 3 + 3	-	21
2	4	4 + 4	3 + 3 + 3	-	21
3	4 + 4	4 + 4	3 + 3	-	22
4	4 + 4 + 4	-	3 + 3 + 3	-	21
5	4 + 4 + 4 + 4 + 4	-	3	-	23
6	4 + 4 + 4 + 4 + 4	-	3	2	25
Total for Three Years	68	24	39	2	133
7	4 + 4 + 4 + 4 + 4	-	-	-	20
8	4 + 4 + 4	4 + 4 + 4	-	12*	24
* Instead of three Major courses					
Total for Four Years	88 + 12 = 100	36	39	2	177

DISTRIBUTION OF MAJOR COURSES IN Mathematics

FOR PATHWAYS 1 – 4

1. Single Major **2. Major with Multiple Disciplines**

3. Major with Minor **4. Major with Vocational Minor**

Semester	Course Code	Course Title	Hours/ Week	Credits
1	MAT1CJ101 /MAT1MN100	Core Course 1 in Major – Differential Calculus	4	4
2	MAT2CJ101 /MAT2MN100	Core Course 2 in Major – Integral Calculus	4	4
3	MAT3CJ201	Core Course 3 in Major – Multivariable Calculus	5	4
	MAT3CJ202 /MAT3MN200	Core Course 4 in Major – Matrix Algebra	4	4
4	MAT4CJ203	Core Course 5 in Major – Real Analysis I	5	4
	MAT4CJ204	Core Course 6 in Major – Basic Linear Algebra	4	4
	MAT4CJ205	Core Course 7 in Major – Fundamentals of Python and SageMath (P)	5	4
5	MAT5CJ301	Core Course 8 in Major – Real Analysis II	5	4
	MAT5CJ302	Core Course 9 in Major – Abstract Algebra I	4	4
	MAT5CJ303	Core Course 10 in Major – Complex Analysis I	4	4
		Elective Course 1 in Major	4	4
		Elective Course 2 in Major	4	4
6	MAT6CJ304 / MAT8MN304	Core Course 11 in Major – Complex Analysis II	4	4

	MAT6CJ305 /MAT8MN305	Core Course 12 in Major – Elementary Number Theory	4	4
	MAT6CJ306 /MAT8MN306	Core Course 13 in Major – Methods of Differential Equations	4	4
		Elective Course 3 in Major	4	4
		Elective Course 4 in Major	4	4
	MAT6CJ349	Internship in Major	-	2
Total for the Three Years				70
7	MAT7CJ401	Core Course 14 in Major - Mathematical Analysis	5	4
	MAT7CJ402	Core Course 15 in Major – General Topology	5	4
	MAT7CJ403	Core Course 16 in Major – Abstract Algebra II	5	4
	MAT7CJ404	Core Course 17 in Major – Linear Algebra	5	4
	MAT7CJ405	Core Course 18 in Major – Discrete Mathematics	5	4
	MAT8CJ406 / MAT8MN406	Core Course 19 in Major – Basic Measure Theory	5	4
	MAT8CJ407 / MAT8MN407	Core Course 20 in Major – Number Theory	4	4
	MAT8CJ408 / MAT8MN408	Core Course 21 in Major – Differential Equations	4	4
	OR (instead of Core Courses 19 - 21 in Major)			
	MAT8CJ449	Project (in Honours programme)	13	12
	MAT8CJ499	Project (in Honours with Research programme)	13	12
		Elective Course 5 in Major	4	4
		Elective Course 6 in Major	4	4

8		Elective Course 7 in Major	4	4
	OR (instead of Elective course 7 in Major, in Honours with Research programme)			
	MAT8CJ489	Research Methodology in Mathematics	4	4
Total for the Four Years				114

ELECTIVE COURSES IN MATHEMATICS WITH SPECIALISATION

Group No.	Sl. No	Course Code	Title	Semester	Total Hrs	Hrs/ Week	Credits	Marks		
								Internal	External	Total
1		**MATHEMATICAL COMPUTING**								
	1	MAT5EJ301 (1)	Mathematical Foundations of Computing	5	60	4	4	30	70	100
	2	MAT5EJ302 (1)	Data Structures and Algorithms	5	60	4	4	30	70	100
	3	MAT6EJ301 (1)	Numerical Analysis	6	60	4	4	30	70	100
	4	MAT6EJ302 (1)	Mathematics for Digital Images	6	60	4	4	30	70	100
2		**DATA SCIENCE***								
	1	MAT5EJ303 (2)	Convex Optimization	5	60	4	4	30	70	100
	2	MAT5EJ304 (2)	Applied Probability	5	60	4	4	30	70	100
	3	MAT6EJ303 (2)	Machine Learning I	6	60	4	4	30	70	100
	4	MAT6EJ304 (2)	Machine Learning II	6	60	4	4	30	70	100

ELECTIVE COURSES IN MATHEMATICS WITH NO SPECIALISATION

Sl. No.	Course Code	Title	Semester	Total Hrs	Hrs/ Week	Credits	Marks		
							Internal	External	Total
1	MAT5EJ305	Higher Algebra.	5	60	4	4	30	70	100
2	MAT5EJ306	Linear Programming	5	60	4	4	30	70	100
3	MAT6EJ305	Topology of Metric Spaces.	6	60	4	4	30	70	100
4	MAT6EJ306	Introduction to Fourier Analysis	6	60	4	4	30	70	100
5	MAT8EJ401	Advanced Topology	8	60	4	4	30	70	100
6	MAT8EJ402	Partial Differential Equations	8	60	4	4	30	70	100
7	MAT8EJ403	Rings and Modules	8	60	4	4	30	70	100
8	MAT8EJ404	Coding Theory	8	60	4	4	30	70	100
9	MAT8EJ405	Foundations of Mathematics	8	60	4	4	30	70	100
10	MAT8EJ406	Operations Research	8	60	4	4	30	70	100
11	MAT8EJ407	Cryptography	8	60	4	4	30	70	100
12	MAT8EJ408	Introduction to Fractals	8	60	4	4	30	70	100

*These courses are beyond the minimum course requirements and their syllabi are under preparation and will be updated soon.

**

GROUPING OF MINOR COURSES IN MATHEMATICS

Group No.	Sl. No.	Course Code	Title	Semester	Total Hrs	Hrs/ Week	Credits	Marks		
								Internal	External	Total
1		Minor Group I - Mathematical Methods for Science								
	1	MAT1MN101	Calculus	1	60	4	4	30	70	100
	2	MAT2MN101	Differential Equations and Matrix Theory	2	60	4	4	30	70	100
	3	MAT3MN201	Calculus of Several Variables	3	60	4	4	30	70	100
2		Minor Group II – Foundations for Mathematical Applications								
	1	MAT1MN102	Differential Calculus	1	60	4	4	30	70	100
	2	MAT2MN102	Calculus and Matrix Algebra	2	60	4	4	30	70	100
	3	MAT3MN202	Differential Equations and Fourier Series	3	60	4	4	30	70	100
3		Minor Group III - Integrated Mathematical Methods								
	1	MAT1MN103	Basic Calculus	1	60	4	4	30	70	100
	2	MAT2MN103	Analysis and Some Counting Principles	2	60	4	4	30	70	100
	3	MAT3MN203	Matrix Algebra and Vector Calculus	3	60	4	4	30	70	100

4		Minor Group IV - Discrete Mathematics								
	1	MAT1MN104	Mathematical Logic, Set Theory and Combinatorics	1	60	4	4	30	70	100
	2	MAT2MN104	Graph theory and Automata	2	60	4	4	30	70	100
	3	MAT3MN204	Boolean Algebra and System of Equations	3	60	4	4	30	70	100
		Minor Group V – Linear Algebra								
	1	MAT1MN105	Matrix Theory	1	60	4	4	30	70	100
	2	MAT2MN105	Vector Spaces and Linear Transformations	2	60	4	4	30	70	100
	3	MAT3MN205	Optimization Techniques	3	60	4	4	30	70	100
		Minor Group VI – Mathematical Economics								
	1	MAT1MN106	Principles of Micro Economics	1	60	4	4	30	70	100
	2	MAT2MN106	Optimization Techniques in Economics	2	60	4	4	30	70	100
	3	MAT3MN206	Applied Mathematics for Economic Analysis	3	60	4	4	30	70	100

*** Students from other disciplines can choose up to one group (comprising three courses in total) from the first three options, as these groups share partially overlapping topics.**

**** Students from major mathematics can enrol only in minor group VI or a vocational minor group as per the clauses 7.2.12 and 7.2.13 (amended).**

GROUPING OF VOCATIONAL MINOR COURSES IN MATHEMATICS

VOCATIONAL MATHEMATICS – DATA ANALYTICS										
								Marks		
Group No.	Sl. No.	Course Code	Title	Semester	Total Hrs	Hrs/ Week	Credits	Internal	External	Total
1		**Introduction to AI**								
	1	MAT1VN 101	Python Programming	1	75	5	4	30	70	100
	2	MAT2VN 101	Linear Algebra for Machine Learning	2	75	5	4	30	70	100
	3	MAT3VN 201	Introduction to Machine Learning	3	75	5	4	30	70	100
	4	MAT8VN 401	Introduction to Artificial Intelligence	8	75	5	4	30	70	100
2	**Introduction to Data Science**									
	1	MAT1VN 102	Statistics for Data Science	1	75	5	4	30	70	100
	2	MAT2VN 102	R Programming	2	75	5	4	30	70	100
	3	MAT3VN 202	Data Mining	3	75	5	4	30	70	100
	4	MAT8VN 402	Data Visualization	8	75	5	4	30	70	100

(i). Students in Single Major pathway can choose course/courses from any of the Minor/ Vocational Minor groups offered by a discipline other than their Major discipline.

(ii). Students in the Mathematics with Multiple Disciplines pathway who wish to choose a minor from within the same department are limited to selecting either the sixth minor group (Mathematical Economics) or one of the vocational minor groups listed above as one of their multiple disciplines. For their second multiple discipline choice, students must select a Minor or Vocational Minor group offered by a discipline other than mathematics. If students opt for Mathematical Economics or another vocational group from mathematics, the title of that group will serve as their multiple discipline title.

(iii). Students in Major with Minor pathway can choose all the courses from any two Minor groups offered by a discipline other than their Major discipline. If the students from other major disciplines choose any two Minor groups in Mathematics as given above, then the title of the Minor will be Mathematics.

(iv). Students in Major with Vocational Minor pathway can choose all the courses from any two Vocational Minor groups offered by a discipline other than their Major discipline. If the students from other Major disciplines choose any two Vocational Minor groups in Mathematics as given above, then the title of the Vocational Minor will be Data Analytics.

DISTRIBUTION OF GENERAL FOUNDATION COURSES IN MATHEMATICS

Semester	Course Code	Course Title	Total Hours	Hours / Week	Credits	Marks		
						Internal	External	Total
1	MAT1FM105(1)	Multi-Disciplinary Course 1 - Matrices and Basics of Probability theory	45	3	3	25	50	75
1	MAT1FM105(2)	Multi-Disciplinary Course 2 -Mathematics for Competitive Examinations - Part I	45	3	3	25	50	75
2	MAT2FM106(1)	Multi-Disciplinary Course 3 -Graph Theory and LPP	45	3	3	25	50	75
2	MAT2FM106(2)	Multi-Disciplinary Course 4 – Mathematics for Competitive Examinations - Part II	45	3	3	25	50	75

3	MAT3FV109(1)	Value-Added Course 1 - History of Mathematics	45	3	3	25	50	75
3	MAT3FV109(2)	Value-Added Course 2 - Computational Logic	45	3	3	25	50	75
4	MAT4FV110(1)	Value-Added Course 3 - Statistics and Mathematics with R	45	3	3	25	50	75
4	MAT4FV110(2)	Value-Added Course 4 - The Mathematical Practices of Medieval Kerala	45	3	3	25	50	75
5	MAT5FS112	Skill Enhancement Course 2 - Mathematical Type Setting System - LaTeX	45	3	3	25	50	75
6	MAT6FS113	Skill Enhancement Course 3 - Data Science with Python	45	3	3	25	50	75

COURSE STRUCTURE FOR BATCH A1(B2)

IN PATHWAY 5: DOUBLE MAJOR

A1: 68 credits in Mathematics (Major A) ***B1: 68 credits in Major B***

A2: 53 credits in Mathematics (Major A) ***B2: 53 credits in Major B***

The combinations available to the students: (A1 & B2), (B1 & A2)

Note: Unless the batch is specified, the course is for all the students of the class

Semester	Course Title	Total Hours	Hours/ Week	Credits	Marks		
					Internal	External	Total
1	Core Course 1 in Major Mathematics – Differential Calculus	60	4	4	30	70	100
	Core Course 1 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 2 in Major Mathematics – Matrix Algebra (for batch A1 only)	60	4	4	30	70	100
	Ability Enhancement Course 1 – English	30+30	2+2	2+1	25	50	75
	Ability Enhancement Course 2 – Additional Language	45	3	3	25	50	75
	Multi-Disciplinary Course 1 in Mathematics – Matrices and Basics of Probability theory *Or* Mathematics for Competitive Exams – Part I (for batch A1 only)	45	3	3	25	50	75
	Total		24/ 25	21			525

2	Core Course 3 in Major Mathematics – Integral Calculus	60	4	4	30	70	100
	Core Course 2 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 3 in Major B – (for batch B2 only)	60/ 75	4/ 5	4	30	70	100
	Ability Enhancement Course 3 – English	30+30	2+2	2+1	25	50	75
	Ability Enhancement Course 4 – Additional Language	45	3	3	25	50	75
	Multi-Disciplinary Course 2 in Mathematics – Graph Theory and LPP *Or* Mathematics for Competitive Exams – Part II	45	3	3	25	50	75
	Total		23 / 25	21			525
3	Core Course 4 in Major Mathematics – Multivariable Calculus.	75	5	4	30	70	100
	Core Course 5 in Major Mathematics – Basic Linear Algebra	60	4	4	30	70	100
	Core Course 4 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 5 in Major B	60/ 75	4/ 5	4	30	70	100
	Multi-Disciplinary Course 1 in B	45	3	3	25	50	75

	Value-Added Course 1 in Mathematics – History of Mathematics *Or* Computational Logic (for batch A1 only)	45	3	3	25	50	75
	Total		23 / 25	22			550
4	Core Course 6 in Major Mathematics – Real Analysis	45+30	3+2	2+2	30	70	100
	Core Course 6 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 7 in Major Mathematics - Abstract Algebra I	60	4	4	30	70	100
	Value-Added Course 2 in Mathematics – Statistics and Mathematics with R *Or* The Mathematical Practices of Medieval Kerala	45	3	3	25	50	75
	Value-Added Course 1 in B	45	3	3	25	50	75
	Skill Enhancement Course 1 in Mathematics – Fundamentals of Python and SageMath	30+30	2+2	3	25	50	75
	Total		23/ 24	21			525
5	Core Course 8 in Major – Complex Analysis	45+30	3+2	2+2	30	70	100
	Core Course 7 in Major B –	60/ 75	4/ 5	4	30	70	100

	Core Course 9 in Major Mathematics – Methods of Differential Equations (for batch A1 only)	60	4	4	30	70	100
	Elective Course 1 in Major Mathematics	60	4	4	30	70	100
	Elective Course 1 in Major B	60	4	4	30	70	100
	Skill Enhancement Course 1 in B	45	3	3	25	50	75
	Total		24/ 25	23			575
6	Core Course 10 in Major Mathematics – Elementary Number Theory	60	4	4	30	70	100
	Core Course 8 in Major B –	60/ 75	4/ 5	4	30	70	100
	Core Course 9 in Major B – (for batch B2 only)	60	4	4	30	70	100
	Elective Course 2 in Major Mathematics	60	4	4	30	70	100
	Elective Course 2 in Major B	60	4	4	30	70	100
	Skill Enhancement Course 2 in Mathematics – Mathematical Type Setting System - LaTeX (for batch A1 only)	45	3	3	25	50	75
	Internship in Major Mathematics (Credit for internship to be awarded only at the end of Semester 6)	60		2	50	-	50
	Total		24/ 25	25			625
				133			3325

CREDIT DISTRIBUTION FOR BATCH A1 (B2)

IN PATHWAY 5: DOUBLE MAJOR

Semester	Major Courses in Mathematics	General Foundation Courses in Mathematics	Internship/ Project in Mathematics	Majo Courses in B	General Foundation Courses in B	AEC	Tota l
1	4 + 4	3	-	4	-	3 + 3	21
2	4	3	-	4 + 4	-	3 + 3	21
3	4 + 4	3	-	4 + 4	3	-	22
4	4 + 4	3 + 3	-	4	3	-	21
5	4 + 4 + 4	-	-	4 + 4	3	-	23
6	4 + 4	3	2	4 + 4 + 4	-	-	25
Total for Three Years	48	18	2	44	9	12	133
	68			53		12	133
	Major Courses in Mathematics	Minor Courses					
7	4 + 4 + 4 + 4 + 4	-			-	-	20
8	4 + 4 + 4	4 + 4 + 4	12*		-	-	24
* Instead of three Major courses							
Total for Four Years	88 + 12 = 100	12					177

COURSE STRUCTURE FOR BATCH B1(A2)

IN PATHWAY 5: DOUBLE MAJOR

A1: 68 credits in Mathematics (Major A) ***B1: 68 credits in Major B***

A2: 53 credits in Mathematics (Major A) ***B2: 53 credits in Major B***

Note: Unless the batch is specified, the course is for all the students of the class

Semester	Course Title	Total Hours	Hours/ Week	Credits	Marks		
					Internal	External	Total
1	Core Course 1 in Major Mathematics – Differential Calculus	60	4	4	30	70	100
	Core Course 1 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 2 in Major B (for batch B1 only)	60/ 75	4/ 5	4	30	70	100
	Ability Enhancement Course 1 – English	60	4	3	25	50	75
	Ability Enhancement Course 2 – Additional Language	45	3	3	25	50	75
	Multi-Disciplinary Course 1 in B – (for batch B1 only)	45	3	3	25	50	75
	Total		23 / 25	21			525
2	Core Course 3 in Major Mathematics – Integral Calculus	60	4	4	30	70	100
	Core Course 3 in Major B –	60/ 75	4/ 5	4	30	70	100
	Core Course 2 in Major Mathematics – Elementary Number Theory (for batch A2 only).	60	4	4	30	70	100
	Ability Enhancement Course 3 – English	60	4	3	25	50	75

	Ability Enhancement Course 4 – Additional Language	45	3	3	25	50	75
	Multi-Disciplinary Course 1 Matrices and Basics of Probability theory *or* Mathematics for Competitive Exams - Part I	45	3	3	25	50	75
	Total		24/ 25	21			525
3	Core Course 5 in Major Mathematics – Multivariable Calculus	45+30	3+2	3+1	30	70	100
	Core Course 4 in Major Mathematics – Elementary Linear Algebra	45+30	3+2	3+1	30	70	100
	Core Course 4 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 5 in Major B	60/ 75	4/ 5	4	30	70	100
	Multi-Disciplinary Course 2 in B –	45	3	3	25	50	75
	Value-Added Course 1 in B – (for batch B1 only)	45	3	3	25	50	75
	Total		23/25	22			550
4	Core Course 6 in Major Mathematics – Real Analysis	45+30	3+2	3+1	30	70	100
	Core Course 6 in Major B	60/ 75	4/ 5	4	30	70	100
	Core Course 7 in Major B – (for batch B1 only)	60/ 75	4/ 5	4	30	70	100

	Value-Added Course 1 in Mathematics – History of Mathematics *or* Computational Logic	45	3	3	25	50	75
	Value-Added Course 2 in B –	45	3	3	25	50	75
	Skill Enhancement Course 1 in Mathematics – Fundamentals of Python and SageMath		4	3	25	50	75
	Total		22 / 24	21			525
5	Core Course 7 in Major Mathematics – Abstract Algebra I	60	4	4	30	70	100
	Core Course 8 in Major B –	60/ 75	4/ 5	4	30	70	100
	Core Course 9 in Major B – (for batch B1 only)	60	4	4	30	70	100
	Elective Course 1 in Major Mathematics	60	4	4	30	70	100
	Elective Course 1 in Major B	60	4	4	30	70	100
	Skill Enhancement Course 1 in B	45	3	3	25	50	75
	Total		24/ 25	23			575
6	Core Course 8 in Major Mathematics – Methods of Differential Equations	60	4	4	30	70	100
	Core Course 10 in Major B –	60/ 75	4/ 5	4	30	70	100
	Core Course 9 in Major Mathematics – Complex Analysis (for batch A2 only)	45+30	3+2	2+2	30	70	100

	Elective Course 2 in Major Mathematics	60	4	4	30	70	100
	Elective Course 2 in Major B	60	4	4	30	70	100
	Skill Enhancement Course 2 in B – (for batch B1 only)	45	3	3	25	50	75
	Internship in Major B (Credit for internship to be awarded only at the end of Semester 6)	60		2	50	-	50
	Total		24/ 25	25			625
Total Credits for Three Years				133			3325

CREDIT DISTRIBUTION FOR BATCH B1(A2)

IN PATHWAY 5: DOUBLE MAJOR

Semester	Major Courses in B	General Foundation Courses in B	Internship/ Project in B	Major Courses in Mathematics	General Foundation Courses in Mathematics	AEC	Total
1	4 + 4	3	-	4	-	3 + 3	21
2	4	-	-	4 + 4	3	3 + 3	21
3	4 + 4	3 + 3	-	4 + 4	-	-	22
4	4 + 4	3	-	4	3 + 3	-	21
5	4 + 4 + 4	3	-	4 + 4	-	-	23
6	4 + 4	3	2	4 + 4 + 4	-	-	25
Total for Three Years	48	18	2	44	9	12	133
	68			53		12	133
	Major Courses in B	Minor Courses					
7	4 + 4 + 4 + 4 + 4	-			-	-	20
8	4 + 4 + 4	4 + 4 + 4	12*		-	-	24
* instead of three Major courses							
Total for Four Years	88 + 12 = 100	12					177

EVALUATION SCHEME

1. The evaluation scheme for each course contains two parts: internal evaluation (about 30%) and external evaluation (about 70%). Each of the Major and Minor courses is of 4-credits. It is evaluated for 100 marks, out of which 30 marks are from internal evaluation and 70 marks, from external evaluation. Each of the General Foundation Course is of 3-credits. It is evaluated for 75 marks, out of which 25 marks are from internal evaluation and 50 marks, from external evaluation.

2. The 4-credit courses (Major and Minor courses) are of two types: (i) courses with only theory and (ii) courses with 3-credit theory and 1-credit Practical/Practicum.

In 4-credit courses with only theory component, out of the total 5 modules of the syllabus, one open-ended module with 20% content is designed by the faculty member teaching that course, and it is internally evaluated for 10 marks. The internal evaluation of the remaining 4 theory modules is for 20 marks.

In 4-credit courses with 3-credit theory and 1-credit Practical/Practicum components, out of the total 5 modules of the syllabus, 4 modules are for theory and the fifth module is for Practical/Practicum. The Practical/Practicum component is internally evaluated for 20 marks. The internal evaluation of the 4 theory modules is for 10 marks.

3. All the 3-credit courses (General Foundational Courses) in Mathematics are with only theory component. Out of the total 5 modules of the syllabus, one open-ended module with 20% content is designed by the faculty member teaching that course, and it is internally evaluated for 5 marks. The internal evaluation of the remaining 4 theory modules is for 20 marks.

Sl. No.	Nature of the Course		Internal Evaluation in Marks (About 30% of the Total)		External Exam on 4 Modules (Marks)	Total Marks
			Open-ended Module / Practical/Practicum	On the other 4 Modules		
1	4-credit course	only theory (5 modules)	10	20	70	100
2	4-credit course	Theory (4 modules) + Practical/Practicum	20	10	70	100
3	3-credit course	only theory (5 modules)	5	20	50	75

1. MAJOR AND MINOR COURSES

1.1. INTERNAL EVALUATION OF THEORY COMPONENT

Sl. No.	Components of Internal Evaluation of Theory Part of a Major / Minor Course	Internal Marks for the Theory Part of a Major / Minor Course of 4-credits			
		Theory Only		Theory + Practical/Practicum	
		4 Theory Modules	Open-ended Module	4 Theory Modules	Practical/Practicum
1	Test paper/ Mid-semester Exam	10	4	5	-
2	Seminar/ Viva/ Quiz	6	4	3	-
3	Assignment	4	2	2	-
Total		20	10	10	20*
		30		30	

* Refer the table in section 1.2 for the evaluation of Practical/Practicum component

1.2. EVALUATION OF PRACTICAL/PRACTICUM COMPONENT

The evaluation of Practical/Practicum component in Major and Minor courses is completely by internal evaluation.

- Continuous evaluation of Practical/Practicum by the teacher-in-charge shall carry a weightage of 50%.
- The end-semester Practical/Practicum examination and viva-voce, and the evaluation of Practical/Practicum records shall be conducted by the teacher in-charge and an internal examiner appointed by the Department Council.
- The process of continuous evaluation of Practical/Practicum courses shall be completed before 10 days from the commencement of the end-semester examination.
- Those who passed in continuous evaluation alone will be permitted to appear for the end-semester examination and viva-voce.

The scheme of continuous evaluation and the end-semester examination and viva-voce of Practical/Practicum component shall be as given below:

Sl. No.	Evaluation of Practical/Practicum Component of Credit-1 in a Major / Minor Course	Marks for Practical/Practicum	Weightage
1	Continuous evaluation of Practical/Practicum/ exercise performed in Practical/Practicum classes by the students	10	50%
2	End-semester examination and viva-voce to be conducted by teacher-in-charge along with an additional examiner arranged internally by the Department Council	7	35%
3	Evaluation of the Practical/Practicum records submitted for the end semester viva–voce examination by the teacher-in-charge and additional examiner	3	15%
	Total Marks	20	

1.3. EXTERNAL EVALUATION OF THEORY COMPONENT

External evaluation carries 70% marks. Examinations will be conducted at the end of each semester. Individual questions are evaluated in marks and the total marks are converted into grades by the University based on 10-point grading system (refer section 5).

PATTERN OF QUESTION PAPER FOR MAJOR AND MINOR COURSES

Duration	Type	Total No. of Questions	No. of Questions to be Answered	Marks for Each Question	Ceiling of Marks
2 Hours	Short Answer	10	8 – 10	3	24
	Paragraph/ Problem	8	6 – 8	6	36
	Essay	2	1	10	10
				Total Marks	70

2. INTERNSHIP

- All students should undergo Internship of 2-credits during the first six semesters in Research Institutions, Universities, Firms, Industry or Organizations, or training in labs with faculty and researchers of their own institution or other Higher Educational Institutions (HEIs) or research institutions.
- Internship can be for enhancing the employability of the student or for developing the research aptitude.
- Internship can involve hands-on training on a particular skill/ equipment/ software. It can be a short project on a specific problem or area. Attending seminars or workshops related to an area of learning or skill can be a component of Internship.

A faculty member/ scientist/ instructor of the respective institution, where the student does the Internship, should be the supervisor of the Internship

2.1. GUIDELINES FOR INTERNSHIP

1. Internship can be in Mathematics or allied disciplines.
2. There should be minimum 60 hrs. of engagement from the student in the Internship.
3. Summer vacations and other holidays can be used for completing the Internship.
4. In B.Sc. Mathematics Honours programme, institute/ industry visit or study tour is a requirement for the completion of Internship. Visit to minimum one national research institute, research laboratory and place of scientific importance should be part of the study tour. A brief report of the study tour has to be submitted with photos and analysis.
5. The students should make regular and detailed entries in to a personal log book through the period of Internship. The log book will be a record of the progress of the Internship and the time spent on the work, and it will be useful in writing the final report. It may contain mathematical results, ideas, expressions, experimental conditions, rough work and calculation, computer file names etc. All entries should be dated. The Internship supervisor should periodically examine and countersign the log book.
6. The log book and the typed report must be submitted at the end of the Internship.
7. The institution at which the Internship will be carried out should be prior-approved by the Department Council of the college where the student has enrolled for the UG Honours programme.

2.2. VALUATION OF INTERNSHIP

- The evaluation of Internship shall be done internally through continuous assessment mode by a committee internally constituted by the Department Council of the college where the student has enrolled for the UG Honours programme.
- The credits and marks for the Internship will be awarded only at the end of semester 6.
- The scheme of continuous evaluation and the end-semester viva-voce examination based on the submitted report shall be as given below:

Sl. No.	Components of Evaluation of Internship		Marks for Internship 2 Credits	Weightage
1	Continuous evaluation of internship through interim presentations and reports by the committee internally constituted by the Department Council	Acquisition of skill set	10	40%
2		Interim Presentation and Viva-voce	5	
3		Punctuality and Log Book	5	
4	Report of Institute Visit/ Study Tour		5	10%
5	End-semester viva-voce examination to be conducted by the committee internally constituted by the Department Council	Quality of the work	6	35%
6		Presentation of the work	5	
7		Viva-voce	6	
8	Evaluation of the day-to-day records, the report of internship supervisor, and final report submitted for the end semester viva–voce examination before the committee internally constituted by the Department Council		8	15%
	Total Marks		50	

3. PROJECT

3.1. PROJECT IN HONOURS PROGRAMME

- In Honours programme, the student has the option to do a Project of 12-credits instead of three Core Courses in Major in semester 8.
- The Project can be done in the same institution/ any other higher educational institution (HEI)/ research centre/ training centre.
- The Project in Honours programme can be a short research work or an extended internship or a skill-based training programme.
- A faculty member of the respective institution, where the student does the Project, should be the supervisor of the Project.

3.2. PROJECT IN HONOURS WITH RESEARCH PROGRAMME

- Students who secure 75% marks and above (equivalently, CGPA 7.5 and above) cumulatively in the first six semesters are eligible to get selected to Honours with Research stream in the fourth year.
- A relaxation of 5% in marks (equivalently, a relaxation of 0.5 grade in CGPA) is allowed for those belonging to SC/ ST/ OBC (non-creamy layer)/ Differently-Abled/ Economically Weaker Section (EWS)/ other categories of candidates as per the decision of the UGC from time to time.
- In Honours with Research programme, the student has to do a mandatory Research Project of 12-credits instead of three Core Courses in Major in semester 8.
- The approved research centres of University of Calicut or any other university/ HEI can offer the Honours with Research programme. The departments in the affiliated colleges under University of Calicut, which are not the approved research centres of the University, should get prior approval from the University to offer the Honours with Research programme. Such departments should have minimum two faculty members with Ph.D., and they should also have the necessary infrastructure to offer Honours with Research programme.

- A faculty member of the University/ College with a Ph.D. degree can supervise the research project of the students who have enrolled for Honours with Research. One such faculty member can supervise maximum five students in Honours with Research stream.

The maximum intake of the department for Honours with Research programme is fixed by the department based on the number of faculty members eligible for project supervision, and other academic, research, and infrastructural facilities available.

- If a greater number of eligible students are opting for the Honours with Research programme than the number of available seats, then the allotment shall be based on the existing rules of reservations and merits.

3.3. GUIDELINES FOR THE PROJECT IN HONOURS PROGRAMME

AND HONOURS WITH RESEARCH PROGRAMME

1. Project can be in Mathematics or allied disciplines.
2. Project should be done individually.
3. Project work can be of theoretical/ experimental /computational in nature.

4. There should be minimum 360 hrs. of engagement from the student in the Project work in Honours programme as well as in Honours with Research programme.
5. There should be minimum 13 hrs./week of engagement (the hours corresponding to the three core courses in Major in semester 8) from the teacher in the guidance of the Project(s) in Honours programme and Honours with Research programme.
6. The various steps in project works are the following:
   - Wide review of a topic.
   - Investigation on a problem in a systematic way using appropriate techniques.
   - Systematic recording of the work.
   - Reporting the results with interpretation in a standard documented form.

Presenting the results before the examiners.

7. During the Project the students should make regular and detailed entries in to a personal log book through the period of investigation. The log book will be a record of the progress of the Project and the time spent on the work, and it will be useful in writing the final report. It may contain mathematical models and results, ideas, mathematical expressions, rough work and calculation, computer file names etc. All entries should be dated. The Project supervisor should periodically examine and countersign the log book.

8. The log book and the typed report must be submitted at the end of the Project. A copy of the report should be kept for reference at the department. A soft copy of the report too should be submitted, to be sent to the external examiner in advance.
9. It is desirable, but not mandatory, to publish the results of the Project in a peer reviewed journal.
10. The project report shall have an undertaking from the student and a certificate from the research supervisor for originality of the work, stating that there is no plagiarism, and that the work has not been submitted for the award of any other degree/ diploma in the same institution or any other institution.
11. The project proposal, institution at which the project is being carried out, and the project supervisor should be prior-approved by the Department Council of the college where the student has enrolled for the UG Honours programme.

3.4. EVALUATION OF PROJECT

- The evaluation of Project will be conducted at the end of the eighth semester by both internal and external modes.
- The Project in Honours programme as well as that in Honours with Research programme will be evaluated for 300 marks. Out of this, 90 marks are from internal evaluation and 210 marks, from external evaluation.
- The internal evaluation of the Project work shall be done through continuous assessment mode by a committee internally constituted by the Department Council of the college where the student has enrolled for the UG Honours programme. 30% of the weightage shall be given through this mode.
- The remaining 70% shall be awarded by the external examiner appointed by the University.
- The scheme of continuous evaluation and the end-semester viva-voce of the Project shall be as given below:

Sl. No	Components of Evaluation of Project	Marks for the Project (Honours/ Honours with Research)	Weightage
1	Continuous evaluation of project work through interim presentations and reports by the committee internally constituted by the Department Council	90	30%
2	End-semester viva-voce examination to be conducted by the external examiner appointed by the university	150	50%
3	Evaluation of the day-to-day records and project report submitted for the end-semester viva–voce examination conducted by the external examiner	60	20%
	Total Marks	300	

INTERNAL EVALUATION OF PROJECT

Sl. No	Components of Evaluation of Project	Marks for the Project (Honours/ Honours with Research)
1	Skill in doing project work	30
2	Interim Presentation and Viva-Voce	20
3	Punctuality and Log book	20
4	Scheme/ Organization of Project Report	20
Total Marks		90

EXTERNAL EVALUATION OF PROJECT

Sl. No	Components of Evaluation of Project	Marks for the Project (Honours/ Honours with Research) 12 credits
1	Content and relevance of the Project, Methodology, Quality of analysis, and Innovations of Research	50
2	Presentation of the Project	50
3	Project Report (typed copy), Log Book and References	60
4	Viva-Voce	50
Total Marks		210

4. GENERAL FOUNDATION COURSES

All the General Foundation Courses (3-credits) in Mathematics are with only theory component**.**

4.1. INTERNAL EVALUATION

Sl. No.	Components of Internal Evaluation of a General Foundation Course in Mathematics	Internal Marks of a General Foundation Course of 3-credits in Mathematics	
		4 Theory Modules	Open-ended Module
1	Test paper/ Mid-semester Exam	10	2
2	Seminar/ Viva/ Quiz	6	2
3	Assignment	4	1
Total		20	5
		25	

4.2. EXTERNAL EVALUATION

External evaluation carries about 70% marks. Examinations will be conducted at the end of each semester. Individual questions are evaluated in marks and the total marks are converted into grades by the University based on 10-point grading system (refer section 5)

PATTERN OF QUESTION PAPER FOR GENERAL FOUNDATION COURSES

Duration	Type	Total No. of Questions	No. of Questions to be Answered	Marks for Each Question	Ceiling of Marks
1.5 Hours	Short Answer	10	8 – 10	2	16
	Paragraph/ Problem	5	4 – 5	6	24
	Essay	2	1	10	10
				Total Marks	50

5. LETTER GRADES AND GRADE POINTS

- Mark system is followed for evaluating each question.
- For each course in the semester letter grade and grade point are introduced in 10-point indirect grading system as per guidelines given below.
- The Semester Grade Point Average (SGPA) is computed from the grades as a measure of the student's performance in a given semester.
- The Cumulative GPA (CGPA) is based on the grades in all courses taken after joining the programme of study.
- Only the weighted grade point based on marks obtained shall be displayed on the grade card issued to the students.

LETTER GRADES AND GRADE POINTS

Sl. No.	Percentage of Marks (Internal & External Put Together)	Description	Letter Grade	Grade Point	Range of Grade Points	Class
1	95% and above	Outstanding	O	10	9.50 – 10	First Class with Distinction
2	Above 85% and below 95%	Excellent	A+	9	8.50 – 9. 49	
3	75% to below 85%	Very Good	A	8	7.50 – 8.49	
4	65% to below 75%	Good	B+	7	6.50 – 7.49	First Class
5	55% to below 65%	Above Average	B	6	5.50 – 6.49	
6	45% to below 55%	Average	C	5	4.50 – 5.49	Second Class
7	35% to below 45% aggregate (internal and external put together) with a minimum of 30% in external valuation	Pass	P	4	3.50 – 4.49	Third Class
8	Below an aggregate of 35% or below 30% in external evaluation	Fail	F	0	0 – 3.49	Fail
9	Not attending the examination	Absent	Ab	0	0	Fail

- When students take audit courses, they will be given Pass (P) or Fail (F) grade without any credits.
- The successful completion of all the courses and capstone components prescribed for the three-year or four-year programme with 'P' grade shall be the minimum requirement for the award of UG Degree or UG Degree Honours or UG Degree Honours with Research, as the case may be.

5.1. COMPUTATION OF SGPA AND CGPA

- The following method shall be used to compute the Semester Grade Point Average (SGPA):

  The SGPA equals the product of the number of credits (Ci) with the grade points (Gi) scored by a student in each course in a semester, summed over all the courses taken by a student in the semester, and then divided by the total number of credits of all the courses taken by the student in the semester,

  i.e. SGPA (Si) = Σi (Ci x Gi) / Σi (Ci)

  where Ci is the number of credits of the i^{th} course and Gi is the grade point scored by the student in the i^{th} course in the given semester. Credit Point of a course is the value obtained by multiplying the credit (Ci) of the course by the grade point (Gi) of the course.

ILLUSTRATION – COMPUTATION OF SGPA

Semester	Course	Credit	Letter Grade	Grade point	Credit Point (Credit x Grade)
I	Course 1	3	A	8	3 x 8 = 24
I	Course 2	4	B+	7	4 x 7 = 28
I	Course 3	3	B	6	3 x 6 = 18
I	Course 4	3	O	10	3 x 10 = 30
I	Course 5	3	C	5	3 x 5 = 15
I	Course 6	4	B	6	4 x 6 = 24
	Total	20			139
	SGPA				139/20 = 6.950

The Cumulative Grade Point Average (CGPA) of the student shall be calculated at the end of a programme. The CGPA of a student determines the overall academic level of the student in a programme and is the criterion for ranking the students.

CGPA for the three-year programme in CUFYUGP shall be calculated by the following formula.

CGPA for the four-year programme in CUFYUGP shall be calculated by the following formula.

- The SGPA and CGPA shall be rounded off to three decimal points and reported in the transcripts.
- Based on the above letter grades, grade points, SGPA and CGPA, the University shall issue the transcript for each semester and a consolidated transcript indicating the performance in all semesters.

MAJOR COURSES

Programme	B. Sc. Mathematics Honours			
Course Code	MAT1CJ101 / MAT1MN100			
Course Title	**DIFFERENTIAL CALCULUS**			
Type of Course	**Major**			
Semester	I			
Academic Level	100-199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic knowledge of Sets, Relations and Functions, School Level Algebra and Real Numbers (0-99 level).			
Course Summary	The course covers fundamental concepts in calculus, including functions, shifting of graphs, limits, continuity, differentiation, extreme values, the Mean Value Theorem, graphing with derivatives, and limits at infinity with asymptotes. Students learn techniques for evaluating limits, finding extrema, and graphing functions using derivatives, preparing them for further studies in calculus and related fields.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse a function for its limits, continuity and differentiability and evaluate limits and derivatives.	An	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam
CO2	Apply first and second derivatives and related theorems to find extrema of functions.	Ap	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam
CO3	Sketch the graph of functions by analysing critical points and asymptotes	An	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge (F), Conceptual Knowledge (C), Procedural Knowledge (P), Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Calculus and Analytic Geometry, 9th Edition, George B. Thomas, Jr. Ross L. Finney, Pearson Publications, 2010, ISBN: 978-8174906168.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Marks Ext: 70**
I		**Module I**	**12**	**Min.15**
	1	Preliminaries: Section 3 - Functions		
	2	Preliminaries: Section 4 - Shifting Graphs.		
	3	Section 1.1-Rates of Change and Limits - Limits of Function Values onwards.		
	4	Section 1.2 - Rules for Finding Limits. Topics up to and including Example 3.		
	5	Section 1.2 - Rules for Finding Limits. Rest of the section.		
	6	Section 1.4- Extensions of the Limit Concept. Topics up to and including Example 6.		
II		**Module II**	**15**	**Min.15**
	7	Section 1.5 - Continuity.		
	8	Section 2.1 - The Derivative of a Function (The topic Graphing f' from estimated values is optional).		
	9	Section 2.2 - Differentiation Rules.		
	10	Section 2.3 - Rates of Change. Topics up to and including Example 5.		
	11	Section 2.5 - The Chain Rule. Topics up to and including Example 6.		
	12	Section 2.6- Implicit Differentiation and Rational Exponents. Topics up to and including Example 5.		
III		**Module III**	**11**	**Min.15**
	13	Section 3.1 - Extreme Values of Functions. Topics up to Finding Extrema.		
	14	Section 3.1 - Extreme Values of Functions- Topics from Finding Extrema onwards.		
	15	Section 3.2 - The Mean Value Theorem -Topics up to and including Example 4. (Proof of Theorem 3 is optional).		
	16	Section 3.2 - The Mean Value Theorem- Increasing Functions and Decreasing Functions		

	17	Section 3.3 - The First Derivative Test for Local Extreme Values.		
IV	**Module IV**		**10**	**Min.15**
	18	Section 3.4 - Graphing with y’ and y’’ - Topics up to and including Example 5.		
	19	Section 3.4 - Graphing with y’ and y’’- Topics from The Second Derivative Test for Local Extreme Values onwards.		
	20	Section 3.5 - Limits as x $\rightarrow \pm\infty$, Asymptotes and Dominant Terms. - Topics up to and including Summary for Rational Functions.		
	21	Section 3.5 - Limits as x $\rightarrow \pm\infty$, Asymptotes and Dominant Terms- Topics from Horizontal and Vertical Asymptotes up to and including Example 12.		
	22	Section 3.5 - Limits as x $\rightarrow \pm\infty$, Asymptotes and Dominant Terms-Topics from Graphing with Asymptotes and Dominant Terms onwards.		
V	**Module V (Open Ended)**		**12**	
	Trigonometric Functions, Tangent Values and Formal Definitions of Limits, Derivatives of Trigonometric Functions, Power Rule of Differentiation for rational powers, Optimization, Linearization and Differentials.			

References

1. Howard Anton, Biven, & Stephen Davis, Calculus, 7th Ed., Wiley India
2. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Ed, John Wiley & Sons.
3. Robert T Smith and Roland B Minton, Calculus, 4th Ed. McGraw-Hill Companies
4. Soo T Tan, Calculus, 9th Ed.Brooks/Cole Pub Co.
5. Tom M. Apostol, Calculus, Vol 1: One Variable Calculus with an Introduction to Linear Algebra, 2nd Ed, John Wiley & Sons.
6. Michael Van Biezen Calculus Lectures: https://youtu.be/YZYxPclo2rg?si=qKCt6ty8m5dBR4DG

***Optional topics are exempted for end semester examination**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	0	2	1	3	0	1
CO 2	2	3	2	1	3	0	2	1	3	0	1
CO 3	2	3	2	1	3	0	2	2	3	0	1

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours			
Course Code	MAT2CJ101 / MAT2MN100			
Course Title	**INTEGRAL CALCULUS**			
Type of Course	**Major**			
Semester	II			
Academic Level	100-199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic knowledge of Functions, Limits, Continuity and Differentiation (MAT1CJ101 - Differential Calculus).			
Course Summary	The course provides a comprehensive exploration of integral calculus, covering techniques such as indefinite integrals, Riemann sums, definite integrals, properties of integrals, the Fundamental Theorem, L'Hopital's Rule, basic integration formulas, and applications in finding areas between curves, volumes of solids, lengths of plane curves, and areas of surfaces of revolution. Through these topics, students gain proficiency in solving a wide range of mathematical problems involving integration and its applications in various fields.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Solve indefinite and definite integrals of functions.	Ap	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam
CO2	Learn logarithmic, exponential, inverse trigonometric functions and to evaluate derivatives and integrals of the above transcendental functions and use it for computations of other limits	U	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam
CO3	Apply integration formulas to find the area between two curves, the surface area and volume of a solid of revolution.	Ap	F	Internal Exam/Assignment /Seminar/Viva/ End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Textbook	Calculus and Analytic Geometry, 9th Edition, George B. Thomas, Jr. Ross L. Finney, Pearson Publications, 2010, ISBN: 978-8174906168.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Marks Ext: 70**
	Module I			
I	1	Section 4.1 - Indefinite Integrals.	14	Min.15
I	2	Section 4.3 - Integration by Substitution - Running the Chain Rule Backward.	14	Min.15
I	3	Section 4.5 - Riemann Sums and Definite Integrals. (Example 9 is optional.)	14	Min.15
I	4	Section 4.6 - Properties, Area, and the Mean Value Theorem - Topics up to and including Example 6.	14	Min.15
I	5	Section 4.6 - Properties, Area, and the Mean Value Theorem- Topics from The Average Value of an Arbitrary Continuous Function onwards.	14	Min.15
	Module II			
II	6	Section 4.7 – The Fundamental Theorem (Example 6 is optional).	11	Min.15
II	7	Section 4.8 - Substitution in Definite Integrals.	11	Min.15
II	8	Section 6.2 - Natural Logarithms- Topics up to and including The Graph and Range of ln x.	11	Min.15
II	9	Section 6.2 - Natural Logarithms. -Topics from Logarithmic Differentiation onwards.	11	Min.15
II	10	Section 6.3 - The Exponential Function- Topics up to and including Example 4.	11	Min.15
II	11	Section 6.3 - The Exponential Function- Topics from The Derivative and Integral of e^x onwards.	11	Min.15
	Module III			
III	12	Section 6.6 - L' Hopital's Rule	12	Min.15
III	13	Section 6.9 - Derivatives of Inverse Trigonometric Functions; Integrals.	12	Min.15
III	14	Section 7.1 - Basic Integration Formulas.	12	Min.15
III	15	Section 7.2 - Integration by Parts	12	Min.15
III	16	Section 7.3 Partial Fractions.	12	Min.15
	Module IV			
IV	17	Section 5.1 - Areas Between Curves. - Topics up to and including Example 2.	11	Min.15

	18	Section 5.1 - Areas Between Curves- Topics from Boundaries with Changing Formulas		
	19	Section 5.2 - Finding Volumes by Slicing. (Example 2 may be done as open ended).		
	20	Section 5.3 - Volumes of Solids of Revolution- Disks and Washers - Topics up to and including Example 4.		
	21	Section 5.5 - Lengths of Plane Curves. - Topics up to and including Example 2.		
	22	Section 5.6 - Areas of Surfaces of Revolution- Topics up to and including Example 2.		
V	**Module V (Open Ended)**		**12**	
	Inverse Functions and their Derivatives, a^x and $\log_a x$, Inverse Trigonometric Functions and their derivatives, Hyperbolic Functions, Integrals and their derivatives, Integration using trigonometric substitutions, Moments and Center of Mass.			

References

1. Howard Anton, Biven, & Stephen Davis, Calculus, 7th Ed., Wiley India
2. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Ed, John Wiley & Sons.
3. Robert T Smith and Roland B Minton, Calculus, 4th Ed. McGraw-Hill Companies
4. Soo T Tan, Calculus, 9th Ed. Brooks/Cole Pub Co.
5. Tom M. Apostol, Calculus, Vol 1: One Variable Calculus with an Introduction to Linear Algebra, 2nd Ed, John Wiley & Sons.
6. Michael Van Biezen Calculus Lectures: https://youtu.be/YZYxPclo2rg?si=qKCt6ty8m5dBR4DG

***Optional topics are exempted for end semester examination**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	0	3	1	3	0	1
CO 2	2	3	2	1	3	0	3	1	3	0	1
CO 3	2	3	2	1	3	0	3	2	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B.Sc. Mathematics Honours				
Course Code	MAT3CJ201				
Course Title	**MULTIVARIABLE CALCULUS**				
Type of Course	**Major**				
Semester	III				
Academic Level	200-299				
Course Details	Credit	Lecture/ Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Basic knowledge of vectors, dot product, cross product, triple products, lines and planes in 3-dimensional space				
Course Summary	Multivariable Calculus takes the concepts learned in the single variable calculus course and extends them to multiple dimensions. Topics discussed include: Parameterizations of Plane Curves, Polar Coordinates, Lines and Planes in Space, Cylinders and Quadric Surfaces, Cylindrical and Spherical Coordinates, functions of many variables, limit, continuity, differentiation, and integration of vector-valued functions; application of vector-valued functions limits, and derivatives of multivariable functions, tangent planes and normal lines of surfaces, applying double and triple integrals to multivariable functions to find area, volume, surface area, vector fields, finding curl and divergence of vector fields; line integrals; Green's Theorem; parametric surfaces, including normal vectors, tangent planes, and areas; orientation of a surface; Divergence Theorem; and Stokes's Theorem.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Describe various coordinate systems—Cartesian, polar, cylindrical, and spherical—to represent, analyse, and interpret geometric figures and spatial relationships.	Ap	C	Internal Examination/ Assignment/ End Sem examination
CO2	Compute and apply limits, partial derivatives, and multiple integrals for functions of several variables to solve complex mathematical and real-world problems.	Ap	C	Internal Examination/Seminar/ Assignment/ Report/ End Sem examination
CO3	Apply advanced integration techniques and vector calculus principles to evaluate integrals in various coordinate systems and analyse vector fields and their applications in physics and engineering.	An	C	Internal Examination/Seminar/ Assignment/ Report/ End Sem examination
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Calculus and Analytical Geometry, George B Thomas, Ross L Finney- Addison Wesley- 9th Edition.		
Module	**Unit**	**Content**	**Hrs (45+ 30)**
		Module I	
I	1	Section 9.4: Parameterizations of Plane Curves Topics up to and including Example 7	10
	2	Section 9.6: Polar Coordinates Definition of Polar Coordinates, Negative Values of r, Elementary Coordinate Equations and Inequalities, Cartesian Versus Polar Coordinates.	
	3	Section 10.5: Lines and Planes in Space Lines and Line Segments in Space, The Distance from a Point to a Line in Space, Equations for Planes in Space, Angles Between Planes; Lines of Intersection.	
	4	Section 10.6: Cylinders and Quadric Surfaces Cylinders, Drawing Lesson, Quadric Surfaces, Drawing Lesson.	
	5	Section 10.7: Cylindrical and Spherical Coordinates Cylindrical Coordinates, Spherical Coordinates	
		Module II	
II	6	Section 12.1: Functions of Several Variables Functions and Variables, Graphs and Level Curves of Functions of Two Variables, Contour Lines, Level Surfaces of Functions of Three Variables.	12
	7	Section 12.2: Limits and Continuity Limits, Continuity, Functions of More Than Two Variables.	
	8	Section 12.3: Partial Derivatives Definitions and Notation, Calculations, Functions of More Than Two Variables, The Relationship Between Continuity and the Existence of Partial Derivatives, Second Order Partial Derivatives, Euler's Theorem, Partial Derivatives of Still Higher Order.	
	9	Section 12.4: Differentiability, Linearization, and Differentials	

		Differentiability, How to Linearize a Function of Two Variables, How Accurate is the Standard Linear Approximation? Predicting Change with Differentials (Topics up to and including Example 7)	
	10	Section 12.5: The Chain Rule The Chain Rule for Functions of Two Variables (Proof of Theorem 5 is optional), The Chain Rule for Functions of Three Variables, The Chain Rule for Functions Defined on Surfaces, Implicit Differentiation, Remembering the Different Forms of the Chain Rule, The Chain Rule for Functions of Many Variables.	
III		**Module III**	
	11	Section 12.7: Directional Derivatives, Gradient Vectors, and Tangent Planes Directional Derivatives in the Plane, Geometric Interpretation of the Directional Derivative, Calculation, Properties of Directional Derivatives, Gradients and Tangent to Level Curves, Functions of Three Variables.	**11**
	12	Section 12.7: Directional Derivatives, Gradient Vectors, and Tangent Planes Equations for Tangent Planes and Normal Lines, Planes Tangent to a Surface z=f(x,y), Algebra Rules for Gradients.	
	13	Section 12.8: Extreme Values and Saddle points The Derivative Tests.	
	14	Section 12.8: Extreme Values and Saddle points Absolute Maxima and Minima on Closed Bounded Regions, Conclusion.	
	15	Section 12.9: Lagrange Multipliers Constrained Maxima and Minima, The Method of Lagrange Multipliers (Theorem 9 and Corollary of Theorem 9 are optional).	
	16	Section 12.9: Lagrange Multipliers Lagrange Multipliers with Two Constraints.	
IV		**Module IV**	
	17	Section 13.1: Double Integrals, Double Integrals over Rectangles, Properties of Double Integrals, Double Integrals as Volumes, Fubini's Theorem for Calculating Double Integrals.	**12**
	18	Section 13.1: Double Integrals	

		Double Integrals over Bounded Nonrectangular Regions, Finding the Limits of Integration.	
	19	Section 13.2: Areas, Moments and Centers of Mass Areas of Bounded Regions in the Plane, Average Value.	
	20	Section 13.3: Double Integrals in Polar Form Integrals in Polar Coordinates, Limits of Integration, Changing Cartesian Integrals into Polar Integrals.	
	21	Section 13.4: Triple Integrals in Rectangular Coordinates Triple Integrals, Properties of Triple Integrals, Volume of a Region in Space, Evaluation.	
	22	Section 13.4: Triple Integrals in Rectangular Coordinates Average Value of a Function in Space.	
V	**Practicum**		**30**
	Triple Integrals in Cylindrical Coordinates, Spherical coordinates Substitution in Multiple Integrals Vector Valued Functions and Space Curves Line Integrals Vector Fields, Work, Circulation and Flux Path Independence, Potential Functions and Conservative Fields. Green's Theorem in the Plane (Proof is Optional) Surface area and surface integrals Parametrized surfaces Stoke's theorem (Proof is optional) The Divergence theorem (Proof is Optional)		

References:

1. Anton, Bivens & Davis : Calculus Early Transcendentals (10/e) John Wiley & Sons, Inc.(2012) ISBN: 9780470647691
2. Arnold Ostebee & Paul Zorn: Multivariable Calculus (2/e) W. H. Freeman Custom Publishing, N.Y.(2008)ISBN: 9781429230339
3. James Stewart : Calculus (8/e) Brooks/Cole Cengage Learning(2016) ISBN:9781285740621
4. Jerrold E. Marsden & Anthony Tromba :Vector Calculus (6/e) W. H. Freeman and Company ,New York(2012) ISBN: 9781429215084
5. Joel Hass, Christopher Heil & Maurice D. Weir : Thomas' Calculus (14/e) Pearson(2018) ISBN 0134438981
6. Jon Rogawski: Multivariable Calculus Early Transcendentals (2/e) W. H. Freeman and Company (2012) ISBN: 1429231874

7. Robert A Adams & Christopher Essex : Calculus: A complete Course (8/e) Pearson Education Canada (2013) ISBN: 032187742X
8. William Wade: An Introduction to Analysis, (4/e) Pearson Education

***Optional topics are exempted for end semester examination **70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	3	3	3	2	1	1	1	1	3
CO 2	3	2	2	2	3	2	1	-	3	-	1
CO 3	3	2	1	1	3	2	1	1	1	-	1

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Report
- Final Exam (70%)

Mapping of COs to Assessment Rubrics :

	Internal Exam	Assignment	Seminar	Report	End Semester Examinations
CO 1	√	√			√
CO 2	√		√	√	√
CO 3	√		√	√	√

Programme	BSc Mathematics Honours			
Course Code	MAT3CJ202 / MAT3MN200			
Course Title	**MATRIX ALGEBRA**			
Type of Course	**Major**			
Semester	III			
Academic Level	200 – 299			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	1. System of linear equations and their solution sets. 2. Euclidean Spaces and their algebraic and geometric properties.			
Course Summary	This course covers matrix theory and linear algebra, emphasizing topics useful in many other disciplines. It begins with the study of systems of linear equations and the properties of matrices. Emphasis is given to topics including systems of equations, vector spaces, linear dependence and independence, dimension, linear transformations, eigenvalues and diagonalization.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand row reductions and echelon forms of a matrix and their uses in solving a linear system.	U	C	Internal Exam/Assignment/Seminar/Viva/ End Sem Exam
CO2	Define and compute eigen values and eigen vectors of a square matrix.	An	P	Internal Exam/Assignment/Seminar/Viva/ End Sem Exam
CO3	Interpret Linear Transformations using matrices and visualize geometrically.	An	C	Internal Exam/Assignment/Seminar/Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	Linear Algebra and its Applications, Third Edition, David .C. Lay, Pearson Publications 2006.			
Module	**Unit**	**Content**	**Hrs (60)**	**External Marks (70)**
I		**Module I**		**Min. 15**
	1	Section 1.1: Systems of Linear Equations Systems of Linear Equations, Matrix Notation, Solving a Linear System.	14	
	2	Section 1.1: Systems of Linear Equations Elementary Row Operations, Existence and Uniqueness Questions.		
	3	Section 1.2: Row Reduction and Echelon Forms Row Reduction and Echelon Forms, Pivot Positions, The Row Reduction Algorithm.		
	4	Section 1.2: Row Reduction and Echelon Forms Solutions of Linear Systems, Parametric Descriptions of Solution Sets, Back Substitution, Existence and Uniqueness Questions.		
	5	Section 1.3: Vector Equations Vector Equations, Vectors in $\mathbb{R}^2$, Geometric Descriptions of $\mathbb{R}^2$, Vectors in $\mathbb{R}^3$, Vectors in $\mathbb{R}^n$.		
	6	Section 1.3: Vector Equations Linear Combinations, A Geometric Description of Span$\{v\}$ and Span $\{u, v\}$, Linear Combinations in Applications.		
	7	Section 1.4: The Matrix Equation Ax = b The Matrix Equation Ax = b, Existence of Solutions, Computation of Ax, Properties of the Matrix-Vector Product Ax.		
II		**Module II**		
	8	Section 1.5: Solution Sets of Linear Systems Homogeneous Linear Systems, Parametric Vector Form, Solutions of Non-Homogenous Systems.	13	
	9	Section 1.7: Linear Independence		

		Linear Independence, Linear Independence of Matrix Columns, Sets of One or Two Vectors, Sets of Two or More Vectors.		Min. 15
	10	Section 1.8: Introduction to Linear Transformations Introduction to Linear transformations, Matrix Transformations.		
	11	Section 1.8: Introduction to Linear Transformations Linear Transformations		
	12	Section 1.9: The Matrix of a Linear Transformation The Matrix of a Linear Transformation, Geometric Linear Transformation of $\mathbb{R}^2$.		
	13	Section 1.9: The Matrix of a Linear Transformation Existence and Uniqueness Questions. (Topics up to and including Theorem 11).		
III		**Module III**		Min. 15
	14	Section 2.1: Matrix Operations Matrix Operations, Sums and Scalar Multiples, Matrix Multiplication, Properties of Matrix Multiplication, Powers of a Matrix, The Transpose of a Matrix.	11	
	15	Section 2.2: The Inverse of a Matrix The Inverse of a Matrix (Example 3 is optional), Elementary Matrices (Proof of Theorem 7 is optional).		
	16	Section 2.2: The Inverse of a Matrix An Algorithm for Finding A^{-1}, Another View of Matrix Inversion.		
	17	Section 2.8 : Subspaces of $\mathbb{R}^n$ Subspaces of $\mathbb{R}^n$, Column Space and Null Space of a Matrix, Basis for a Subspace.		
	18	Section 2.9: Dimension and Rank Coordinate Systems, The Dimension of a Subspace (Topics up to and including Theorem 15).		
IV		**Module IV**		
	19	Section 5.1: Eigen Vectors and Eigen Values Eigen Vectors and Eigen Values (Topics up to and including Theorem 2).	10	

	20	Section 5.2: The Characteristic Equation The Characteristic Equation, Determinants (Topics up to and including Theorem 3).		Min. 15
	21	Section 5.2: The Characteristic Equation The Characteristic Equation, Similarity (Topics up to and including Theorem 4).		
	22	Section 5.3: Diagonalization Diagonalization (Proof of Theorem 5 is optional), Diagonalizing Matrices, Matrices Whose Eigen Values Are Not Distinct.		
V		**Module V (Open Ended)**	**12**	
		Determinants, Properties of Determinants, Applications of Linear Systems, Characterizations of Invertible Matrices, Partitioned Matrices, Application to Computer Graphics, Eigen Vectors and Linear Transformations.		

References

1. Elementary Linear Algebra, Howard Anton, Chris Rorres, Wiley Publications
2. Linear Algebra Done Right, 3/e, Sheldon Axler, Springer Nature,2015.
3. Introduction to Linear Algebra, 6/e, Gilbert Strang, Wellesley-Cambridge Press.
4. Basic Linear Algebra, 2/e, T. S. Blyth and E.F. Robertson, Springer, 2002.
5. Linear Algebra And its Applications, 4/e, Gilbert Strang, Cengage India Private Limited
6. Linear Algebra – A Geometric Approach, S.Kumaresan, Prentice Hall of India.
7. Bretscher, Otto. *Linear algebra with applications*. Vol. 52. Eaglewood Cliffs, NJ: Prentice Hall, 1997.
8. Holt, Jeffrey. *Linear Algebra with Applications*. wh freeman, 2017.

***Optional topics are exempted for end semester examination**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	3	0	3	0	3	0	0
CO 2	1	3	2	2	3	0	3	0	3	0	0
CO 3	2	1	3	3	3	0	3	0	3	0	0

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours			
Course Code	MAT4CJ203			
Course Title	**REAL ANALYSIS I**			
Type of Course	**Major**			
Semester	IV			
Academic Level	200 – 299			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus			
Course Summary	After introducing the basic notions in set theory, the course develops into the construction of the Real number system. Thereafter Real functions are introduced and the notions of limit and continuity are developed.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate Proficiency in Set Theory Fundamentals and Real Number Properties	An	C	Internal Exam/ Assignment/Seminar/ Viva/Report/ End Sem Exam
CO2	Apply the completeness property of $\mathbb{R}$, and solve problems involving intervals and applications of the supremum property.	U	C	Internal Exam/ Assignment/Seminar/ Viva/Report/ End Sem Exam
CO3	Analyse sequences and their limits, apply limit theorems, and demonstrate an understanding of concepts such as monotone sequences, sub-sequences, and the Cauchy Criterion, as well as their applications in solving problems related to sequences and limits.	An	C	Internal Exam/ Assignment/Seminar/ Viva/Report/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Introduction to Real Analysis, 4/e, Robert G Bartle, Donald R Sherbert John Wiley & Sons (2011)			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Introduction to Set theory**	**8**	**Min.15**
	1	Section 1.1 - Sets and functions (for review only)		
	2	Section 1.2 - Mathematical Induction (Proofs of results included in practicum part).		
	3	Section 1.3 – Finite and Infinite sets.		
	4	Section 1.3 – Countable and Uncountable sets.		
II		**The Real numbers**	**13**	**Min.15**
	5	Section 2.1 – The algebraic properties of $\mathbb{R}$.		
	6	Section 2.1 – The order properties of $\mathbb{R}$.		
	7	Section 2.2 – Absolute value and the Real Line.		
	8	Section 2.3 – Completeness property of $\mathbb{R}$ (Proofs included in Practicum).		
	9	Section 2.4 – Applications of the Supremum property - 2.4.3 to 2.4.6 and 2.4.8 to 2.4.9 (All other discussions included in Practicum).		
	10	Section 2.5 – Intervals – 2.5.2 to 2.5.4 (All other discussions included in Practicum).		
III		**Sequences and Limits**	**12**	**Min.15**
	11	Section 3.1 – Sequences and their limits.		
	12	Section 3.1 – Problems to find limits of sequence.		
	13	Section 3.2 – Limit theorems.		
	14	Section 3.2 – Problems using Limit theorems.		
	15	Section 3.3 – Monotone sequences – Monotone Convergence Theorem.		
	16	Section 3.3 – Applications of Monotone Convergence Theorem – Euler's number introduction only.		
IV		**Sequences and Limits (continued)**	**12**	**Min.10**
	17	Section 3.4 – Sub sequences and the Bolzano Weierstrass theorem (Second proof of Theorem 3.4.8 is omitted for external exam and limits superior and inferior are included in practicum).		
	18	Section 3.4 – Problems using Divergence criteria.		
	19	Section 3.5 – The Cauchy Criterion (Examples 3.5.9, 3.5.11 and Corollary 3.5.10 are included in Practicum).		
	20	Section 4.1- Limits of functions (Proofs included in Practicum).		
	21	Section 4.2: Limit theorems of functions (Proofs included in Practicum).		

	22	Section 4.3: Some extensions of limit concepts (Proofs included in Practicum).		
V	**Practicum:** The goal is for the students to learn the following topics in 15 practicum sessions of two hours each via self-study and group activities. The lecturer may assist by running group discussions, supervising class seminars and referring library books for self-study and note preparation.		**30**	**-**
	1	Section 1.2 - for detailed discussions including proofs		
	2	Section 2.3 – re do it with all the proofs		
	3	Section 2.4 – Worked out examples for applying the ideas of supremum and infimum and the existence of square root of 2		
	4	Section 2.5 – Characterization theorem for intervals and representations of real numbers		
	5	Section 3.4 – discussions of limit inferior and limit superior with examples		
	6	Section 3.5 – Estimation of errors in contractive sequences with examples		
	7	Section 3.6 – Properly divergent Sequences		
	8	Section 3.7 – Introduction to Infinite Series – conditions for convergence – Harmonic Series		
	9	Section 3.7 – Comparison Tests with examples		
	10	Section 4.1 – Formulate a precise definition of limit and illustrate with examples		
	11	Section 4.1 – Sequential Criterion for Limits for convergence and divergence with examples		
	12	Section 4.2 – Limit theorems for functions in parallel to that of sequences.		
	13	Section 4.3 – One sided and infinite limits.		
	14	Section 11.1 – Open sets, their properties and characterization.		
	15	Section 11.1 - Closed sets, their properties and characterization.		

References

1. Tom.M. Apostol, Calculus I, Wiley & Sons.
2. Tom.M. Apostol, Mathematical Analysis, 2/e, Addison-Wesley.
3. Richard R Goldberg, Methods of Real Analysis, 2/e, Wiley
4. Raymond L Wilder, Introduction to the Foundations of Mathematics,2/e, John WileySons

Optional Programming References for Practicum:

(1) SageMath Calculus Tutorial https://www.sagemath.org/calctut/limits.html

(2) SageMath 2D plotting https://doc.sagemath.org/html/en/reference/plotting/sage/plot/plot.html#

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	2	3	0	3	0	3	0	0
CO 2	1	3	2	2	3	0	3	0	3	0	0
CO 3	3	2	3	3	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT4CJ204				
Course Title	**BASIC LINEAR ALGEBRA**				
Type of Course	**Major**				
Semester	IV				
Academic Level	200 – 299				
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours	
	4	4	--	60	
Pre-requisites	1.Familiarity with system of equations and their solutions 2. Knowledge about matrices and matrix operations.				
Course Summary	This course is a quick review of linear algebra, intended for students who have already taken a previous course in linear algebra or have some experience with vectors and matrices. It begins with the concepts of vector spaces, subspaces, bases and dimension. Linear transformations are introduced as 'natural maps' between vector spaces. The course opens up the classical finite dimensional inner product theory for the canonical reduction of a matrix as a special case of a self-adjoint operator.				

Course Outcomes:

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply concepts related to vector spaces and subspaces, including determining whether a set forms a subspace and finding the span of a set	U	C	Internal Exam/Assignment/Seminar/ Viva/ End Sem Exam
CO2	Demonstrate proficiency in analysing null spaces, column spaces, and linear transformations, including understanding the kernel and range of a linear transformation and contrasting the properties of null space and column space.	An	P	Internal Exam/Assignment/Seminar/ Viva/ End Sem Exam
CO3	Evaluate and apply concepts related to bases, dimensionality, and rank of vector spaces, including understanding bases for null space and column space, determining dimensions of subspaces, and applying the rank theorem to systems of equations.	E	C	Internal Exam/Assignment/Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	Linear Algebra and its Applications, Third Edition, David .C. Lay, Pearson Publications			
Module	**Unit**	**Content**	**Hrs (48+ 12)**	**External Marks (70)**
I	**Module I**			**Min 15**
	1	Section 4.1: Vector Spaces and Subspaces Vector Spaces and Subspaces, Subspaces, A Subspace Spanned by a Set.	**14**	
	2	Section 4.2: Null Spaces, Column Spaces, and Linear Transformations. The Null Space of a Matrix, An Explicit Description of Nul A.		
	3	Section 4.2: Null Spaces, Column Spaces, and Linear Transformations. The Column Space of a Matrix, The Contrast Between Nul A and Col A.		
	4	Section 4.2: Null Spaces, Column Spaces, and Linear Transformations. Kernel and Range of a Linear Transformation.		
	5	Section 4.3: Linearly Independent Sets; Bases. Linearly Independent Sets; Bases, The Spanning Set Theorem.		
	6	Section 4.3: Linearly Independent Sets; Bases. Bases for Nul A and Col A, Two Views of a Basis.		
II	Module II			Min 15
	7	Section 4.4: Coordinate Systems. Coordinate Systems, A Graphical Interpretation of Coordinates, Coordinates in $\mathbb{R}^n$.	**12**	
	8	Section 4.4: Coordinate Systems. The Coordinate Mapping.		
	9	Section 4.5: The Dimension of a Vector Space. The Dimension of a Vector Space.		
	10	Section 4.5: The Dimension of a Vector Space. Subspaces of a Finite-Dimensional Space, The Dimensions of Nul A and Col A.		
	11	Section 4.6: Rank Rank, The Row Space.		
	12	Section 4.6: Rank The Rank Theorem, Applications to Systems of Equations (Topics up to and including Example 5).		
III	Module III			Min 15
	13	Section 6.1: Inner Product, Length and Orthogonality The Inner Product, The Length of a Vector, Distance in $\mathbb{R}^n$.	**12**	
	14	Section 6.1: Inner Product, Length and Orthogonality Orthogonal Vectors, Orthogonal Complements, Angles in $\mathbb{R}^2$ and $\mathbb{R}^3$.		

	15	Section 6.2: Orthogonal Sets Orthogonal Sets, An Orthogonal Projection (Topics up to and including Example 4).		
	16	Section 6.2: Orthogonal Sets Orthonormal Sets.		
	17	Section 6.4: The Gram-Schmidt Process The Gram -Schmidt Process, Orthonormal Bases.		
	18	Section 6.4: The Gram -Schmidt Process QR Factorization of Matrices.		
IV	Module IV			Min 15
	19	Section 7.1: Diagonalization of Symmetric Matrices Diagonalization of Symmetric Matrices.	**10**	
	20	Section 7.1: Diagonalization of Symmetric Matrices The Spectral Theorem. Spectral Decomposition.		
	21	Section 7.2: Quadratic Forms Quadratic Forms (Topics up to and including Example 3), Classifying Quadratic Forms.		
	22	Section 7.4: The Singular Value Decomposition The Singular Value Decomposition, The Singular Values of an $m \times n$ Matrix , The Singular Value Decomposition (Topics up to and including Example 4 only).		
V	**OPEN ENDED**		12	
	Linear Algebra Lab Sessions Book: Mike Cohen, Practical Linear Algebra for Data Science, O'Reilly, 2019, ISBN 978-1-098-12061-0. Jupyter: https://github.com/mikexcohen/LinAlg4DataScience Choose lab demos and exercises for 12 hours as per lecturer's discretion. For Module I & II, Ch 2, 3, 5, 6 of book for Lab. For Module III, Ch 2 and Ch 9 of book for Lab. For Module IV, Ch 14 of book for Lab. Python and Jupyter review in Ch 16 of book.			

References

1. Elementary Linear Algebra: Application Version,11/e, Howard Anton & Chris Rorres Wiley
2. Algebra Done Right, 3/e, Sheldon Axler, Springer Nature,2015.
3. Introduction to Linear Algebra, 6/e, Gilbert Strang, Wellesley-Cambridge Press.
4. Basic Linear Algebra, 2/e, T. S. Blyth and E.F. Robertson, Springer, 2002.
5. Linear Algebra, 2/e, Hoffman K and Kunze R, Prentice Hall of India,1991.
6. Bretscher, Otto. *Linear algebra with applications*. Vol. 52. Eaglewood Cliffs, NJ: Prentice Hall, 1997.
7. Blyth, Thomas Scott, and Edmund F. Robertson. *Basic linear algebra*. Springer Science & Business Media, 2013.

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	2	2	3	0	3	0	3	0	0
CO 2	1	3	2	2	3	0	3	0	3	0	0
CO 3	3	2	3	3	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT4CJ205				
Course Title	**FUNDAMENTALS OF PYTHON AND SAGEMATH**				
Type of Course	**Major**				
Semester	IV				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	1) Basic knowledge to start a desktop/laptop computer 2) A basic course in calculus with an understanding of differential and integral calculus (higher secondary level and one or two semester courses from Bsc) 3) A basic course in linear algebra ((higher secondary level))				
Course Summary	In the first part of the course, it intends to give a quick introduction to writing python programs using various popular interfaces. How to handle data and save and read them files is introduced next along with the concepts of repeating the tasks using conditionals and loops. The problems connected with matrices and arrays is solved using the python module numpy. The python module SymPy is used to do various mathematical problems related with symbolic computations. A brief introduction of python module pandas is given, which is used to do data analysis. Using the Python programming structure, an introduction to the advance mathematics software sagemath is given in the second part of the course. Various practical problems making use of concepts from the calculus and linear algebra are to be solved using the sagemath software so that the students will come to know some of the applications of mathematics in real life.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category #	Evaluation Tools used
CO1	Develop proficiency in fundamental to advanced Python programming concepts, including variables, data types, control structures, functions, modules, file handling, and matrix operations.	C	C	Internal Exam/Quiz/End Sem
CO2	Demonstrate competence in data visualization techniques using Matplotlib, encompassing plotting mathematical functions, 2D and 3D graphics, and animated plots.	Ap	C	Internal Exam /Assignment/ End Sem
CO3	Develop proficiency in symbolic computation with SymPy, data manipulation with Pandas, and algebraic computations with SageMath, enabling them to solve diverse mathematical problems numerically and analytically.	C	C	Internal Exam /viva/ Seminar/End Sem

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

<table>
<tr><td>Textbook</td><td colspan="3">1. Ajith Kumar B.P., Python for Education, https://scischool.in/python/pythonForEducation.pdf
2. Gregory V. Bard, Sage for Undergraduates (online version) http://www.people.vcu.edu/~clarson/bard-sage-for-undergraduates-2014.pdf
3. Tuan A. Le and Hieu D. Nguyen, SageMath Advice For Calculus, https://users.rowan.edu/~nguyen/sage/SageMathAdviceforCalculus.pdf</td></tr>
<tr><td>Module</td><td>Unit</td><td>Content</td><td>Hrs (45+ 30)</td></tr>
<tr><td rowspan="7">I</td><td colspan="2">Introductory Python and Arrays
(Text 1: Chapter 2, Chapter 3)</td><td></td></tr>
<tr><td>1</td><td>Section 2.1: Getting started with Python
Section 2.2: Variables and Data Types, Keywords,
Section 2.3: Operators and their Precedence.</td><td rowspan="6">12</td></tr>
<tr><td>2</td><td>Section 2.4: Python Strings
Section 2.5: Python Lists
Section 2.6: Mutable and Immutable Types.
Section 2.7: Input from the Keyboard
Section 2.8: Python Syntax, Colon & Indentation</td></tr>
<tr><td>3</td><td>Section 2.9: Controlling the Programe Flow
Section 2.10: Iteration: for loops
Section 2.11: Conditional Execution: if, elif and else
Section 2.12: Modify loops: break and continue..</td></tr>
<tr><td>4</td><td>Section 2.15: Functions
Section 2.17: Python Modules and Packages.
Section 2.18: File Input/Output
Section 2.19: Formatted Printing.
Section 2.21: Matrices in pure Python.</td></tr>
<tr><td>5</td><td>All topics up to Section 3.1,
Section: 3.1: NumPy Arrays</td></tr>
<tr><td>6</td><td>Section: 3.2: Vectorizing Functions.</td></tr>
</table>

II	**Data Visualization (Text 1: Chapter 4)**		
	7	Section: 4.1: The Matplotlib Module	**10**
	8	Section: 4.2: Plotting mathematical functions Section: 4.3: Plotting Error Bars, Section: 4.4: Simple 2D animation.	
	9	Section: 4.5: Famous Curves Section: 4.6: 2D plot using colors.	
	10	Section: 4.7: 3D Plots.	
III	**Introduction to SymPy and Pandas (Text 1: Chapter 5 and Chapter 6)**		
	11	All topics up to Section 5.1, Section 5.1: SymPy, Symbolic Computation in Python.	**10**
	12	Section 5.2: SymPy, Derivative and Integral	
	13	Section 5.3: SymPy, Operation on sets	
	14	Section 6.1: Series	
	15	Section 6.2: Data Frame	
	16	Section 6.3: Practical Examples	
IV	**Sagemath – An Introduction**		
		(Text 2: Chapter 1, For units 17,18,19)	
	17	Getting and installing sagemath in Windows, Ubuntu OS Using sagemath using cocalc (online) Section 1.1: Using Sage as a Calculator Section 1.2: Using Sage with Common Functions Section **1.3:** Using Sage for Trigonometry	**13**
	18	Section 1.5: Matrices and Sage, Part One 1.5.1: A First Taste of Matrices 1.5.3: Doing the RREF in Sage	
	19	Section 1.5: Using Sage to Manipulate Polynomials	
		(Text 3: Chapter 2, 3, 5, For units 20,21,22)	
	20	Section 2.1: Plotting Graphs	

	21	Section 3.1: The Derivative Section 3.2: Higher-Order Derivatives	
	22	Section 5.1: Antiderivatives (Indefinite Integral), Section 5.2: Riemann Sums and the Definite Integral All topics up to 5.2.1, 5.2.1: Riemann Sum Using Left Endpoints	
	Practical (Open-ended)		**30**
	Online References for Practical		
	1 Python official website and documentation, https://www.python.org/ 2 Spyder official website and documentation, https://www.spyder-ide.org/ 3 Getting Started: Python and IDLE, MIT Courseware, https://web.mit.edu/6.s189/www/handouts/GettingStarted.html 4 Jupyter Notebook, https://jupyter.org/ 5 Google Colaboratory (colab), https://colab.google/ 6 Pydroid 3 IDE for Android (https://play.google.com/store/apps/details?id=ru.iiec.pydroid3&hl=en_US&pli=1) with Pydroid 3 repository plugin (https://play.google.com/store/apps/details?id=ru.iiec.pydroid3.quickinstallrepo&gl=US).		
	Practical problems in basic Python 1) Write a programme to work as a basic Income Tax Calculator 2) Write a program that takes the length of an edge (an integer) as input and prints the cube’s surface area as output. 3) Write a loop that counts the number of space characters in a string. Recall that the space character is represented as ' '. 4) Write a while loop that computes the factorial of a given integer N.		

5) Write a program that computes square roots.

6) Write a programme for data Encryption based on Caeser shift.

7) Develop a program that computes the Flesch Index for a text file.

8) Using a List to Find the Median of a Set of Numbers

9) Finding the Mode of a List of Values.

Numerical methods using python (Text1: Chapter 7)(7.1 - 7.10, 7.12)

1) Evaluate a Taylor series numerically.

2) Interpolate a function using

   a) Newton's forward interpolation

   b) Newton's backward interpolation

   c) Lagrange's Interpolation

   d) Newton's General Interpolation

3) Find integral of function using

   a) Trapezoidal rule

   b) Simpson's 1/3-rule

4) Find derivative of function numerically.

5) Solve first order differential equations numerically.

   a) Euler method

   b) Fourth order Runge-Kutta method

6) Solve algebraic equations numerically.

   a) The Bisection method

   b) Regula Falsi Method

Practical problems using numpy, matplotlib, pandas and sympy

1) Various vector operations. such as dot product, cross product and divergent using numpy module.

2) Various matrix operations such as determinant, inverse and transpose using numpy module.

3) Solve system of linear equations using numpy module.

4) Plot various 2-D, 3-D curves using matplotlib module.

5) Plot various 3-D surfaces using matplotlib module.

6) Find maxima and minima of a function using SymPy module.

7) Necessary data analysis of a given data using pandas module.

Practical problems in Sage

1) Solve a system of linear equations (Text 2)

2) Constrained Optimization by Lagrange Multipliers (Text 2, 4.18.2)

3) Traffic Flow (Text 3)

4) Minimum Cost (Text 3)

5) Packaging (Minimum Surface Area) (Text 3)

6) Maximize Revenue (Text 3)

7) Area Between Curves (Text 3)

8) Average Value and mean value theorem (Text 3, 6.2)

9) Newton's Method to find approximate roots (Text 3)

References:

1 Amit Saha, Doing Math with Python, No Starch Press, 2015.
2 Vernon L. Ceder, The Quick Python Book, Second Edition, Manning.
3 Python tutorial online, https://www.geeksforgeeks.org/python-programming-language/
4 2D plotting, https://doc.sagemath.org/html/en/reference/plotting/sage/plot/plot.html
5 3D Graphics, https://doc.sagemath.org/html/en/reference/plot3d/index.html
6 Linear Algebra, https://doc.sagemath.org/html/en/tutorial/tour_linalg.html
7 John Harris, Karen Kohl, and John Perry, Peering into Advanced Mathematics through Sage-colored Glasses
8 Paul Zimmermann, Alexandre Casamayou, Computational Mathematics with SageMath, https://www.sagemath.org/sagebook/english.html
Kenneth A Lambert, Fundamentals of Python First Programs, Edn 2, Cengage

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	3	1	3	2	3	3	1	1	2
CO 2	2	2	3	1	3	2	3	3	1	1	2
CO 3	2	2	3	1	3	2	3	3	1	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Quiz
- Practical Based Assessment
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Semi nar	Quiz	Viva	Practical based assessment	End Semester Examinations
CO 1	√			√		√	√
CO 2	√	√				√	√
CO 3	√		√		√	√	√

Programme	B. Sc. Mathematics Honours				
Course Code	MAT5CJ301				
Course Title	**REAL ANALYSIS II**				
Type of Course	**Major**				
Semester	V				
Academic Level	300 - 399				
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours	
	4	3	2	75	
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus 3. Real Analysis I				
Course Summary	Continuous real functions are introduced rigorously using the epsilon-delta argument. The equivalent sequential criterion is established later. Differentiable and (Riemann) Integrable functions are introduced followed by the fundamental theorem of calculus connecting the two notions. The course concludes with a discourse on series of functions and various results discussing the compatibility of the above three notions with the limiting operations on series of functions.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse and explain the concept of continuous functions and their properties on intervals, and apply the principles of uniform continuity.	An	C	Internal Exam/Assignment/ Seminar/ Viva/Report/ End Sem Exam
CO2	Analyse the vitality of continuous functions when they are defined on intervals.	An	C	Internal Exam/Assignment/ Seminar/ Viva/Report/ End Sem Exam
CO3	Apply the derivative and the Mean Value Theorem to solve problems and prove related theorems.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva/Report/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Introduction to Real Analysis, 4/e, Robert G Bartle, Donald R Sherbert John Wiley & Sons(2011)			
Module	**Unit**	**Content**	**Hrs (45+30)**	**Marks Ext:70**
I		**Continuous Functions**	**14**	**Min.15**
	1	Section 5.1 – Continuous functions		
	2	Section 5.3 – Continuous functions on intervals — 5.3.1 to 5.3.5		
	3	Section 5.3 – from 5.3.7 - 5.3.10		
	4	Section 5.4 – Uniform Continuity-up to 5.4.3		
	5	Section 5.4 – Uniform Continuity-5.4.4 to 5.4.14(proof of Weierstrass Approximation Theorem is optional)		
	6	Selected problems from the above sections.		
II		**Differentiation**	**10**	**Min.15**
	7	Section 6.1 – The Derivative – 6.1.1 to 6.1.7		
	8	Section 6.2- The Mean Value Theorem - 6.2.1 to 6.2.6		
	9	Section 6.2 - from 6.2.7 to 6.2.9		
	10	Section 6.2-The Mean Value Theorem- 6.2.10 to 6.2.13		
	11	Selected problems in the above sections.		
III		**The Riemann Integral**	**14**	**Min.20**
	12	Section 7.1 – Riemann Integral – up to 7.1.4 (a)		
	13	Section 7.1 – from 7.1.5 to 7.1.7 (proof of 7.1.7 is optional)		
	14	Section 7.2 – Riemann Integrable functions – 7.2.1 to 7.2.5 (Examples 7.2.2 are optional)		
	15	Section 7.2 – from 7.2.7 to 7.2.13		
	16	Section 7.3 – The Fundamental Theorem – 7.3.1 to 7.3.7		
	17	Section 7.3 – from 7.3.8 to 7.3.18 (proof of theorem 7.3.18 is optional)		
	18	Selected problems in the above sections.		
IV		**Sequences and Series of functions**	**7**	**Min.10**
	19	Section 8.1 – Pointwise and Uniform Convergence – 8.1.1 to 8.1.3		
	20	Section 8.1 – from 8.1.4 to 8.1.10		
	21	Section 8.2 – Interchange of limits – 8.2.1		
	22	Section 8.2 – Interchange of limits- 8.2.3		
V		**Practicum:** The goal is for the students to learn the following selected topics in 15 practicum sessions of two hours each via self-study and group activities. The lecturer may assist by running group discussions, overseeing class seminars and referring library books for self-study and note preparation.	**30**	
	1	Section 5.2 – Combinations of continuous functions		

	2	Section 5.6 – from 5.6.5 to 5.6.7		
	3	Section 6.1 – Inverse Functions – 6.1.8 to 6.1.10		
	4	Section 6.3 – from 6.3.5 to 6.3.7		
	5	Section 6.4 – Taylor's theorem – 6.4.1 to 6.4.4		
	6	Section 6.4 – from 6.4.5 to 6.4.8		
	7	Section 9.1 – Absolute Convergence – 9.1.1 to 9.1.3		
	8	Section 9.1 – 9.1.4 to 9.1.5		
	9	Section 9.2 – Limit Comparison Test with examples		
	10	Section 9.2 – Root Test with examples		
	11	Section 9.2 – Ratio Test with examples		
	12	Section 9.2 – Integral Test with examples		
	13	Section 9.2 – Raabe's Test with examples		
	14	Section 9.3 – Alternating Series Test		
	15	Section 9.4 – Infinite Series – Series of Functions – 9.4.1 to 9.4.7		

Reference

1. Apostol, Tom M. Calculus, Volume 1. John Wiley & Sons, 1991.
2. Tom.M. Apostol, Mathematical Analysis, 2/e, Addison-Wesley, 2002.
3. Richard R Goldberg, Methods of Real Analysis, 2/e, Wiley, 2020
4. Raymond L Wilder, Introduction to the Foundations of Mathematics,2/e, John Wiley & Sons
5. Malik, Subhash Chandra, and Savita Arora. Mathematical analysis. New Age International, 1992.

***Optional topics are exempted for end semester examination**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	2	1	2	0	2	0	3	0	0
CO 2	2	2	2	1	2	0	2	0	3	0	0
CO 3	3	2	3	1	3	0	3	0	3	0	0

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT5CJ302			
Course Title	**ABSTRACT ALGEBRA I**			
Type of Course	**Major**			
Semester	V			
Academic Level	300-399			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic set theory, algebra of Integers, operations on functions, basic proof techniques etc.			
Course Summary	This course explores the algebraic concepts of Binary Operations, Binary Structures, Groups, Rings, Integral Domains and Fields. We further study the Theory of Groups. Elementary properties, Subgroups, Finite Groups, Cyclic Groups, Groups of Permutations, Orbits, Cycles, Alternating Groups, Cosets and the Theorem of Lagrange are studied. Then we study mappings between groups or Homomorphisms. Finally, the Open-ended section points to Generating sets, Factor Groups and Field of Quotients of an Integral Domain.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Discuss about binary operations, isomorphic binary structures and groups	U	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO2	Analyse and classify subgroups and cyclic groups, and determine their properties using group theory.	An	P	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO3	Evaluate and apply theorems related to cosets, Lagrange's theorem, homomorphisms, rings, and fields to solve complex algebraic problems.	E	F	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text book	A first course in abstract algebra, Fraleigh, John B.. Seventh Edition, Pearson Education India, 2003			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Marks Ext(70)**
I		**Module I**	**12**	**Min.15**
	1	Section 2- Binary Operations (2.1 to 2.10)		
	2	Section 2- Binary Operations (2.11 to 2.25)		
	3	Section 3- Isomorphic Binary Structures (3.1 to 3.11).		
	4	Section 3- Isomorphic Binary Structures (3.12 to 3.17)		
	5	Section 4- Groups (4.1 to 4.14)		
	6	Section 4- Groups – Elementary Properties of Groups, Finite Groups and Group tables (4.15 onwards)		
II		**Module II**	**14**	**Min.15**
	7	Section 5- Subgroups (5.1 to 5.16)		
	8	Section 5 -Subgroup - Cyclic Subgroups (5.17 to 5.23)		
	9	Section 6 -Cyclic Groups (6.1 to 6.9) (Proof of Theorem 6.3 is optional)		
	10	Section 6- Cyclic Groups (6.10 to 6.17) (Proof of Theorem 6.14 is optional).1		
	11	Section 8-Groups of Permutations (up to 8.6)		
	12	Section 8- Groups of Permutations (8.7 to 8.18)		
III		**Module III**	**10**	**Min.15**
	13	Section 9 - Orbits, Cycles, and the Alternating Groups (Up to 9.10)		
	14	Section 9 - Orbits, Cycles, and the Alternating Groups (9.11 to 9.21) (Proof 2 of theorem 9.15 is optional).		
	15	Section 10- Cosets and the theorem of Lagrange (Up to 10.9)		
	16	Section 10- Cosets and the theorem of Lagrange (10.10 to 10.14)		

IV	**Module IV**		**12**	**Min.15**
	17	Section 13- Homomorphisms (13.1 to 13.10)		
	18	Section 13-Homomorphism (13.11 to 13.20)		
	19	Section 18-Rings and Fields (18.1 to 18.13)		
	20	Section 18-Rings and Fields (18.14 to 18.18)		
	21	Section 19-Integral Domains (19.1 to 19.8)		
	22	Section 19-Integral Domains (19.9 to 19.15)		
V	**Module V (Open Ended)**		**12**	**-**
		Generating Sets in Groups		
		Factor Groups		
		The Field of Quotients of an Integral Domain		

References

1. Herstein, Israel Nathan. *Topics in algebra*. John Wiley & Sons, 1991.

2. Gallian, Joseph. *Contemporary abstract algebra*. Chapman and Hall/CRC, 2021.

3. Wallace, David AR. *Groups, rings and fields*. Springer Science & Business Media, 2001

4. Reis, Clive. *Abstract algebra: an introduction to groups, rings and fields*. World Scientific Publishing Company, 2011.

5. Allan Clark, *Elements of Abstract Algebra,* Dover Publications, 1984

6. C Musili, *Introduction to Rings and Modules*, Narosa Publications, 2009

Suggested Programming Exercises for Open-Ended

1. Form congruence groups, their Cayley tables (Section 9.2, Ref (3)).
2. Form symmetric groups of various orders, list the elements, find the power of some elements, find out the product of some of the elements. Find the order of the elements. Form a group table using conditionals and loops. (Section 9.3, Ref (3) or Ref (1)).
3. List S_3. Find a subgroup from this group. How many distinct subgroups can be found from this group? List all of them.
4. Form the Dihedral group D_4, check if it is abelian using is_abelian(). Conduct the same experiments as listing the elements ,finding the orders etc as above. (Section 9.4, Ref (3) or Ref (1)).
5. Test the command is normal () on a few subgroups of S_3. (Ref (1)).
6. Create cyclic groups. (Section 9.5, Ref (3)).

7. Form finitely generated abelian groups. (Section 9.6, Ref (3)).
8. Form a subgroup of a group (say, S_3) (Section 9.8, Ref (3)).

References

1. Robert A. Beezer; Group Theory and SAGE: A Primer, http://people.reed.edu/~davidp/332/sage-group-theory.pdf
2. Group Theory and Sage - SageMath tutorial https://doc.sagemath.org/html/en/thematic_tutorials/group_theory.html
3. Ajit Kumar, Vikas Bist; Group Theory An Expedition with SageMath, Narosa Publishing House.
4. Thomas W. Judson, Robert A. Beezer; Abstract Algebra Theory and Applications with Sage Exercises for Abstract Algebra, http://abstract.ups.edu/download/ aata-20130816.pdf

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	1	0	2	0	0	0	2	0	0
CO 2	1	2	3	0	2	0	2	0	3	0	0
CO 3	0	1	2	3	2	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT5CJ303			
Course Title	**COMPLEX ANALYSIS I**			
Type of Course	**Major**			
Semester	V			
Academic Level	300-399			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Basics of Real Number System and Calculus.			
Course Summary	This course begins with the concepts of complex numbers. complex plane, polar form of complex numbers, powers and roots, etc. Next we discuss complex functions including power functions and nth root functions. Then we discuss limits, continuity, differentiability and analyticity of complex functions. Cauchy Riemann equations and Harmonic conjugates are also studied. Finally the course discusses some standard complex functions like Exponential functions, Logarithmic functions, Trigonometric and Hyperbolic functions.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and explain the properties and representations of complex numbers, including their polar form and operations.	U	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO2	Apply the principles of limits, continuity, and differentiability to complex functions and utilize the Cauchy-Riemann equations.	Ap	P	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO3	Evaluate and create complex exponential, logarithmic, trigonometric, and hyperbolic functions, understanding their properties and applications.	C	F	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Textbook	Complex Analysis (Third Edition): Dennis G. Zill & Patric D. Shanahan, Jones & Bartlett Learning, 2018.			
Module	**Unit**	**Content**	**Hrs 60**	**External Marks (70)**
I		**Module I**	**13**	**Min.15**
	1	Section 1.1-Complex Numbers and Their Properties		
	2	Section 1.2-Complex Plane		
	3	Section 1.3- Polar Form of Complex Numbers		
	4	Section 1.4- Powers and Roots		
	5	Section 1.5 -Sets of Points in Complex Plane		
II		**Module II**	**12**	**Min.15**
	6	Section 2.1 -Complex Functions		
	7	Section 2.2- Complex Functions as Mappings- up to and including Example 4.		
	8	Section 2.4- Special Power Functions- The Power Function z^n (All the topics in 2.4.1)		
	9	Section 2.4- Special Power Functions-The power function $z^{\frac{1}{n}}$ (Topics in 2.4.2, up to and including Example 5.)		
	10	Section 2.4- Special Power Functions-Principal nth Root Functions and Example 9.		
III		**Module III**	**15**	**Min.20**
	11	Section 3.1- Limits and Continuity-Limits (All the topics in 3.1.1)		
	12	Section 3.1- Limits and Continuity-Continuity (Topics in 3.1.2, up to Example 7.)		
	13	Section 3.1-Limits and Continuity-Continuity (Theorem 3.1.4 to up to and including a bounding property.		
	14	Section 3.2- Differentiability and Analyticity- up to and including Example 2.		
	15	Section 3.2- Differentiability and Analyticity- All the topics after Example 2.		
	16	Section 3.3- Cauchy-Riemann Equations-up to and including Theorem 3.3.2		
	17	Section 3.3 - Cauchy Riemann Equations: -All the topics after Theorem 3.3.2.		
	18	Section 3.4 - Harmonic Functions		
IV		**Module IV**	**8**	**Min.15**
	19	Section 4.1 Exponential and Logarithmic Functions- Complex Exponential Function (Topics in 4.1.1 up to and including Periodicity)		

	20	Section 4.1 Exponential and Logarithmic Functions- Complex Logarithmic Function (Topics in 4.1.2 up to and including Example 4)		
	21	Section 4.3 Trigonometric and Hyperbolic Functions- Complex Trigonometric Functions (Topics in 4.3.1, up to and excluding trigonometric mapping.)		
	22	Section 4.3 Trigonometric and Hyperbolic Functions- Complex Hyperbolic Functions (All the topics in 4.3.2)		
V	**Module V (Open Ended)**		**12**	
		Linear Mappings, Reciprocal Functions		
		Branches, Branch Cuts and Points, Complex Powers		
		Inverse Trigonometric and Hyperbolic Functions.		

References

1. Brown, James Ward, and Ruel V. Churchill. Complex variables and applications. McGraw-Hill, 2009.
2. Stein, Elias M., and Rami Shakarchi. Complex analysis. Vol. 2. Princeton University Press, 2010.
3. Burckel, Robert B. An Introduction to Classical Complex Analysis: Vol. 1. Vol. 64. Birkhäuser, 2012
4. Hormander, Lars. An introduction to complex analysis in several variables. Elsevier, 1973.
5. Priestley, Hilary A. Introduction to complex analysis. OUP Oxford, 2003.
6. Silverman, Richard A. Introductory complex analysis. Courier Corporation, 2013
7. Bak, Joseph, Donald J. Newman, and Donald J. Newman. *Complex analysis*. Vol. 8. New York: Springer, 2010.

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	0	0	3	0	0	0	2	0	0
CO 2	0	3	1	0	2	0	3	0	3	0	0
CO 3	1	0	3	0	2	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT6CJ304 / MAT8MN304			
Course Title	**COMPLEX ANALYSIS-II**			
Type of Course	**Major**			
Semester	VI			
Academic Level	300-399			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Idea of complex numbers, Polar representations, Differentiability and Analyticity.			
Course Summary	We continue from Complex Analysis-I and begin by discussing complex integrals, followed by Cauchy-Goursat Theorem. Independence of path, Cauchy's Integral formula, sequence and series of complex numbers are next studied. It is then followed by Taylor series, Laurent series. zeros and poles, and Residue Theorem. Applications of Residue theorem are also discussed.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply the principles of real and complex integrals, including the Cauchy-Goursat theorem	Ap	P	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO2	Analyse the independence of path and evaluate the Cauchy's integral formulas, along with understanding their consequences and applications.	An	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO3	Create and utilize Taylor and Laurent series, and apply the residue theorem to evaluate complex functions and integrals.	C	F	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Complex Analysis (Third Edition): Dennis G. Zill & Patric D. Shanahan, Jones & Bartlett Learning, 2018.			
Module	**Unit**	**Content**	**Hrs (60)**	**External Marks (70)**
I		**Module I**	**12**	**Min.15**
	1	Section 5.1-Real Integrals.		
	2	Section 5.2-Complex Integrals-up to and including Example 2		
	3	Section 5.2- Complex Integrals- All the topics after Example 2		
	4	Section 5.3- Cauchy- Goursat Theorem-up to and including Example 4.		
	5	Section 5.3 -Cauchy- Goursat Theorem-All the topics after Example 4.		
II		**Module II**	**12**	**Min.15**
	6	Section 5.4- Independence of Path		
	7	Section 5.5 -Cauchy's Integral Formulas and Their Consequences- Cauchy's Two Integral Formulas (All the topics in 5.5.1)		
	8	Section 5.5 -Cauchy's Integral Formulas and Their Consequences- Some Consequences of the Integral Formulas (All the topics in 5.5.2)		
	9	Section 6.1 -Sequences and Series- up to and including Example 4.		
	10	Section 6.1- Sequences and Series- All the topics after Example 4.		
III		**Module III**	**14**	**Min.15**
	11	Section 6.2 -Taylor Series-up to and Excluding Theorem 6.2.4.		
	12	Section 6.2- Taylor Series-From Theorem 6.2.4 to Example 3.		
	13	Section 6.3 -Laurent Series-up to and including Example 1.		
	14	Section 6.3- Laurent Series- All the topics after Example 1(proof of Laurent's Theorem is optional)		
	15	Section 6.4 -Zeros and Poles- up to and including Example 2.		
	16	Section 6.4- Zeros and Poles- All the topics after Example 2.		
IV		**Module IV**	**10**	
	17	Section 6.5 -Residues and Residue Theorem-up to and including Example 3.		
	18	Section 6.5 - Residues and Residue Theorem-All the topics after Example 3.		
	19	Section 6.6- Some Consequences of the Residue Theorem- Evaluation of Real Trigonometric Functions (up to and including example1 of 6.6.1)		

	20	Section 6.6 -Some Consequences of the Residue Theorem- Evaluation of Real Improper Integrals (up to and including Example 2)		**Min.15**
	21	Section 6.6 -Some Consequences of the Residue Theorem- Theorem 6.6.1 and Example 3.		
	22	Section 6.6 -Some Consequences of the Residue Theorem- Theorem 6.6.2 and Example 4.		
V	**Module V (Open Ended)**		**12**	
		Definite Integrals, Line Integrals in the Plane, Indented Contours		
		Integration along a Branch Cut, The Argument Principle		
		Rouche's Theorem and its applications		
References				
	1	Brown, James Ward, and Ruel V. Churchill. Complex variables and applications. McGraw-Hill, 2009.		
	2	Stein, Elias M., and Rami Shakarchi. Complex analysis. Vol. 2. Princeton University Press, 2010.		
	3	Burckel, Robert B. An Introduction to Classical Complex Analysis: Vol. 1. Vol. 64. Burkhouse, 2012.		
	4	Hormander, Lars. An introduction to complex analysis in several variables. Elsevier, 1973.		
	5	Priestley, Hilary A. Introduction to complex analysis. OUP Oxford, 2003.		
	6	Silverman, Richard A. Introductory complex analysis. Courier Corporation, 2013.		
	7	Bak, Joseph, Donald J. Newman, and Donald J. Newman. *Complex analysis*. Vol. 8. New York: Springer, 2010.		

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	1	0	3	0	3	0	3	0	0
CO 2	1	2	1	0	2	0	3	0	3	0	0
CO 3	1	2	1	0	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT6CJ305 / MAT8MN305			
Course Title	**ELEMENTARY NUMBER THEORY**			
Type of Course	**Major**			
Semester	VI			
Academic Level	300-399			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Arithmetic of integers, basic set theory and proof techniques.			
Course Summary	We start number theory with the division algorithm, g.c.d., and the Euclidean algorithm for computing it, essential for solving Diophantine equations like ax + by = c. We then prove the Fundamental Theorem of Arithmetic, discuss the infinitude of primes and the sieve of Eratosthenes. Following that, we cover Linear Congruences, the Chinese Remainder theorem, and Fermat's Little Theorem. Finally, we explore Wilson's Theorem, Euler's Phi Function, and Euler's Theorem.			

Course Outcomes:

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply the division algorithm and Euclidean algorithm to compute greatest common divisors (gcd) and solve related divisibility problems.	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Solve Diophantine equations for integer solutions, deduce prime factorization through the fundamental theorem of arithmetic, and identify prime numbers using the sieve of Eratosthenes.	Ap	C	Internal Exam/ Assignment/ Seminar/Viva/ End Sem Exam
CO3	Apply the properties of congruence and the Chinese Remainder Theorem to solve systems of linear congruences.	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Textbook	Elementary Number Theory, David Burton, M, Seventh Edition, Mcgraw – Hill (2007).			
Module	**Unit**	**Content**	**Hrs (60)**	**External Marks (70)**
I		**Module I**	**12**	**Min.15**
	1	Section 2.2 The division algorithm (proof of theorem 2.1 omitted).		
	2	Section 2.3 The greatest common divisor - up to and including theorem 2.3 and its corollary.		
	3	Section 2.3 The greatest common divisor - All topics from definition 2.3 onwards.		
	4	Section 2.4 The Euclidean algorithm - up to Theorem 2.7.		
	5	Section 2.4 The Euclidean algorithm - All topics from Theorem 2.7 onwards.		
II		**Module II**	**11**	**Min.15**
	6	Section 2.5 The Diophantine equation ax+by = c - up to and including Theorem 2.9.		
	7	Section 2.5 - All topics from Example 2.4 onwards.		
	8	Section 3.1 The fundamental theorem of arithmetic - up to Theorem 3.2.		
	9	Section 3.1 The fundamental theorem of arithmetic - All topics from Theorem 3.2 onwards.		
	10	Section 3.2 The sieve of Eratosthenes (up to and including theorem 3.4 only)		
III		**Module III**		

	11	Section 4.2 Basic properties of congruence – up to Theorem 4.2.	13	Min.15
	12	Section 4.2 Basic properties of congruence – All topics from Theorem 4.2 onwards.		
	13	Section 4.4 Linear congruences and the Chinese remainder theorem – up to Theorem 4.8.		
	14	Section 4.4 Linear congruences and the Chinese remainder theorem – All Topics from Theorem 4.8 (proof of Theorem 4.8 omitted).		
	15	Section 5.2 Fermat's little theorem and pseudo primes – up to Lemma. (omit a different proof for Fermat's theorem)		
	16	Section 5.2 Fermat's little theorem and pseudo primes – All topics from Lemma onwards.		
IV	**Module IV**		12	Min.15
	17	Section 5.3 Wilson's theorem – Up to Theorem 5.5.		
	18	Section 5.3 Wilson's theorem – All topics from Theorem 5.5 onwards.		
	19	Section 7.2 Euler's phi-function – up to Lemma.		
	20	Section 7.2 Euler's phi-function – All Topics from Lemma onwards. (proof of Theorem 7.2 omitted).		
	21	Section 7.3 Euler's theorem. (Second proof of Euler's theorem omitted).		
	22	Section 7.4 Some properties of the phi-function (Proof of Theorem 7.8 omitted).		
V	**Module V (Open Ended)**			

	Proof of Theorem 4.8. Chinese Remainder Theorem and remaining portions of Section 4.4 Section 6.1 The sum and the number of divisors Linear congruences and the Chinese remainder theorem. Section 6.3 The Greatest Integer Function - up to Theorem 6.11.	**12**	

References

1. Rosen, Kenneth H. *Elementary number theory*. London: Pearson Education, 2011.
2. Eynden, Charles Vanden. *Elementary number theory*. Waveland Press, 2006.
3. Gehring, F. W., and P. R. Halmos. G*raduate Texts in Mathematics*, 1976.
4. Hsiung, C. Y. *Elementary theory of numbers*. World Scientific, 1992.
5. Hoffman P., *The man who loved only numbers: The story of Paul Erdös and the search for mathematical truth*, Little Brown & Company, 1999.

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	1	1	0	0	3	0	3	0	3	0	0
CO 2	1	1	0	0	3	0	3	0	3	0	0
CO 3	0	0	1	0	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT6CJ306 / MAT8MN306				
Course Title	**METHODS OF DIFFERENTIAL EQUATIONS**				
Type of Course	**Major**				
Semester	VI				
Academic Level	300-399				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Foundations of basic calculus (0-99 level)				
Course Summary	The course enhances the skill to solve ordinary differential equation using specific methods analytically and computationally for first and higher order differential equations.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Classify and solve first order differential equation by applying appropriate methods	Ap	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO2	Apply different methods to solve higher order homogeneous and non-homogeneous linear differential equations with constant coefficients	Ap	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
CO3	Use Laplace transform and inverse Laplace transform to solve linear differential equations	Ap	C	Internal Exam/ Assignment/Seminar/ Viva/End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

<table>
<tr><td>Textbook</td><td colspan="4">Dennis G. Zill , A First Course in Differential Equations with Modeling Applications 10th Edn, Cengage Learning (2012) ISBN-13 978-1111827052</td></tr>
<tr><td rowspan="2">Module</td><td rowspan="2">Unit</td><td rowspan="2">Content</td><td rowspan="2">Hrs (60)</td><td>Marks</td></tr>
<tr><td>Ext: 70</td></tr>
<tr><td rowspan="9">I</td><td colspan="2">First order differential equations</td><td rowspan="9">14</td><td rowspan="9">Min.15</td></tr>
<tr><td></td><td>Quick review of Introduction to differential equations (Definitions only)</td></tr>
<tr><td>1</td><td>2.1.1-Direction Fields</td></tr>
<tr><td>2</td><td>2.1.2 - Autonomous First-Order DEs</td></tr>
<tr><td>3</td><td>2.2 - Separable Equations</td></tr>
<tr><td>4</td><td>2.3 - Linear Equations</td></tr>
<tr><td>5</td><td>2.4- Exact Equations</td></tr>
<tr><td>6</td><td>2.5- Solutions by Substitutions</td></tr>
<tr><td>7</td><td>Problems from the above sections</td></tr>
<tr><td rowspan="6">II</td><td colspan="2">Higher-Order Differential Equations</td><td rowspan="6">12</td><td rowspan="6">Min.15</td></tr>
<tr><td>8</td><td>4.1.1 Initial-Value and Boundary-Value Problems</td></tr>
<tr><td>9</td><td>4.1.2 Homogeneous Equations (proof of Theorems 4.1.2 and 4.1.5 are optional)</td></tr>
<tr><td>10</td><td>4.1.3 Nonhomogeneous Equations</td></tr>
<tr><td>11</td><td>4.2 Reduction of Order</td></tr>
<tr><td>12</td><td>4.3 Homogeneous Linear Equations with Constant Coefficients</td></tr>
<tr><td rowspan="6">III</td><td colspan="2">Higher-Order Differential Equations (Cont..)</td><td rowspan="8">14</td><td rowspan="8">Min.20</td></tr>
<tr><td>13</td><td>4.4 -Undetermined Coefficients—Superposition Approach (up to and including Example 9)</td></tr>
<tr><td>14</td><td>4.5 - Undetermined Coefficients—Annihilator Approach (up to and including Example 3)</td></tr>
<tr><td>15</td><td>4.5 - Undetermined Coefficients—Annihilator Approach (all the topics after Example 3)</td></tr>
<tr><td>16</td><td>4.6- Variation of Parameters</td></tr>
<tr><td>17</td><td>4.7 - Cauchy-Euler Equation (up to and including Example 4)</td></tr>
<tr><td></td><td>18</td><td>4.7 - Cauchy-Euler Equation (all the topics after Example 4)</td></tr>
<tr><td></td><td>19</td><td>4.9 - Solving Systems of Linear DEs by Elimination</td></tr>
<tr><td rowspan="4">IV</td><td colspan="2">Laplace Transforms</td><td rowspan="4">8</td><td rowspan="4">Min.10</td></tr>
<tr><td>20</td><td>7.1 Definition of the Laplace Transforms (proof of Theorems 7.1.2 and 7.1.3 are optional)</td></tr>
<tr><td>21</td><td>7.2.1 Inverse Transforms</td></tr>
<tr><td>22</td><td>7.2.2 Transforms of Derivatives</td></tr>
<tr><td rowspan="2">V</td><td colspan="2">Open Ended: Mastering differential equation using software</td><td rowspan="2">12</td><td rowspan="2"></td></tr>
<tr><td colspan="2">IVP and BVP Problem-solving using mathematical software like Sage/Python/ Mathematica/Matlab/ Maple/Scilab etc (Instructor may choose any software appropriately)</td></tr>
</table>

	Suggestions: ● Plotting solution curves -2 hrs ● Solve first order initial value problems -2 hrs ● Solve second order initial value problems -2 hrs ● Plot Laplace transform of given function -2 hrs ● find Laplace transform and inverse Laplace transform -2 hrs ● Solve the initial value problem using Laplace transform -2 hrs		

References

1. G. F. Simmons and S. G. Krantz, Differential Equations: Theory, Technique, and Practice, McGraw Hill (2006), ISBN-13. 978-0072863154
2. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall India (2009). ISBN: 9788120303614
3. E. Boyce , Richard C. Diprima, Douglas B Meade, Elementary Differential Equations and Boundary Value Problems, 11 Edn. William John Wiely & Sons (2017) ISBN: 1119169879
4. William F. Trench, Elementary Differential Equations with Boundary Value Problems, S.Chand (G/L) & Company Ltd (2013) ISBN 13: 9780534368418.
5. S. L. Ross, Differential Equations, 3rd edition, Wiley India, (2007) ISBN-13. 978-8126515370
6. Martha L. Abell, James P. Braselton, Differential Equations with Mathematica, 5th edn. Elsevier Science Publishing Co Inc (2022), ISBN: 9780128241608
7. Amit Saha, Doing Math with Python", No Starch Press, US . (2015), ISBN 13 978-1593276409

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	0	3	0	3	0	0
CO 2	2	3	1	2	3	0	3	0	3	0	0
CO 3	2	1	3	3	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT7CJ401				
Course Title	**MATHEMATICAL ANALYSIS**				
Type of Course	**Major**				
Semester	VII				
Academic Level	400-499				
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours	
	4	3	2	75	
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus 3. Real Analysis I, Real Analysis II				
Course Summary	The topology of the real line is explored in detail, as is necessary later for an in-depth understanding of the theory of real functions. Limits, Continuity & Differentiation are rigorously covered. Riemann-Stieltjes Integration is introduced as a generalisation of the Riemann integration covered in earlier semesters, enabling the student to view summation of series and integration as extensions of the same concept. After a discourse on series of functions and various results discussing the compatibility of the above three notions with the limiting operations on series of functions, the course concludes with a presentation of the famous Stone-Weierstrass' Theorem.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse and differentiate between finite, countable, and uncountable sets, and apply these concepts to problems in R	An	C	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO2	Evaluate the properties of compact, perfect, and connected sets in the context of metric spaces.	E	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO3	Synthesize the principles of continuity, differentiability, integrability and convergence of sequences and series including the application of the Mean Value Theorem and L'Hospital's Rule, to solve complex problems involving real-valued and vector-valued functions.	E	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Principles of Mathematical Analysis, Walter Rudin,, (3/e), McGraw Hill Inc(2013)			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Basic Topology of the Real Line**	**13**	**Min.15**
	1	Chapter 2 – Finite, Countable & Uncountable Sets – 2.1 to 2.14		
	2	Chapter 2 – Metric Spaces – 2.15 to 2.24		
	3	Chapter 2 – Metric Spaces – 2.25 to 2.30		
	4	Chapter 2 – Compact Sets – 2.31 to 2.42		
	5	Chapter 2 – Perfect Sets – 2.43 to 2.44		
	6	Chapter 2 – Connected Sets – 2.45 to 2.47		
II		**Continuity and Differentiation**	**16**	**Min.20**
	7	Chapter 4 – Limits of Functions and Continuous Functions – 4.1 to 4.12		
	8	Chapter 4 – Continuity and Compactness – 4.13 to 4.21		
	9	Chapter 4 - Continuity and Connectedness – 4.22 to 4.24		
	10	Chapter 4 – Discontinuities and Monotonic Functions – 4.25 to 4.30		
	11	Chapter 5 – The Derivative – 5.1 to 5.6		
	12	Chapter 5 – Mean Value Theorems – 5.7 to 5.12		
	13	Chapter 5 – L'Hospital's rule, Higher Derivatives & Taylor's Theorem, Differentiation of Vector Valued Functions – 5.13 to 5.19 (proof of theorem 5.13 and theorem 5.15 are optional)		
III		**The Riemann-Stieltjes Integral**	**9**	**Min.15**
	14	Chapter 6 – Definition and Existence – 6.1 to 6.6		
	15	Chapter 6 – Definition and Existence – 6.6 to 6.11		
	16	Chapter 6 – Properties – 6.12 to 6.13		
	17	Chapter 6 – Properties – 6.14 to 6.19 (proof of theorem 6.19 is optional)		
	18	Chapter 6 – Integration & Differentiation – 6.20 to 6.22		
IV		**Sequences & Series of functions**	**7**	**Min.10**
	19	Chapter 7 – Discussion of Main Problem - 7.1 to 7.3		
	20	Chapter 7 – Discussion of Main Problem - 7.4 to 7.6		
	21	Chapter 7 –Uniform Convergence – 7.7-7.10		
	22	Chapter 7 –Uniform Convergence & Continuity – 7.11 to 7.13		
V		**Practicum :** The goal is for the students to learn the following selected topics via self-study and group activities. The lecturer may	**30**	**-**

	assist by running and overseeing group discussions and class seminars and referring library books for self-study and note preparation.			
	1	Chapter 3 – Convergent Sequences, Subsequences		
	2	Chapter 3 – Cauchy Sequences, Upper and Lower Limits		
	3	Chapter 3 – Some Special Sequences, Series		
	4	Chapter 3 – Series of Non-Negative Terms, The Root and Ratio Tests		
	5	Chapter 3 – Power Series, Absolute Convergence		
	6	Chapter 3 – Addition and Multiplication of Series, Rearrangements.		
	7	Chapter 4 – Infinite Limits & Limits at Infinity – 4.32 to 4.34		
	8	Chapter 6 – Integration of Vector-valued Functions and Rectifiable curves - 6.23 to 6.27		
	9	Chapter 7 – Uniform Convergence, Integration and Differentiation – 7.16 to 7.18		
	10	Chapter 7 –Equicontinuity and Stone-Weierstrass Theorem – 7.19 to 7.27		

References

1. Mathematical Analysis,T. M. Apostol, (2nd Edn.); Narosa; 2002.
2. Introduction to Real Analysis, R. G. Bartle and D.R. Sherbert:; John Wiley Bros; 1982.
3. Real Analysis- a first course, R. A. Gordon:(2nd Edn.); Pearson; 2009.
4. Analysis-I, H. Amann and J. Escher, Birkhuser, 2006
5. The way of Analysis, Robert Strichartz, (R/e), Jones and Bartlett Mathematics (2000)
6. A first course in Real Analysis, M. H. Protter and C. B. Moray, Springer Verlag UTM (1977)

***Optional topics are exempted for end semester examination**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1	0	3	0	3	0	3	0	0
CO 2	2	3	2	0	3	0	3	0	3	0	0
CO 3	3	3	3	1	3	0	3	0	3	0	0

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT7CJ402			
Course Title	**GENERAL TOPOLOGY**			
Type of Course	**Major**			
Semester	VII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus 3. Real Analysis I, Real Analysis II			
Course Summary	The subject of general topology is introduced with motivations from the theory of real functions and of metric spaces. Basic concepts like open and closed sets, interiors, closures, boundaries, neighbourhoods, bases and sub-bases are introduced. After a discussion of continuity and related topics, the universal properties of strong and weak topologies are discussed. Compactness, connectedness, and various countability axioms are studied in some detail. After a detailed study of the hierarchy of separation axioms and their interplay with other properties such as compactness, the course concludes with a presentation of the famous Urysohn & Tietze characterisations of normality.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Define and classify topological spaces, bases, and subspaces, and apply these concepts to identify examples of different topological structures.	Ap	C	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO2	Analyse and evaluate closed sets, interior points, and accumulation points within topological spaces, and understand the concepts of continuity and related topological properties.	An	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO3	Synthesize the concepts of connectedness, separation axioms, and compactness to determine specific topological properties of spaces and analyse their applications in solving problems related to paths and separation.	E	C	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Textbook	Introduction to General Topology, K. D. Joshi,, New Age International Publishers, 1983**.**			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Topological Spaces**	**12**	**Min.15**
	1	Chapter 4 – Section 1: Definition of Topological Space		
	2	Chapter 4 – Section 2: Examples of Topological Spaces		
	3	Chapter 4 – Section 3: Bases and Sub-bases – 3.1 to 3.7		
	4	Chapter 4 – Section 3: Bases and Sub-bases – 3.8 to 3.10		
	5	Chapter 4 – Section 4: Subspaces – 4.1 to 4.6		
II		**Basic concepts**	**10**	**Min.15**
	6	Chapter 5 – Section 1: Closed Sets and Closure (Proof of Theorem 1.5 is optional)		
	7	Chapter 5 – Section 2: Neighbourhoods, Interior and Accumulation Points – 2.1 to 2.8		
	8	Chapter 5 – Section 2: Neighbourhoods, Interior and Accumulation Points –2.9 to 2.10 and 2.13		
	9	Chapter 5 – Section 3: Continuity and Related Concepts – 3.1 to 3.6		
	10	Chapter 5 – Section 3: Continuity and Related Concepts – 3.7 to 3.11		
III		**Spaces with special properties**	**12**	**Min.15**
	11	Chapter 5 – Section 4: Making Functions Continuous, Quotient Spaces – 4.1 to 4.7		
	12	Chapter 5 – Making Functions Continuous, Quotient Spaces – 4.8 to 4.12		
	13	Chapter 6 – Section 1: Smallness Conditions on a Space – 1.1 to 1.9		
	14	Chapter 6 – Section 1: Smallness Conditions on a Space – 1.10 to 1.18		
	15	Chapter 6 – Section 2: Connectedness – 2.1 to 2.6 (Proof of Theorem 2.5 is optional)		
	16	Chapter 6 – Connectedness – 2.7 to 2.15		
IV		**Separation axioms**	**11**	**Min.15**
	17	Chapter 6 – Section 3: Local Connectedness and Paths – 3.1 to 3.8		
	18	Chapter 7 – Hierarchy of Separation Axioms - 1.1 to 1.6.		
	19	Chapter 7 – Hierarchy of Separation Axioms - 1.7 to 1.12		
	20	Chapter 7 – Hierarchy of Separation Axioms - 1.13 to 1.17		

	21	Chapter 7 – Section 2: Compactness and Separation Axioms - 2.1 to 2.6		
	22	Chapter 7 – Section 2: Compactness and Separation Axioms- 2.7 to 2.10		
V Practicum		**Practicum:** The goal is for the students to learn the following selected topics in 10 practicum sessions of hours each via self-study and group activities. The lecturer may assist by running group discussions, supervising class seminars and referring library books for self-study and note preparation.	**30**	**-**
1		Chapter 1 - Logical Warm-up		
2		Chapter 2 – Preliminaries		
3		Chapter 3 – Motivation for Topology		
4		Chapter 6 - Connectedness: Theorem 2.5 and its proof		
5		Chapter 6 - Local connectedness and Paths - 3.9 to 3.11		
6		Chapter 7 - Compactness and Separation Axioms - 2.11 to 2.16		
7		Chapter 7 – Section 3: Urysohn Characterisation of Normality -3.1 to 3.4		
8		Chapter 7 – Section 3: Urysohn Characterisation of Normality - 3.5 to 3.6		
9		Chapter 7 –Section 4: Tietze Characterisation of Normality - 4.1 to 4.5		
10		Chapter 7 –Section 4: Tietze Characterisation of Normality - 4.6 to 4.8		

References

1. Topology, J. R. Munkres, Prentice Hall of India, 2000.
2. General Topology, S. Willard, Addison Wesley Pub. Company, 1976.
3. General Topology, J. L. Kelley, D. van Nostrand, 1955.
4. Introduction to Topology and Modern Analysis, G. F. Simmons, McGraw-Hill, 1963.
5. Topology, James Dugundji, Prentice Hall of India, 1975.

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	2	0	3	0	3	0	3	0	0
CO 2	3	2	2	1	3	0	3	0	3	0	0
CO 3	3	3	3	2	3	0	3	0	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT7CJ403			
Course Title	**ABSTRACT ALGEBRA II**			
Type of Course	**Major**			
Semester	VII			
Academic	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. First Course on Group Theory			
Course Summary	The subject of group theory is taken upon from where it was left off in previous introductory courses. The basic constructions in group theory – those of direct products and quotient groups are introduced. The Fundamental Theorem of Finitely Generated Abelian Groups is introduced (without proof) and the consequences explored in order to compare the challenges in the theory of Abelian vs non-Abelian groups. After an introductory delving into normal and subnormal series of groups, group actions are introduced and Sylow Theory discussed in the context of classifying non-Abelian groups. The course concludes with a basic discussion on polynomial rings and their factorisation, paving the way for the theory of extension fields in later, more advanced courses.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply the concept of direct products of groups and factor groups to construct new groups from existing ones.	Ap	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO2	Analyse and evaluate the isomorphism theorems, series of groups, and Sylow theorems to understand the structural properties and classifications of groups.	E	C	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO3	Synthesize the concepts of rings of polynomials, factorization of polynomials, and ideal structures within rings and fields, with a focus on homomorphisms and factor rings.	E	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	A First Course in Abstract Algebra, J. B. Fraleigh, 7th Edition, Pearson Education Limited, 2014.			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Basic Constructions – New Groups From Old**	**11**	**Min.15**
	1	Section 11 – Direct Products of Groups (11.1 to 11.11)		
	2	Section 11 – Finitely Generated Abelian Groups (11.12 to 11.17)		
	4	Section 14 – Factor Groups		
	5	Section 15 – Factor Group Computations (15.1 to 15.13)		
	6	Section 15 – Simple Groups, The Centre and Commutator Subgroups (15.14 to 15.21).		
II		**Advanced Group Theory** (Pre-requisites: Sections 16 and 17 of Practicum)	**14**	**Min.20**
	7	Section 34 – Isomorphism Theorems		
	8	Section 35 – Series of Groups - 35.1 to 35.19 (Proofs of Zassenhaus Lemma and Schreier Theorem are optional)		
	9	Section 36 – Sylow Theorems (36.1 to 36.4)		
	10	Section 36 – Sylow Theorems (36.5 to 36.13).		
	11	Section 37 – Applications of the Sylow Theory (37.1 to 37.6)		
	12	Section 37 – Further Applications (37.7 to 37.15)		
III		**Rings and Fields**	**11**	**Min.15**
	13	Section 22 – Rings of Polynomials – (22.1 to 22.3) (proof of Theorem 22.2 is optional)		
	14	Section 22 – The Evaluation Homomorphisms (22.4 to 22.11)		
	15	Section 23 – Factorisation of Polynomials over a Field (23.1 to 23.6)		

	16	Section 23 – Irreducible Polynomials (23.7 to 23.21)		
	17	Section 24 – Non-commutative Examples. (24.1 to 24.3)		
	18	Section 24 – Non-commutative Examples (24.4 to 24.10)		
IV	**More Ring Theory**		**8**	**Min.10**
	19	Section 26 – Homomorphism and Factor Rings (26.1 to 26.6).		
	20	Section 26 – Factor Rings (26.7 to 26.19)		
	21	Section 27 – Prime and Maximal Ideals (27.1 to 27.20).		
	22	Section 27 – Ideal Structure in F[x] (27.21 to 27.27)		
V	**Practicum:** The goal is for the students to learn the following selected topics in 5 practicum sessions of six hours each via self-study and group activities. The lecturer may assist by running group discussions, supervising class seminars and referring library books for self-study and note preparation.		**30**	**-**
1	Section 12 – Plane isometries			
2	Section 16 – Group Action on a Set			
3	Section 17 – Application of G-sets to Counting			
4	Section 21 – The Field of Quotients of an Integral Domain			
	Section 35 - Series of Groups - Ascending central series - 35.20 to 35.21			
5	Section 39 – Free Groups			

References

1. Abstract Algebra, Dummitt and Foote, Wiley India, 2011.
2. Contemporary Abstract Algebra, Joseph A. Gallian, CRC Press, 1986.
3. Topics in Algebra, I. N. Herstein, John Wiley and Sons, 2006.
4. Algebra, T. W. Hungerford, Springer-Verlag, 1987.
5. Algebra, Micheal Artin, Birkhauser, 2011
6. Algebra, Serge Lang, Springer, 2002.
7. Advanced Higher Algebra, J G Chakravorthy and P R Gosh, Kolkata U N Dhur, 2014 (ISBN: 9789380673059)

Suggested Programming Exercises for Practicum:

1. Form congruence groups Z_3, Z_2. Verify that $Z_3 \times Z_2 \cong \mathbb{Z}_6$. Form its

cosets (Section 9.11, Ref (3)).

2. Find the centre of the dihedral group. (Section 9.12, Ref (3))
3. For an element from the dihedral group, find its stabilizer. (Section 9.12, Ref (3))
4. Find the conjugacy classes of an element from the dihedral group. (Section 9.12, Ref (3))
5. Take a subgroup (say H) of S_3. List the conjugacy classes using the command conjugacy classes subgroups (). Can you find out all the subgroups using these conjugacy classes? (Ref (1) or Section 9.12, Ref (3))
6. Find Sylow-2-subgroups and Sylow-3-subgroups or D_{18} (Section 9.13, Ref (3))

References

1. Robert A. Beezer; Group Theory and SAGE: A Primer, http://people.reed.edu/~davidp/332/sage-group-theory.pdf

2. Group Theory and Sage - SageMath tutorial https://doc.sagemath.org/html/en/thematic_tutorials/group_theory.html

3. Ajit Kumar, Vikas Bist; Group Theory An Expedition with SageMath, Narosa Publishing House.

4. Thomas W. Judson, Robert A. Beezer; Abstract Algebra Theory and Applications with Sage Exercises for Abstract Algebra, http://abstract.ups.edu/download/ aata-20130816.pdf

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	0	3	0	2	0	1
CO 2	2	3	1	2	3	0	3	0	3	0	2
CO 3	2	1	3	3	3	0	3	0	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT7CJ404
Course Title	**LINEAR ALGEBRA**
Type of Course	**Major**
Semester	VII
Academic Level	400-499

Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75

Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Matrices and Determinants 3. Systems of Linear Equations and their solutions
Course Summary	Vector spaces in the abstract are introduced. Linear transformations are introduced as structure preserving maps between them. Representation of linear transformations as matrices is discussed. The algebraic dual and double dual space of a vector space are studied in some detail. The concept of the transpose of a linear transformation is introduced and discussed as well. The course then passes on to spectral theory on finite dimensional spaces, introducing characteristic values and vectors. After an extended discussion leading up to the characterisation of diagonalisable and triangulable operators, an elementary decomposition of a linear operator is established. The course ends with a short discussion of inner products and inner product spaces.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse and apply the concepts of vector spaces, subspaces, and bases to solve problems involving linear independence and dimensionality.	An	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO2	Evaluate the properties of linear transformations and their algebraic representations using matrices.	E	C	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam
CO3	Synthesize the concepts of linear functionals, the double dual space, and the transpose of linear transformations to understand advanced topics in linear algebra and apply them to canonical forms	E	P	Internal Exam/Assignment/Seminar/ Viva/Report/ End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Textbook	Linear Algebra, Kenneth Hoffman and Ray Kunze, 2nd Edition, Prentice Hall of India, 1991.			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Vector Spaces**	**12**	**Min.15**
	1	Section 2.1 – Vector Spaces		
	2	Section 2.2 – Subspaces		
	3	Section 2.3 – Bases and Dimension – up to Theorem 5		
	4	Section 2.3 – Bases and Dimension – rest of the section starting from Theorem 5		
	5	Section 2.4 – Coordinates – up to and including Theorem 7		
	6	Section 2.4 – Coordinates – rest of the section		
II		**Linear Transformations**	**11**	**Min.15**
	7	Section 3.1 – Linear Transformations – upto and including Example 7		
	8	Section 3.1 – Linear Transformations – rest of the section.		
	9	Section 3.2 – The Algebra of Linear Transformations – up to and including Theorem 5		
	10	Section 3.2 – The Algebra of Linear Transformations – rest of the section		
	11	Section 3.3 – Isomorphism		
	12	Section 3.4 – Representation of Transformations by Matrices – up to and including Example 15		
III		**Linear Transformations**	**11**	**Min.15**
	13	Section 3.4 – Representation of Transformations by Matrices – rest of the section		
	14	Section 3.5 – Linear Functionals – upto and including Example 22.		
	15	Section 3.5 – Linear Functionals – rest of the section.		
	16	Section 3.6 – The Double Dual – upto and including Theorem 18.		
	17	Section 3.6 – The Double Dual – the rest of the section		
	18	Section 3.7 – The Transpose of a Linear Transformation – up to and including Theorem 22		
	19	Section 3.7 – The Transpose of a Linear Transformation – rest of the section.		
IV		**Elementary Canonical Forms**	**11**	**Min.15**
	20	Section 6.1 and 6.2 – Introduction and Characteristic Values		
	21	Section 6.3 – Annihilating Polynomials (Proof of Theorem 4 omitted)		
	22	Section 6.4 – Invariant Subspaces.		

<table>
<tr><td rowspan="11">V</td><td colspan="2">Practicum
The goal is for the students to learn the following selected topics in 10 practicum sessions of three hours each via self-study and group activities. The lecturer may assist by running group discussions, supervising class seminars and referring library books for self-study and note preparations.</td><td rowspan="11">30</td><td rowspan="11">-</td></tr>
<tr><td>1</td><td>Section 1.3 – Matrices and Elementary Row Operations</td></tr>
<tr><td>2</td><td>Section 1.4 – Row Reduced Echelon Matrices</td></tr>
<tr><td>3</td><td>Section 1.5 – Matrix Multiplication</td></tr>
<tr><td>4</td><td>Section 1.6 – Invertible Matrices</td></tr>
<tr><td>5</td><td>Section 6.4 – Triangulation and Diagonalisation</td></tr>
<tr><td>6</td><td>Section 6.6 – Direct-sum Decompositions</td></tr>
<tr><td>7</td><td>Section 6.7 – Invariant Direct Sums</td></tr>
<tr><td>8</td><td>Section 8.1 – Inner Products</td></tr>
<tr><td>9</td><td>Section 8.2 – Inner Product Spaces</td></tr>
<tr><td>10</td><td>Section 6.8 – The Primary Decomposition Theorem</td></tr>
</table>

References

1. Finite Dimensional Vector Spaces, P. R. Halmos, Narosa Pub House, 1980..
2. Linear Algebra, S. Lang, Addison Wesley Pub Company, 1972.
3. Topics in Algebra, I. N. Herstein, John Wiley & Sons, 2006.
4. Linear Algebra, R. R. Stoll & E. T. Wong, Academic Press International Edition, 1968.

Suggested Programming Exercises for Practicuum :

1. Form a four-dimensional vector space over Q. Take two vectors from this, find its span. (Chapter VS, Ref (1))
2. Find basis of the vector subspace found in the above question. (Chapter VS, Ref (1))
3. Take some elements from this vector space, test for linear independence. (Chapter V Section LI, Ref (1))
4. Form two vector spaces over Q. Define symbolic linear transformations between them, find the image of selected elements under it. (Chapter LT, Ref (1))
5. Define linear transformations (LT) from matrices. (Chapter LT, Ref (1))
6. Check if linear transformation is injective (Section ILT , Ref (1))
7. Define two LT, add them. Find the individual matrices of these with respect to certain bases. Verify that the matrix of the sum of LT is the sum of matrices of individual LT .(Section OLT, , Ref (1)))
8. Find the kernel of an LT, find its nullitty. (Section ILT, Ref (1))
9. Find inverse of LT (Section IVLT, Ref (1))
10. Take a matrix, find Eigenvalues, Eigen vectors, check if it is

diagonalizable, diagonalize if it is. (Chapter E ILT, Ref (1))

References

1. Robert A. Beezer, Sage for Linear Algebra A Supplement to A First Course in Linear Algebra http://linear.ups.edu/sage-fcla.html
2. Sang-Gu Lee *et al.*, Linear Algebra with Sage https://www.researchgate.net/publication/280093747_Linear_Algebra_with_Sage_BigBook_Free_e-book_English_ Version_All

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	0	3	1	3	0	2
CO 2	3	3	2	1	3	0	3	2	3	0	2
CO 3	3	3	2	2	3	0	3	2	3	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT7CJ405			
Course Title	**DISCRETE MATHEMATICS**			
Type of Course	**Major**			
Semester	VII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	Basic Logical thinking and Set theory.			
Course Summary	The "Discrete Mathematics" course (MAT7CJ405) covers essential concepts in discrete structures and their applications. Students explore topics like graph theory, automorphisms, connectivity, and order relations through carefully structured modules. The course includes practical exercises and references to foundational works in the field, providing students with theoretical understanding and problem-solving skills necessary for further studies or real-world applications in mathematics and related areas.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Describe and explain fundamental concepts in graph theory, including subgraphs, vertex degrees, paths, connectedness, and operations on graphs.	U	C	Internal Exam/ Assignment/ Seminar/ Viva /Report/ End Sem Exam
CO2	Apply and analyse concepts related to automorphisms of graphs, vertex and edge cuts, and graph connectivity, utilizing definitions, theorems, and exercises.	An	P	Internal Exam/ Assignment/ Seminar/ Viva/ Report/ End Sem Exam
CO3	Evaluate and compare order relations in mathematical contexts and their implications for understanding and applying order theory.	E	C	Internal Exam/ Assignment/ Seminar/ Viva/ Report/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	1. A Textbook of Graph Theory. (2/e) Balakrishnan, R, & Ranganathan, K, Springer-Verlag, New York Inc., 2020 2. Foundations of Discrete Mathematics, K. D Joshi, New Age International (P) Limited, New Delhi, 1989. 3. An Introduction to Formal Languages and Automata (2/*e*), Peter Linz, Narosa Publishing House, New Delhi, 1997			
Module	**Unit**	**Content**	**Hrs (75)**	**External Marks (70)**
I		**Fundamentals of Graph Theory**	**12**	**Min.15**
	1	Section 1.0 Introduction (Text 1)		
	2	Section 1.1 Basic Concepts (Text 1)		
	3	Section 1.2 Sub Graphs (Text 1)		
	4	Section 1.3 Degrees of Vertices (Text 1)		
	5	Section 1.4 Paths and Connectedness (Text 1)		
II		**Graph Operations and Connectivity**	**11**	**Min.15**
	6	Section 1.5 Automorphisms of a simple graph (Definition 1.5.1 to Theorem 1.5.3) (Text 1)		
	7	Section 1.5 Automorphisms of a simple (Exercise 5.1 to Exercise 5.5) (Text 1)		
	8	Section 1.7 Operations on Graphs (Definition 1.7.1 to Example 1.7.10) (Text 1)		
	9	Section 1.7 Operations on Graphs (Exercise 7.3 to Exercise 7.6) (Text 1)		
	10	Section 3.1 Vertex Cuts and edge Cuts (Definition 3.1.1 to Theorem 3.1.10) (Text 1)		
	11	Section 3.1 Vertex Cuts and edge Cuts (Proposition 3.1.2 to Exercise 1.4) (Text 1)		
	12	Section 3.2 Connectivity and Edge - Connectivity (Definition 3.2.1 to Exercise 2.10) (Text 1)		
	13	Section 3.2 Connectivity and Edge - Connectivity (Theorem 3.2.10 to Theorem 3.2.11) (Text 1)		
III		**Order Relations**	**11**	**Min.15**
	14	Section 3 Order Relations (Sections 3, 3.1, 3.2 of Text 2)		
	15	Section 3 Order Relations (Sections 3.3, 3.4 of Text book 2)		
	16	Section 3 Order Relations (Sections 3.5, 3.6 of Text book 2)		
	17	Section 3 Order Relations (Sections 3.7 of Text book 2)		
	18	Section 3 Order Relations (Sections 3.8, 3.9, 3.10 of Text 2)		
	19	Section 3 Order Relations (Sections 3.11 of Text book 2)		
IV		**Finite Automata and Acceptors**	**11**	**Min.15**
	20	Section 2.1 Deterministic Finite Accepters (Text 3)		
	21	Section 2.2 Non-Deterministic Finite Accepters (Text 3)		
	22	Section 2.3 Equivalence of Deterministic and Nondeterministic Finite Accepters (Text 3)		

V	**Practicum**		**30**	
		Line Graphs and Directed Graphs		
		Eulerian Graphs and Hamiltonian Graphs		
		Planar and Non planar Graphs		
		Applications of Lattices in Switching Circuits		
		Applications of Automata in Theory of Computing		

References

1. J. C. Abbot: Sets, lattices and Boolean Algebras; Allyn and Bacon, Boston; 1969.
2. J. A. Bondy, U.S.R. Murty: Graph Theory; Springer; 2000.
3. S. M. Cioaba and M.R. Murty: A First Course in Graph Theory and Combinatorics; Hindustan Book Agency; 2009
4. R. P. Grimaldi: Discrete and Combinatorial Mathematics- an applied introduction(5th edn.); Pearson; 2007.
5. J. L. Gross: Graph theory and its applications(2nd edn.); Chapman & Hall/CRC; 2005
6. Graph Theory and Decomposition, Jomon Kottarathil, Sudev Naduvath and Joseph Varghese Kureethara, CRC Press, London, New York, 2024.

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	1	2	2	0	3	0	2	1	3	0	2
CO 2	1	3	2	1	3	0	3	2	3	0	3
CO 3	0	2	2	1	3	0	3	1	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8CJ406 / MAT8MN406			
Course Title	**BASIC MEASURE THEORY**			
Type of Course	**Major**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	3	2	75
Pre-requisites	1. Fundamental Mathematics Concepts: Set, Functions, Logic 2. Real Analysis			
Course Summary	This course familiarises students with the Lebesgue Measure on the real line and how it enables the construction of a theory of integration that does away with many of the drawbacks of Riemann integration.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and explain the concepts of Lebesgue measure, including outer measure, measurable sets, and properties such as countable additivity and the Borel-Cantelli Lemma.	U	C	Internal Exam/ Assignment/ Seminar/ Viva /Report/ End Sem Exam
CO2	Apply theorems related to Lebesgue measurable functions, including Littlewood's Three Principles, Egoroff's, and Lusin's Theorems, to analyse function behaviour and approximations.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva /Report/ End Sem Exam
CO3	Evaluate and integrate functions using the Lebesgue integral, understanding its differences from the Riemann integral and applying it to bounded and non-negative measurable functions.	E	F	Internal Exam/ Assignment/ Seminar/ Viva /Report/ End Sem Exam
	* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create(C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)			

Detailed Syllabus:

Text book	Real Analysis, H. L. Royden & P. M. Fitzpatrick, 4th Edition, Prentice Hall of India, 2000			
Module	**Unit**	**Content**	**Hrs (45+30)**	**Ext. Marks (70)**
I		**Chapters 0, 1, 2: The Lebesgue Measure**	**15**	**Min.15**
	1	Preliminaries On Sets, Mappings & Relations (Review only)		
	2	Chapter 1: The Real Numbers: Sets, Sequences & Functions (Proofs of results included in Practicum)		
	3	2.1 Introduction – Measure as a set function		
	4	2.2 Lebesgue Outer Measure		
	5	2.3 The σ–Algebra of Lebesgue Measurable Sets		
	6	2.4 Outer & Inner Approximation of Lebesgue Measurable Sets		
	7	2.5 Countable Additivity, Continuity & the Borel-Cantelli Lemma		
	8	2.6 Non-Measurable Sets		
II		**Chapter 3: Lebesgue Measurable Functions**	**8**	**Min.15**
	10	3.1 Sums, Products & Compositions		
	11	3.2 Sequential Pointwise Limits & Simple Approximation		
	12	3.3 Littlewood's Three Principles, Egoroff's & Lusin's Theorems		
III		**Chapter 4: The Lebesgue Integral**	**12**	**Min.20**
	13	4.1 The Riemann Integral		
	14	4.2 Lebesgue Integral of Bounded Measurable Function Over a Set of Finite Measure.		
	15	4.3 Lebesgue Integral of a Non-negative Measurable Function.		
	16	4.4 The General Lebesgue Integral		
	17	4.5 Countable Additivity & Continuity of Integration (proofs included in practicum)		
	18	4.6 Uniform Integrability: The Vitali Convergence Theorem (proofs included in Practicum)		
IV		**Chapter 5: Differentiation & Lebesgue Integration**	**10**	**Min.10**
	19	6.1 Continuity of Monotone Functions.		
	20	6.2 Differentiability of Monotone Functions: Lebesgue's Theorem		
	21	6.3 Functions of Bounded Variation: Jordan's Theorem		
	22	6.4 Absolutely Continuous Functions (Proof of Theorem 9 is optional)		
	23	6.5 Integrating Derivatives: Differentiating Indefinite Integrals		
V		**Practicum:** The goal is for the students to learn the following selected topics in 10 practicum sessions of three hours each via self-study and group activities. The lecturer may assist by running group discussions and supervising class seminars and referring library books for self-study and note preparations.	**30**	
	1	Proofs in Chapter 1: The Real Numbers		
	2	Section 2.7 - The Cantor Set & the Cantor-Lebesgue Function		
	3	Proofs in Section 4.5		

	4	Proofs in Section 4.6		
	5	5.1: Uniform Integrability & Tightness		
	6	5.2: Convergence in Measure		
	7	5.3: Characterizations of Riemann & Lebesgue Integrability		
	8	7.1: Normed Linear Spaces		
	9	7.2: Inequalities		
	10	7.3: Riesz-Fischer Theorem		

References

1. R. G. Bartle, Wiley, The Elements of Integration & Lebesgue Measure,1995..
2. G. de Barra, Measure Theory & Integration, New Age International Publications, 1981.
3. David M. Bressoud, A Radical Approach to Lebesgue's Theory of Integration (ARALTI), Cambridge University Press, 2008.
4. P. R. Halmos, Measure Theory, GTM, Springer-Verlag
5. Walter Rudin, Principles of Mathematical Analysis, 3rd Edition, Tata McGraw Hill Inc., 1976.
6. Walter Rudin, Real & Complex Analysis, 3rd Edition, McGraw Hill Inc., 1987.

***Optional topics are exempted for end semester examination.**
****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	0	0	3	0	2	1	3	0	2
CO 2	2	2	0	0	3	0	3	2	3	0	3
CO 3	1	0	3	0	3	0	3	1	3	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Report
- Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment/ Report	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8CJ407 / MAT8MN407			
Course Title	**NUMBER THEORY**			
Type of Course	**Major**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Basic algebra of integers, basic set theory, basic proof techniques.			
Course Summary	This is a more advanced course than MAT6CJ305 / MAT8MN305 Elementary Number Theory. Here we focus on arithmetical functions, their averages, distribution of prime numbers, quadratic reciprocity and in the last open-ended section, Cryptography. Arithmetical functions are geared towards the study of prime numbers and their distribution. We provide a rigorous examination of several of them such as Mobius function, Euler's totient function, and compositions through techniques such as Dirichlet multiplication and convolution. Next we study their asymptotic behaviour using techniques such elementary estimates, partial summation and Dirichlet products. Next, we study the distribution of prime numbers. The prime number theorem is stated along with some equivalent versions and a build-up to it. Next the concept of quadratic residues, quadratic reciprocity and how to compute the same, along with applications, are studied. The open-ended part is Cryptography.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and analyse the properties of arithmetical functions, including the Möbius function, Euler totient function, and their relationships and products.	An	C	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO2	Apply Dirichlet multiplication and inversion formulas to solve problems involving arithmetical functions, including the Mangoldt function and Liouville's function.	Ap	P	Internal Exam/Assignment /Seminar/ Viva/ End Sem Exam
CO3	Evaluate and create asymptotic formulas and theorems related to the distribution of prime numbers and quadratic residues, utilizing tools such as Chebyshev's functions and the quadratic reciprocity law.	C	F	Internal Exam/Assignment /Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	1. Introduction to Analytic Number Theory,Tom M. Apostol , Springer International Student Edition ,Narosa Publishing House, New Delhi, 1990 2. A course in Number Theory and Cryptography, second Edition,Neal Koblitz Springer, 1991			
Module	**Unit**	**Content**	**Hrs (48+ 12)**	**Marks** **Ext: 70**
I		Arithmetical Functions and their properties	18	**Min.15**
		Arithmetical Functions and Dirichlet Multiplication		
	1	Section 2.1-Introduction		
	2	Section 2.2- The Mobius function $\mu(n)$		
	3	Section 2.3- The Euler totient function $\phi(n)$		
	4	Section 2.4- A relation connecting μ and ϕ		
	5	Section 2.5- A product formula for $\phi(n)$		
	6	Section 2.6- The Dirichlet product of arithmetical functions		
	7	Section 2.7- Dirichlet inverses and Mobius inversion formula		
	8	Section 2.8- The Mangoldt function $\Lambda(n)$		
	9	Section 2.9- Multiplicative functions		
	10	Section 2.10- Multiplicative functions and Dirichlet Multiplication		
	11	Section 2.11- Inverse of a completely multiplicative function		
	12	Section 2.12- Liouville's function $\lambda(n)$		
	13	Section 2.13- The divisor functions $\sigma_\alpha(n)$		
	14	Section 2.14- Generalized Convolutions		
II		**Averages of Arithmetical Functions**	10	**Min.15**
	15	Section 3.1- Introduction		
	16	Section 3.2--The big oh notation. Asymptotic equality of functions		
	17	Section 3.3- Euler's Summation formula		
	18	Section 3.4- Some elementary asymptotic formulas		
	19	Section 3.10- The Partial sums of a Dirichlet product		
	20	Section 3.11- Applications of $\mu(n)$ and $\Lambda(n)$		
	21	Section 3.12- Another identity for the partial sums of a Dirichlet product		
III		**Some Elementary Theorems on the Distribution of Prime Numbers**	10	**Min.15**
	22	Section 4.1- Introduction		
	23	Section 4.2- Chebyshev's functions $\psi(x)$ and $\vartheta(x)$		
	24	Section 4.3- Relations connecting $\vartheta(x)$ and $\pi(x)$		
	25	Section 4.4- Some equivalent forms of the prime number theorem		
	26	Section 4.5- Inequalities for $\pi(n)$ and p_n		
IV		**Quadratic Residues and the Quadratic Reciprocity Law**	10	**Min.15**
	27	Section 9.1- Quadratic residues		

	28	Section 9.2- Legendre's symbol and its properties		
	29	Section 9.3- Evaluation of (-1| p) and (2| p)		
	30	Section 9.4- Gauss' lemma		
	31	Section 9.5- The quadratic reciprocity law		
	32	Section 9.6- Applications of the reciprocity law		
V	**Open Ended: Cryptography**		**12**	
	Chapter III ● 1: Some simple cryptosystems -3 hrs ● 2: Enciphering Matrices-4hrs Chapter IV ● 1: The idea of public key cryptography -3 hrs ● 2: RSA-2 hrs			

References

1. A. Beautel spacher: Cryptology; Mathematical Association of America (Incorporated); 1994
2. H. Davenport: The higher arithmetic(6th Edn.); Cambridge Univ.Press;
3. G. H. Hardy and E.M. Wright: Introduction to the theory of numbers; Oxford International Edn; 1985
4. A. Hurwitz & N. Kritiko: Lectures on Number Theory; Springer Verlag ,Universi text;1986
5. T. Koshy: Elementary Number Theory with Applications; Harcourt / Academic Press;2002
6. D. Redmond: Number Theory; Monographs & Texts in Mathematics No: 220; Mar cel Dekker Inc.; 1994
7. P. Ribenboim: The little book of Big Primes; Springer-Verlag, New York; 1991
8. K.H. Rosen: Elementary Number Theory and its applications(3rd Edn.); Addison WesleyPub Co.; 1993
9. W. Stallings: Cryptography and Network Security-Principles and Practices; PHI; 2004
10. D.R. Stinson: Cryptography- Theory and Practice(2nd Edn.); Chapman & Hall / CRC (214. Simon Sing: The Code Book The Fourth Estate London); 1999
11. J. Stopple: A Primer of Analytic Number Theory-From Pythagoras to Riemann; Cambridge Univ Press; 2003
12. S.Y. Yan: Number Theory for Computing(2nd Edn.); Springer-Verlag; 2002

***70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	1	2	1	1	3	0	3	1	3	0	2
CO 2	2	3	2	1	3	0	3	2	3	0	3
CO 3	3	2	3	2	3	0	3	1	3	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8CJ408 / MAT8MN408			
Course Title	**DIFFERENTIAL EQUATIONS**			
Type of Course	**Major**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic knowledge of calculus of one variable and an introductory course in Real Analysis			
Course Summary	The course enhances the skill to solve ordinary differential equation using specific methods analytically and computationally for first and higher order differential equations. Most of the fundamental phenomena occurring in the nature are expressed as a differential equation. Students must know how to model any physical phenomena using differential equations.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply the existence and uniqueness theorems for second-order differential equations, including methods such as the method of successive approximations and Picard's theorem.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse and solve second-order differential equations using power series methods, including ordinary points, regular singular points, and specific functions such as Gauss's Hypergeometric Equation and Legendre Polynomials.	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Evaluate and determine the stability of autonomous systems and critical points for linear and nonlinear systems using the phase plane analysis and Lyapunov's direct method.	E	M	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	Differential Equations With Applications And Historical Notes, Third Edition,George F. Simmons.			
Module	**Unit**	**Content**	**Hrs (48+ 12)**	**Marks** **Ext: 70**
I		**Second Order Differential Equations**	**12**	**Min.15**
		Existence and Uniqueness of Solutions and Power Series method of solving differential equations		
	1	69 Method of Successive Approximations		
	2	70 Picard's theorem, theorems A& B (proofs are optional).		
	3	71 Systems. The Second Order Equations		
	4	26 Introduction. A review of Power Series		
	5	27 Series solutions of first order equations		
	6	28 Second order Equations. Ordinary points		
	7	29 Regular singular points		
II		**Power Series Solutions and Special Functions**	**11**	**Min.15**
	8	30 Regular Singular Points continued		
	9	31 Gauss's Hypergeometric Equation		
	10	31 Gauss's Hypergeometric Equation Reduction to Hypergeometric equation		
	11	32 The Point at Infinity		
	12	44 Legendre Polynomials (proofs of Rodrigues' formula is optional)		
III		**Special Functions (Contd.)**	**12**	**Min.15**
	13	45 Properties of Legendre Polynomials		
	14	46 Bessel functions.		
	15	46 Bessel functions. The Gamma function		
	16	47 Properties of Bessel functions		
	17	47 Properties of Bessel functions Zeros and Bessel series. Bessel expansions		
IV		**Autonomous Systems. Stability of Linear and Nonlinear Systems**	**13**	**Min.15**
	18	58 Autonomous systems. The phase plane and its phenomena		
	19	59 Types of critical points		
	20	59 Types of critical points. Stability		
	21	60 Critical points and stability for linear system		
	22	61 Stability by lyapunov direct method		
V		**Open Ended**	**12**	
		• Proof of Picard's theorem • Proof of theorem B of Unit I • Proof of Rodrigues' formula for Legendre polynomials		

	• Analyse solutions of Differential Equations using softwares like Python		

References

1. G. Birkhoff and G.C. Rota: Ordinary Differential Equations (3rd Edn.); Edn. Wiley & Sons; 1978
2. W.E. Boyce and R.C. Diprima: Elementary Differential Equations and boundary value problems (2nd Edn.); John Wiley & Sons, NY; 1969
3. A. Chakrabarti: Elements of ordinary Differential Equations and special functions; Wiley Eastern Ltd., New Delhi; 1990
4. E.A. Coddington: An Introduction to Ordinary Differential Equations; Prentice Hall of India, New Delhi; 1974
5. A. K. Nandakumaran, P. S. Datti, Raju K. George: Ordinary Differential Equations: Principles and Applications, Cambridge University Press

***Optional topics are exempted for end semester examination.**

****70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.**

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	2	1	3	0	3	1	3	0	2
CO 2	2	2	1	0	3	0	3	2	3	0	3
CO 3	1	2	2	2	3	0	3	1	3	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

ELECTIVE COURSES

Programme	B. Sc. Mathematics Honours			
Course Code	MAT5EJ301(1)			
Course Title	**MATHEMATICAL FOUNDATIONS OF COMPUTING**			
Type of Course	**Elective (Specialisation- Mathematical Computing)**			
Semester	V			
Academic Level	300 - 399			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Fundamental Mathematics Concepts: Set, Functions, Logic			
Course Summary	This course familiarises students with a selection of topics from discrete mathematics which find regular applications in Computer Science.			

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply mathematical induction to solve a variety of combinatorial problems.	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO2	Analyse and classify different types of relations and equivalences in combinatorial settings.	An	C	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO3	Evaluate and demonstrate proficiency in using combinatorial techniques such as permutations, factorials, and binomial coefficients to solve complex problems.	E	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

TextBook	(I) Jiří Matoušek and Jaroslav Nešetřil, Invitation to Discrete Mathematics, (2/e) Oxford University Press (II) Robin J Wilson, Introduction to Graph Theory (4/e), Prentice Hall			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Ext. Marks (70)**
I		**Combinatorial Counting (Text 1)**	**12**	
	1	1.1 An Assortment of problems		
	2	1.3 Mathematical Induction (Proof of Theorem 1.3.1 is optional)		
	3	1.5 Relations, 1.6 Equivalences and other special type of relation		
	4	3.1 Functions and subsets, 3.2 Permutations and factorials		
	5	3.3 Binomial Coefficients-		
	6	3.7 Inclusion-Exclusion Principle. (Third proof of Theorem 3.7.2 is optional)		
II		**Basics of Graph Theory (Text 1)**	**12**	
	7	4.1 The notion of a graph; Isomorphism		
	8	4.2 Subgraphs, Components, Adjacency Matrix		
	9	4.3 Graph Score (Proof of Theorem 4.3.3 is optional)		
	10	4.4 Eulerian Graphs (Second proof of Theorem 4.4.1 and lemma 4.4.2 are optional)		
	11	4.5 Eulerian Directed Graph		
	12	5.1 Definition and characterizations of trees		
III		**Matching and Colouring (Text 2)**	**12**	
	13	12. Planar Graphs (Proof of Theorem 12.2 and Theorem 12.3 are optional)		
	14	13. Euler's formula (up to Corollary 13.4)		
	15	13. Euler's formula (from Corollary 13.4)		
	16	17. Coloring Graphs		

	17	19. Coloring Maps (Proof of Theorem 19.2 and Theorem 19.4 are optional)		
	18	25 Hall's Marriage theorem		
IV	**Probabilistic Method (Text 1)**		**12**	
	19	10.1 Proofs by Counting (2-Coloting revisited and related topics are optional)		
	20	10.2 Finite Probability Spaces (up to Random graphs)		
	22	10.2 Finite Probability Spaces (From Random graphs)		
	22	10.3 Random Variables and their Expectations		
V	**Open Ended**		**12**	
	Hamiltonian Graphs, 2-Connectivity, Examples of applications of Probabilistic Method, Ramsey Theory, Generating Functions, simulating random experiments in python and calculating expectations. Brook's Theorem.			

References:

1. Discrete Mathematics by Norman L. Biggs (2nd Edition, 2002), Oxford University Press (ISBN- 13: 978-0198507178)
2. Discrete Mathematics and Applications by Kenneth Rosen (7th Edition, 2012), McGraw-Hill Education (ISBN-13: 978-0073383095)
3. Discrete Mathematics: Elementary and Beyond by László Lovász, József Pelikán, Katalin Vesztergombi, Springer 2003, ISBN-13: 978-0387955858.

Note: 1) Optional topics are exempted for end semester examination
2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	1	1	3	1	3	1	3	0	2
CO 2	2	2	1	1	3	1	3	2	3	0	2
CO 3	2	3	2	2	3	1	3	2	3	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT5EJ302(1)
Course Title	**DATA STRUCTURES AND ALGORITHMS**
Type of Course	**Elective (Specialisation- Mathematical Computing)**
Semester	V
Academic Level	300 - 399

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	1. Fundamental Mathematics Concepts: Sets, Functions 2. Discrete Mathematics
Course Summary	This course familiarises students with computational problems and computational thinking using some of the basic algorithmic strategies.

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse and compare the efficiency of algorithms for computing Fibonacci numbers, distinguishing between exponential and polynomial approaches.	E	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Demonstrate proficiency in asymptotic analysis to assess the efficiency of algorithms.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply classical algorithms for number operations, including addition, multiplication, and modular arithmetic, to solve computational problems efficiently.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text Book		*Algorithms* by Sanjoy Dasgupta, Christos H. Papadimitriou, Umesh Vazirani. McGraw- Hill Education, 2006. ISBN: 978-0073523408.		
Module	**Unit**	**Content**	**Hrs (48+12)**	**Ext. Marks (70)**
I		**Introduction**	**12**	
	1	Computing Fibonacci Numbers: Exponential and Polynomial Algorithms		
	2	Efficiency of Algorithms: Asymptotic Analysis, Big-O Notation		
	3	Algorithms with Numbers: Efficiency of classical Addition and Multiplication algorithms		
	4	Algorithms for Modular Arithmetic		
	5	Euclid's Algorithm for GCD		
	6	Primality Testing		
	Sections from Text: 0.2, 0.3, 1.1, 1.2, 1.3			
II		**Divide and Conquer Algorithms and Graph Search**	**12**	
	7	Fast Integer Multiplication		
	8	Recursive Relations		
	9	Binary Search		
	10	Merge Sort		
	11	Graph Representations: Adjacency Matrix, Adjacency List		
	12	Depth First Search Undirected Graphs		
	13	Depth First Search in Directed Graphs		
	Sections from Text: 2.1, 2.2. 2.3, 3.1-3.3.			
III		**Graph Algorithms**	**12**	
	14	Checking connectivity		
	15	Directed Acyclic Graphs, Strongly Connected Components		
	16	Breadth First Search and Computation of distances.		
	17	Weighted Graphs and Dijkstra's Algorithm		
	18	Priority queue implementations		

	19	Shortest Paths in Directed Acyclic Graphs		
	Sections from Text: 3.4, 4.1 to 4.4, 4.5, 4.7			
IV	**Greedy & Dynamic Programming Algorithms**		**12**	
	20	Minimum Spanning Trees: Cut Property		
	21	Kruskal's Algorithm		
	22	Data structure for disjoint sets.		
	23	Prim's algorithm		
	24	Dynamic Programming and Shortest Path in Directed Acyclic Graphs (DAG)		
	25	All pairs of Shortest Paths and Floyd Warshall Algorithm		
	Sections from Text: 5.1, 5.4, 6.1, 6.6.			
V (Open Ended)	**Advanced Topics (Practical)**		**12**	
	27	Implement the following algorithms in Python - Fibonacci Numbers (exponential and polynomial) - Euclid's algorithm (extended version) - Primality Testing - Depth First Search (and checking connectivity) - Breadth First Search (and calculating distances) - Dijkstra's Algorithm		

References:

1. *The Design and Analysis of Algorithms* by Dexter C Kozen. Texts and Monographs in Computer Science, Springer, 1992. ISBN:0-387-97687-6.
2. *Introduction to Algorithms* (3rd Edition) by Thomas H. Cormen, Charles E. Leiserson, Ronald L Rivest, Clifford Stein. PHI Learning, 2009. ISBN:978-81-203-4007-7.
3. *Algorithm Design* by Jon Kleinberg and Eva Tardos. Pearson, 2015. ISBN:978-93-325-1864.

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	3	2			3	1	3	3	3	0	3
CO 2	2	3	2	2			3	1	3	3	3	0	2
CO 3	2	3	3	2			3	1	3	3	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT6EJ301(1)			
Course Title	**NUMERICAL ANALYSIS**			
Type of Course	**Elective (Specialisation- Mathematical Computing)**			
Semester	VI			
Academic Level	300- 399			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	1. Real analysis 2. Linear algebra 3. Basics of Python Programming			
Course Summary	This course familiarises students with the fundamental numerical analysis. Moreover, the course facilitates students to apply results from real analysis and linear algebra to perform quantitative analysis of numerical solutions.			

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply the Bisection Method, Iteration Method, Newton-Raphson Method, and Secant Method to solve algebraic and transcendental equations numerically.	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO2	Implement interpolation methods such as Newton's formulae, Lagrange's interpolation formula, and divided differences to approximate functions from discrete data.	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO3	Implement numerical methods such as Euler's method, Modified Euler's Method, Runge-Kutta method, and Adams-Moulton Method to solve ordinary differential equations (ODEs).	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book		[1]. S. S. Sastry, Introductory Methods of Numerical Analysis (5/e), PHI Learning (2012) [2]. Dimitrios Mitsotakis: Computational Mathematics: An Introduction to Numerical Analysis and Scientific Computing with Python, CRC Press (2023), ISBN 978-1-032-26240-6. [3]. Jupyter Notebooks of [2] available at: https://github.com/dmitsot/computational_mathematics	
Module	**Unit**	**Content**	**Hrs (48 +12)**
I		**Numerical Solutions of Algebraic and Transcendental equations (Text 1)**	**12**
	1	2.1 Introduction	
	2	2.2 Bisection Method	
	3	2.4 Iteration Method (Derivation of Condition for Convergence and Acceleration of Convergence are optional)	
	4	2.5 Newton- Raphson Method (Generalized Newton's Method is optional)	
	5	2.7 Secant Method	
II		**Interpolation (Text 1)**	**12**
	6	3.1 Introduction, 3.3.1 Forward differences, 3.3.2 Backward differences	
	7	3.6 Newton's formulae for interpolation (up to and including Example 3.5)	
	8	3.6 Newton's formulae for interpolation (From Example 3.6)	
	9	3.9.1 Langrange's interpolation formula	
	10	3.10 Divided differences and their properties	
	11	3.10.1 Newton's General interpolation formula	
III		**Numerical Differentiation and Integration (Text 1)**	**12**
	12	6.1 Introduction, 6.2 Numerical Differentiation (6.2.1, 6.2.2 and 6.2.3 are optional)	
	13	6.4.1 Trapezoidal Rule	
	14	6.4.2 Simpson's 1/3-Rule	
	15	6.4.3 Simpson's 3/8 Rule	
	16	6.10 Numerical Double Integration	
IV		**Numerical Solutions of Ordinary Differential Equation (Text 1)**	**12**
	17	8.1 Introduction	
	18	8.2 Solution by Taylor's series,	
	19	8.4 Euler's method (8.4.1 is optional)	
	20	8.4.2 Modified Euler's Method	
	21	8.5 Runge-Kutta method	
	22	8.6.1 Adams-Moulton Method	
V		**Numerical Algorithms and Lab Practicals**	**12**
	1	Jupyter Lab and Notebooks. Google Colab. Instructions in [6] and [7]. Quick review of Python Programming. Ch 1 Notebook from [3].	

	2	Continue Quick Review of Python. Notebook [9]. Numpy and Scipy review from [7]. Ch 2 Notebook from [3].	
	3	Bisection Method. Algorithm and Program. Jupyter Notebook: Ch 5 of [3]. Refer also 5.1 of [2]. Optional: Program to compute speed of convergence. Optional: False Position variant from [12].	
	4	Fixed Point Method (Iteration Method). Algorithm and Program. Notebook: Ch 5 of [3]. Reference: 5.2 of [2].	
	5	Newton-Raphson Method. Algorithm and Program. Notebook: Ch 5 of [3]. Reference: 5.3 of [2].	
	6	Secant Method. Algorithm and Program. Notebook: Ch 5 of [3]. Reference: 5.4 of [2].	
	7	Fast computation using SciPy.Optimize. Notebook: Ch 5 of [3]. Reference: 5.6 of [2].	
	8.	Lagrange Interpolation. Notebook: Ch 6 of [3]. Reference: 6.1 of [2].	
	9	Newton's method for Interpolation using Divided Differences. Notebook: Ch 6 of [3]. Reference: 6.2 of [2].	
	10	Using SciPy.Interpolate Module. Lagrange Interpolation Only. Notebook: Ch 6 of [3]. Reference: 6.6 of [2].	
	11	Numerical Differentiation. Forward and Backward Differences. First Order and Second Order Derivative Approximations. Notebook: Ch 8 of [3]. Reference: 8.1 of [2].	
	12	Numerical Integration. Midpoint Rule. Composite Trapezoidal Rule. Composite Simpson's Rule. Notebook: Ch 7 of [3]. Reference: 7.1. of [2].	
	13	The Module scipy.integrate. Trapezoidal, Simpson. Reference: 7.4 of [2]. Notebook: Ch 7 of [3].	
	14	Euler's Method. Improved Euler's Method. Reference: 8.2 of [2]. Notebook: Ch 8 of [3].	

References:

1. F.B. Hildebrand: Introduction to Numerical Analysis, TMH.
2. J.B. Scarborough: Numerical Mathematical Analysis, Oxford and IBH
3. Joakim Sundnes, Introduction to Scientific Programming with Python. Springer (2020). ISBN 978-3-030-50355-0. Open Access at: https://link.springer.com/book/10.1007/978-3-030-50356-7
4. Sven Linge and Hans Petter Langtagen, Programming for Computations -- Python. A Gentle Introduction to Numerical Simulations With Python. Springer (2018). ISBN 978-3-319-81282-3. Open Access at: https://link.springer.com/book/10.1007/978-3-319-32428-9

Note: 1) Optional topics are exempted for end semester examination.
2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.
3) Module V is algorithms and lab computations. Algorithms for each numerical method can be taught along with the Python code in lab sessions. The second text [2] stresses computation from the beginning and is a lab reference. The Jupyter Notebooks [3] intended for live lab lessons.

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	1	3	1	3	3	3	0	2
CO 2	2	3	3	2	3	1	3	3	3	0	2
CO 3	3	3	3	2	3	1	3	3	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT6EJ302(1)
Course Title	**MATHEMATICS FOR DIGITAL IMAGES**
Type of Course	**Elective (Specialisation- Mathematical Computing)**
Semester	VI
Academic Level	300 - 399

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	Basic Geometry and Algebraic Structures
Course Summary	The focus of this paper is mathematics underlying patterns which in converse can be used to produce patterns automatically by computer, allocating some design decisions to the user. We begin with isometries, those transformations of the plane which preserve distance and hence shape. These fall into two classes: the direct ones are rotations or translation, and the indirect ones reflections or glides. We derive the rules for combining isometries, and introduce groups, and the dihedral group in particular. We also apply this to classifying all 1-dimensional or ‘braid’ patterns into seven types. Our next focus is on symmetries; that is, those isometries which send a pattern onto itself, each part going to another with the same size and shape. A plane pattern is one having translation symmetries in two non-parallel directions. These are made up of parallelogram shaped cells, falling into five types. Finally, we deduce the existence of 17 pattern types, each with its own set of interacting symmetry operations.

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Describe the concept of isometries in geometry, including translation, rotation, and reflection, and understand their properties and how they preserve distances.	U	C	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO2	Demonstrate the ability to compose isometries, understand their combined effects, and analyse the outcomes of sequential transformations.	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO3	Investigate the classification of plane patterns, including different net types such as parallelogram nets, rectangular nets, centred rectangular nets, square nets, and hexagonal nets, and analyse examples of the 17 plane pattern types.	An	F	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text Book	MATHEMATICS FOR DIGITAL IMAGES : Creation, Compression, Restoration, Recognition. S G Hoggar- Cambridge University Press.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Ext. Marks (70)**
I		**Introduction**	**12**	
	1	Isometries and their sense		
	2	The plane and vectors		
	3	Isometries – Translation, Rotation, Reflection		
	4	The sense of an isometry		
	5	The Classification of isometries		
	6	Composing isometries		
	Sections from Text (i): Chapter 1 – 1.1, 1.2, 1.3			
II		**How Isometries Combine**	**12**	
	7	Reflections are the key		
	8	Some useful compositions		
	9	The Image of a line of symmetry		
	10	The dihedral group		
	11	Appendix on groups		
	Sections from Text (i):Chapter 2 – 2.1, 2.2, 2.3, 2.4, 2.5			
III		**The Seven Braid Patterns, Plane Patterns & Symmetries**	**12**	
	12	Classification of braids		
	13	Constructing braid patterns		
	14	Translations and nets		
	15	Cells		
	16	The five net types		
	17	Nets allowing a reflection		
	Sections from Text (i): Chapter 3, Chapter 4 – 4.1, 4.2, 4.3			
IV		**The 17 Plane Patterns**	**12**	
	18	Preliminaries		
	19	The general parallelogram net		
	20	The rectangular net		
	21	The centred rectangular net		
	22	The square net		
	23	The hexagonal net		
	24	Examples of the 17 plane pattern types		
	25	Scheme for identifying pattern types		
	Sections from Text (i): Chapter 5 – 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8			
V (Open Ended)		**Advanced Topics (Practical)**	**12**	
	26	Basic Syntax and Scalar arithmetic operations and calculations by Using MATLAB		
	27	Arithmetic operations in matrix data & Reading an Image File by Using MATLAB		
References:				

1. Baldock R and Graham J (2000) Image Processing and analysis, a practical approach, Oxford University Press
2. Gonzalez R C and Woods R E (1993) Digital Image Processing, Addison-Wesley

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	1	3	1	2	2	3	0	2
CO 2	2	3	2	1	2	1	2	2	2	0	2
CO 3	3	3	2	1	3	1	3	3	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT5EJ305			
Course Title	**HIGHER ALGEBRA**			
Type of Course	**Elective**			
Semester	V			
Academic Level	300 - 399			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Fundamental Mathematics Concepts: Set, Functions, Logic			
Course Summary	This course explores topics that follow as a direct continuation of high school algebra, like the general theory of equations, and classification of second-degree curves and surfaces.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply the algebraic methods used in solving polynomial equations of low degrees and place them in a general context	Ap	P	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam
CO2	Understanding of the fundamental concepts of algebraic equations, including the Identity Theorem and the Fundamental Theorem of Algebra.	U	C	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam
CO3	Analyse and evaluate various solutions of equations, including Cardan's Formulas and trigonometric solutions, and identify the irreducible cases.	An	C	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text	**1.** Geometry(2/e), David A Brannan, Mathew F. Esplen, Jeremy J Gray, Cambridge University Press (2012) ISBN: 978-1-107-64783-1 **2**. Theory of Equations, J. V. Uspensky, McGraw Hill (1948), ISBN:07-066735-7			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Ext. Marks (70**
I		**Theory of Equations**	**16**	
	1	Chapter II -Section 3**:** Division of Polynomials		
	2	Chapter II -Section 4: The Reminder Theorem		
	3	Chapter II- Section 5**:** Synthetic Division		
	4	Chapter II- Section 7: Taylor's Formula		
	5	Chapter III - Section 1: Algebraic Equations		
	6	Chapter III - Section 2: Identity Theorem		
	7	Chapter III - Section 3: The Fundamental Theorem of Algebra		
II		**Cubic And Biquadratic Equations**	**16**	
	8	Chapter III - Section 4: Imaginary Roots of Equations with Real Coefficients		
	9	Chapter III - Section 5: Relations Between Roots and Coefficients		
	10	Chapter IV - Section 1**:** Limits of Roots Section 2: A Method to Find an Upper Limit of Positive Roots		
	11	Chapter IV - Section 3**:** Limit for Moduli of Roots		
	12	Chapter V - Section 1: What is the "Solution" of an Equation?, Section 2: Cardan's Formulas, Section 3: Discussion of Solution		
	13	Chapter V - Section 4: Irreducible Case Section 5: Trigonometric Solution		
	14	Chapter V- Section 6: Solution of Biquadratic Equations		

III	**Conic Sections**		**12**	
	15	Section 1.1.1: Conic Sections, **Section 1.1.2:** Circles		
	16	Section 1.1.3: Focus-Directrix Definition of the Non-Degenerate Conics		
	17	Section 1.1.4: Focal Distance Properties of Ellipse and Hyperbola		
	18	Section 1.1.5: Dandelin Spheres		
IV	**Quadric Surfaces**		**4**	
	19	Section 1.2.2: Reflections		
	20	Section 1.3: Recognizing Conics		
	21	Section 1.4.1: Quadric Surfaces in $\mathbb{R}^3$		
	22	Section 1.4.2: Recognizing Quadric Surfaces		
V	**Open Ended Module: Affine Maps**		**12**	
	1	Geometry and Transformations - What is Euclidean Geometry? Isometry, Euclidean properties, Euclidean transformation**,** Euclidean-Congruence		
	2	Affine Transformations, Basic Properties of Affine Transformations		
	3	Fundamental Theorem of Affine Geometry		

References:

1. Higher Algebra, Barnard & Child, St. Martin's Press, NY, USA (Public Domain, Copyright exhausted)
2. Thomas & Finney, Calculus & Analytic Geometry, Addison Wesley
3. George A Jennings: Modern Geometry with Applications Universitext, Springer (1994) ISBN: 0-387-94222-X
4. Walter Meyer: Geometry and its Application(2/e) Elsever, Academic Press(2006) ISBN: 0-12-369427-0

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	3	2	3	1	2	1	3	0	1
CO 2	3	3	2	2	3	1	2	1	3	0	1
CO 3	2	3	3	2	3	1	3	1	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT5EJ306
Course Title	**LINEAR PROGRAMMING**
Type of Course	**Elective**
Semester	V
Academic Level	300 - 399

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	Basic Calculus and Linear Algebra
Course Summary	Linear Programming is a mathematical modelling technique in which a linear function is maximized or minimized when subjected to various constraints. This technique has been useful for guiding quantitative decisions in business planning, in industrial engineering, and—to a lesser extent—in the social and physical sciences. This course begins with convex sets and extrema of functions for a sound basis of the subject. It then develops into LP problems including Transportation and Assignment problems.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Able to identify and analyse the properties of convex sets, including open and closed sets, convex hulls, and vertices.	An	C	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam
CO2	To demonstrate proficiency in applying optimization techniques such as gradient descent, constrained extrema, and the method of Lagrange multipliers to solve real-valued functions.	Ap	P	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam
CO3	To formulate and solve linear programming problems, including transportation and assignment problems, using techniques such as simplex method and duality.	U	P	Internal Exam/Assignment/Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text book	Optimization Methods in Operation Research and System Analysis (4th edition), K.V Mittal, C Mohan, New Age International (P)Limited (2016)	
Module	**Unit**	**Content**
I		**Module I**
	1	Chapter 1 Section 11: Open and Closed sets in E_n
	2	Section 12: Convex Linear Combination, Convex Sets
	3	Section 13: Intersection of Convex Sets, Convex Hull of a Set Section 14: Vertices or Extreme Points of a Convex Set
	4	Section 15: Convex Polyhedron Section 16: Hyperplanes, Half-spaces and Polytopes
	5	Section 17: Separating and Supporting Hyperplanes (Proof of Theorem 18 is optional) Section 18: Vertices of a Closed Bounded Convex Set (Proof of Theorem 21,22,23 are optional) Section 19: Summary Section 20: Quadratic Forms
II		**Module II**
	6	Chapter 2 Section 11: Convex Functions
	7	Section 12: General Problem of Mathematical Programming
	8	Chapter 3 Section 1: Introduction Section 2: LP in Two-Dimensional Space
	9	Section 3: General L P Problem Section 4: Feasible Solutions (Proof of Theorem 1 is optional) Section 5: Basic Solutions Section 6: Basic Feasible Solutions (Proof of Theorem 2,3 are optional) Section 7: Optimal Solution (Proof of Theorem 4,5 are optional) Section 8: Summary
	10	Section 9: Simplex Method Section 10: Canonical Form of Equations Section 11: Simplex Method (Numerical Example) Section 12: Simplex Tableau
	11	Section 13: Finding the First b.f.s; Artificial Variables Section 14: Degeneracy
	12	Section 15: Simplex Multipliers
III		**Module III**
	13	Chapter 3 Section 17: Duality in LP Problems
	14	Section 18: Duality Theorems (Proof of Theorem 7,8,9, 10,11 are optional) Section 19: Applications of Duality
	15	Section 20: Dual Simplex Method Section 21: Summary of Simplex Methods (III Revised Simplex Method is optional)
	16	Section 22: Applications of LP
IV		**Module IV**

	17	Chapter 4 Section 1: Introduction Section 2: Transportation Problem Section 3: Transportation Array Section 4: Transportation Matrix Section 5: Triangular Basis (Proof of Theorem 1 is optional) Section 6: Finding a Basic Feasible Solution
	18	Section 7: Testing For Optimality
	19	Section 8: Loop in Transportation Array (Proof of Theorem 2 is optional) Section 9: Changing the Basis
	20	Section 10: Degeneracy Section 11: Unbalanced Problem
	21	Section 14: Assignment Problem (Proof of Theorem 3 is optional)
	22	Section 15: Generalized Transportation Problem Exercise Questions in Assignment Problem
V	**Open Ended**	
		Linear Programming Using Scipy, Prog Reference 1.
		Dual Simplex Solved Programming Exercises in Python from Vanderbei (Reference 1), Prog Reference 2.
		Linear Programming in Python using IBM CPlex Community Edition. Prog Reference 3.
		Transportation Problem in Python. Prog Reference 4.
		Linear Programming in Julia. Prog Reference 5. Ch 3 Basics of Julia Programming Language, Ch 5 The Simplex Method.

. **References**:

1. G. Hadley : Linear Programming Addison-Wesley Pub Co Reading, Mass (1975)

2. S.S. Rao : Optimization – Theory and Applications (2nd Edn.) Wiley Eastern (P) Ltd. New Delhi.

3. Russel L Ackoff and : Fundamentals of Operation Research Maurice W.Sasioni Wiley Eastern Ltd. New Delhi. (1991)

4. Charles S. Beightler, : Foundations of Optimization D.T. Philips & D.J. Wilde (2nd Edn.) Prentice Hall of India, Delhi (1979)

Programming References for Open-Ended section:

1. Linear Programming using Scipy, https://python.quantecon.org/lp_intro.html
2. Vanderbei's book homepage: https://vanderbei.princeton.edu/LPbook/
3. CPlex Jupyter Notebook: https://github.com/IBMDecisionOptimization/tutorials/blob/master/jupyter/Linear_Programming.ipynb

Installation: http://ibmdecisionoptimization.github.io/docplex-doc/README.md.html

	4. Solving Transportation Problem using Linear Programming in Python: https://machinelearninggeek.com/solving-transportation-problem-using-linear-programming-in-python/ 5. Changhyun Kwon, Julia Programming for Operations Research 2/e , https://www.softcover.io/read/7b8eb7d0/juliabook2/simplex

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	1	2	1	3	0	1
CO 2	3	3	3	2	2	1	3	1	3	0	1
CO 3	2	3	3	2	3	1	3	1	3	0	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT6EJ305
Course Title	**TOPOLOGY OF METRIC SPACES**
Type of Course	**Elective**
Semester	VI
Academic Level	300 - 399

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	1. Fundamental Mathematics Concepts: Set, Functions, Logic 2. Real Analysis
Course Summary	This course familiarises students with the basic tools and phenomenology of topology by introducing metric spaces as a generalisation of the familiar Euclidean spaces.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate understanding of fundamental concepts in metric spaces and basic examples of metric spaces.	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	To analyse and evaluate the basic topology of metric spaces, including open sets, closed sets, interior, closure, and boundary points	An	E	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Demonstrate proficiency in applying concepts of convergence, completeness, and continuity in metric spaces, including understanding Cauchy sequences, completeness, and continuity of functions.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Introduction to Topology and Modern Analysis, George F. Simmons, Krieger Publishing Company (1982) ISBN-0-89874-551-9		
Module	**Unit**	**Content**	**Hrs (48+ 12)**
I	**Introduction to Metric Spaces**		
	1	Chapter 1 Section 5: Partitions and Equivalence Relations	**12**
	2	Chapter 1 Section 6: Countable Sets	
	3	Chapter 1 Section 7: Uncountable Sets	
	4	Chapter 2 Section 9: The Definition and Some Examples (Topics up to and including Example 2)	
	5	Chapter 2 Section 9: The Definition and Some Examples (Topics from Example 3 onwards)	
II	**Basic Topology of Metric Spaces**		
	6	Chapter 2 Section 10: Open Sets (Topics up to and including Theorem A)	**10**
	7	Chapter 2 Section 10: Open Sets (Theorem B and Theorem C)	
	8	Chapter 2 Section 10: Open Sets (Topics from Theorem D onwards)	
	9	Chapter 2 Section 11: Closed Sets (Topics up to and including Theorem C)	
	10	Chapter 2 Section 11: Closed Sets (Topics from Theorem D onwards)	
III	**Convergence, Completeness & Continuity**		
	11	Chapter 2 Section 12: Convergence, Completeness, and Baire's Theorem (Topics up to Theorem A)	**12**
	12	Chapter 2 Section 12: Convergence, Completeness, and Baire's Theorem (Theorem A and Theorem B)	
	13	Chapter 2 Section 12: Convergence, Completeness, and Baire's Theorem (Topics from Theorem C onwards)	
	14	Chapter 2 Section 13: Continuous Mappings (Topics up to and including Theorem A)	
	15	Chapter 2 Section 13: Continuous Mappings (Theorem B and Theorem C)	
	16	Chapter 2 Section 13: Continuous Mappings (Topics from Theorem D onwards)	
IV	**Special Classes of Metric Spaces**		
	17	Chapter 2 Section 14: Spaces of Continuous Functions (Topics up to First Lemma)	**14**
	18	Chapter 2 Section 14: Spaces of Continuous Functions (First Lemma, Second Lemma)	
	19	Chapter 2 Section 14: Spaces of Continuous Functions (Topics from Theorem A onwards)	
	20	Chapter 2 Section 15: Euclidean and Unitary Spaces (Topics up to First Lemma)	
	21	Chapter 2 Section 15: Euclidean and Unitary Spaces (First Lemma, Second Lemma)	
	22	Chapter 2 Section 15: Euclidean and Unitary Spaces (Topics from Theorem A onwards)	
	Compactness In Metric Spaces		

V (Open Ended)		The Heine-Borel Property Bolzano-Weierstrass Property Lebesgue's Covering Lemma Sequential Compactness Compactness – Open Cover Formulation Total Boundedness Compactness, Completeness & Total Boundedness Equicontinuity & the Arzela-Ascoli Theorem	**12**

References:

1. Introduction to General Topology, K. D. Joshi, New Age International.
2. A First Course In Topology, James R. Munkres, Prentice Hall of India
3. Topology of Metric Spaces, S. Kumaresan, Narosa Publishing House.

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1	1	3	1	2	1	3	0	1
CO 2	3	3	1	1	3	1	3	1	3	0	1
CO 3	3	3	2	1	3	1	3	1	3	0	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT6EJ306				
Course Title	**INTRODUCTION TO FOURIER ANALYSIS**				
Type of Course	**Elective**				
Semester	VI				
Academic Level	300-399				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	An introductory course in Real Analysis including series of functions				
Course Summary	Fourier analysis is a fundamental component in the tool-kit of every pure and applied mathematician with numerous applications to signal processing, image processing, tomography and several other areas of engineering. In this course we shall look at the most basic theoretical foundations of this subject. Along the way we shall have to recapitulate some of the requisite results from functional analysis.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate proficiency in defining and applying concepts related to inner product spaces, including orthogonality and linear operators.	Ap/An	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
CO2	Describe orthogonality, including definitions and examples. Demonstrate the use of orthogonal projections, including the Gram-Schmidt orthogonalization process.	Ap	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO3	Compute Fourier series on various intervals including cosine and sine expansions, and understand the complex form of Fourier series.	Ap	P	Internal Exam/Assignment /Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	A First Course in Wavelets with Fourier Analysis, 2e, Albert Boggess and Francis J Narcowich, Wiley.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**Marks** **Ext: 70**
I	**Inner Product Spaces**		**12**	
		Quick review through the preface of the text book for the discussions Fourier Analysis and Wavelets		
	1	0.1 and 0.2 – Motivation, definition and examples of inner product.		
	2	0.3 – The spaces L^2 and ℓ^2 – 0.3.1 - Construction of inner products in L^2 and ℓ^2 .		
	3	0.3.2 – Convergence in L^2 versus uniform convergence.		
	4	0.4 – Schwarz Inequality		
	5	0.4 - Triangle Inequality		
	6	0.5 – Orthogonality 0.5.1 – Definitions and examples.		
	7	0.5.2 – Orthogonal Projections – up to and including example 0.23		
II	**Inner Product Spaces – contd.**		**12**	
	8	0.5.2 – Orthogonal Projections – rest of the section		
	9	0.5.3 – Gram – Schmidt Orthogonalization.		
	10	0.6 – Linear Operators and their Adjoints 0.6.1- Linear Operators		
	11	0.6.2 – Adjoints - (up to and including Example 0.31)		
	12	0.6.2 – Adjoints – rest of the section.		

III	**Fourier Series**		**12**	
	13	1.1 – Introduction (1.1.1 to 1.1.3)		
	14	1.2 – Computation of Fourier Series 1.2.1 – On the interval [-π , +π] – with examples		
	15	1.2.2 – Other intervals – with examples		
	16	1.2.3 – Cosine and Sine expansions with examples		
	17	1.2.5 – The complex form of Fourier Series		
	Modules III and IV are presented only for motivations and examples for the theory. All the proofs of theorems in these modules are optional to study and exempted from external examination.			
IV	**Fourier Transforms**		**12**	
	18	2.1 – Informal development of the Fourier transform 2.1.1 – Fourier Inversion Theorem		
	19	2.2.2 – Fourier Transform of a convolution		
	20	2.2.3 – Adjoint of the Fourier Transform		
	21	2.2.4 – Plancherel Theorem		
	22	More problems from the above sections		
V (Open Ended)	**Fourier Analysis**		**12**	
	After having the above basics of Fourier Analysis, one can look at the discrete versions of Fourier Analysis and can enter into Wavelets theory (for instance refer sections 4.1 and 4.2 of text book). The Haar wavelet analysis with its decomposition and reconstruction theorems open the window to signal theory which is an active area of research for both pure and applied Mathematicians			

References

1. Ten lectures on Wavelets, Daubechies, Philadelphia, SIAM, 1992.
2. Fourier Analysis and its Applications, Gerald B Folland, Wadsworth and Brooks/Cole Advanced Books and Software, Pacific Grove, California.
3. Introduction to Fourier Analysis on Euclidean Spaces, Elias M Stein and Guido -Weiss, Princeton University Press.
4. How to make Wavelets, Robert S. Strichartz, The American Mathematical Monthly.

Note: 1) Optional topics are exempted for end semester examination.
2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	1	3	1	3	1	3	0	1
CO 2	3	3	2	1	3	1	3	1	3	0	1
CO 3	3	3	2	1	3	1	3	1	3	0	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8EJ401			
Course Title	**ADVANCED TOPOLOGY**			
Type of Course	**Elective**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	0	60
Pre-requisites	1. Topology I			
Course Summary	The advanced topology course extends Topology I by introducing further concepts and tools. It starts with the product topology and explores its properties. Embeddings, including the Tychonoff embedding theorem, are discussed. Urysohn's Lemma from the previous course is used to prove the Urysohn Metrisation Theorem. Nets and filters are introduced to address sequence limitations. Various forms of compactness and compactifications are examined, with a focus on their relation to completeness in metric spaces. The course concludes with important results such as the Baire category theorems.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Learn basic structures and constructions in Topology	U	F	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse and apply the concepts of Nets, Filters, and Convergence in the context of Topological Spaces	An	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	To develop the student's ability to handle abstract ideas of mathematics and mathematical proofs	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	Introduction to General Topology, 2nd Edition, K. D. Joshi, New Age International Publishers, 1983.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**External Marks (70)**
I		**Chapter 8: Products & Coproducts**	**10**	
	1	Cartesian Products of Families of Sets – 8.1		
	2	The Product Topology – 8.2		
	3	Productive Properties – Separation Axioms 8.3		
	4	Productive Properties – Connectedness – 8.3		
	5	Countably Productive Properties – Metrisability–8.4		
	6	Countably Productive Properties – Countability–8.4		
	7	The Case of Separability – 8.4		
II		**Chapter 9: Embedding & Metrisation**	**10**	
	8	Evaluation Functions into Products – 9.1		
	9	Embedding Lemma – 9.2		
	10	Tychonoff Embedding – 9.2		
	11	The Urysohn Metrisation Theorem – 9.3		
III		**Chapter 10: Nets & Filters**	**12**	
	12	Definition & Convergence of Nets – 10.1		
	13	Topology & Convergence of Nets – 10.2		
	14	Nets & Compactness – 10.2		
	15	Filters & Their Convergence – 10.3		
	16	Topology & Filters – 10.3		
	17	Ultrafilters and Compactness – 10.4		
IV		**Chap 11,12: Compactness & Complete Metric Spaces**	**16**	

	18	Variations of Compactness – 11.1		
	19	The Alexander Sub-base Theorem – 11.2		
	20	Local Compactness – 11.3		
	21	Compactifications – 11.4 (Wallman Compactification 11.15 to 11.20 may be relegated to Practicum)		
	22	Complete Metrics – 12.1		
	23	Consequences of Completeness – 12.2		
	24	Completions of a Metric – 12.4		
V	**Practicum:**		**12**	
	1	Wallman Compactification: 11.15 to 11.20		
	2	12.3: Some Applications (of Completeness)		
	3	Chapter 13: Category Theory		
	4	Chapter 14: Uniform Spaces		
	5	Chapter 15 Section 2: Paracompactness		
	6	Chapter 15 Section 3: Use of Ordinal Numbers		
	7	Nagata-Smirnov Metrisation Theorem		

References

1. Topology, J. R. Munkres, Prentice Hall of India, 2000.
2. General Topology, S. Willard, Addison Wesley Pub. Company, 1976.
3. General Topology, J. L. Kelley, D. van Nostrand, 1955.
4. Introduction to Topology and Modern Analysis; G. F. Simmons, McGraw-Hill, 1963.
5. Topology, James Dugundji, Prentice Hall of India, 1975.

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	3	1	2	1	3	0	1
CO 2	3	3	2	1	3	1	3	1	3	0	1
CO 3	3	3	3	3	2	1	2	1	2	0	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT8EJ402				
Course Title	**PARTIAL DIFFERENTIAL EQUATIONS**				
Type of Course	**Elective**				
Semester	VIII				
Academic Level	400-499				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	1. Real Analysis 2. Basic Concepts of Vector functions 2. Ordinary Differential Equations				
Course Summary	This introductory Partial Differential Equations (PDEs) course equips students with the mathematical tools and problem-solving skills necessary to analyse and solve real-world phenomena governed by PDEs. The syllabus focuses on analytical methods for solving first and second-order PDEs, laying the foundation for further exploration of advanced PDEs and their applications.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understanding of basic concepts, definitions, and mathematical problems related to first-order quasilinear equations.	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse and evaluate the classification of second-order linear equations, including the Cauchy problem and wave equations.	An	E	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Evaluate solutions for boundary value problems and apply them in solving PDEs.	E	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text: Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Tyn Myint-U, Lokenath Debnath, Birkhauser(2007), ISBN : 978-81-8489-079-2.				
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70**
I	**First Order Quasilinear Equations and Method of Characteristics**		**9**	
	1	Basic Concepts, definitions and mathematical problems		
	2	Classification of first order equations		
	3	Construction of a first order equation		
	4	Geometrical Interpretation of a First- Order Equation		
	5	Method of characteristics and General solutions		
	Sections from Text: 1.2, 1.3, 2.1, 2.2,2.3, 2.4, 2.5.			
II	**Classification of Second Order Linear Equations, The Cauchy Problem and Wave Equations**		**21**	
	6	Second order equations in two independent variables		
	7	Canonical Forms		
	8	Equations with constant coefficients		
	9	General Solutions		
	10	The Cauchy Problem		
	11	Homogeneous Wave Equations		
	12	Initial Boundary-Value Problems		
	13	Equations with Nonhomogeneous Boundary Conditions		
	14	Vibration of Finite String with Fixed Ends		
	15	Nonhomogeneous Wave Equations		
	16	The Riemann Method		

	Sections from Text: 4.1 - 4.4, 5.1, 5.3-5.8			
III	**Method of Separation of Variables**		**13**	
	17	Introduction		
	18	Separation of Variables		
	19	The Vibrating String Problem		
	20	Existence and Uniqueness of Solution of the Vibrating String Problem		
	21	The Heat Conduction Problem		
	22	Existence and Uniqueness of Solution of the Heat Conduction Problem		
	23	The Laplace and Beam Equations		
	24	Nonhomogeneous Problems		
	Sections from Text: 7.1-7.8			
IV	**Boundary Value Problems and Applications**		**7**	
	25	Boundary Value Problems		
	26	Maximum and Minimum Principles		
	27	Uniqueness and Continuity Theorems		
	28	Dirichlet Problem for a circle		
	29	Neumann Problem for a circle		
	30	Dirichlet Problem for a rectangle		
	31	The Neumann Problem for a Rectangle		
	Sections from Text: 9.1-9.4, 9.6, 9.7, 9.8,9.9			
V (Open Ended)	**Green's Functions, Boundary Value Problems and Nonlinear Equations**		**12**	
		Green's Functions for Ordinary Differential Equations, Construction of Green's Functions, The Dirac Delta Function, Properties of Green's Functions, Method of Green's Functions (only for Laplace operator) Nonlinear PDEs -brief overview from any text		

References:

1. Partial Differential Equations -An Introduction, Second Edition, Walter A. Strauss, John Wiley and Sons Limited.

2. Partial Differential Equations-Classical Theory with a Modern Touch, A.K. Nandakumaran, P.S. Datti, Cambridge-IISc Series.

3. Elements of Partial Differential Equations, I.N. Sneddon, McGraw-Hill, New York (1972).

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	1	2	1	3	0	1
CO 2	3	3	2	1	3	1	3	1	3	0	1
CO 3	2	3	2	1	3	1	3	1	3	0	1

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8EJ403			
Course Title	**RINGS AND MODULES**			
Type of Course	**Elective**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Elementary number theory, algebra, combinatorics, basic linear algebra			
Course Summary	This course is a self-contained elementary introduction to Rings and Modules. The course will cover basic topics of Ring Theory and Module Theory which is a core course in Algebra			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Define and differentiate between various types of rings, including rings of continuous functions, matrix rings and polynomial rings	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse and apply the concepts of ideals within rings, including definitions, maximal ideals, generators for subrings and ideals.	An	Ap	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Evaluate and synthesize the concepts of homomorphisms of rings, including quotient rings, ideals in quotient rings, endomorphism rings and field of fractions.	E	M	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text book	Introduction to Rings and Modules, C. Musili, Narosa Publishing House, 2001.			
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70**
I		**Rings**	12	
	1	Chapter 1 – Section 1.1: Terminology		
	2	Chapter 1 – Section 1.2: Rings of Continuous functions		
	3	Chapter 1 – Section 1.3 to 1.5: Matrix Rings, Polynomial Rings and Power series rings		
	4	Chapter 1 – Section 1.8 to 1.9: Some Special Rings and Direct Products		
	5	Chapter 1 – Section 1.10 to 1.12: Several Variables, Opposite rings, Characteristic of a ring		
II		**Ideals**	12	
	6	Chapter 2 – Section 2.1 to 2.2 : Definitions, Maximal Ideals		
	7	Chapter 2 – Section 2.3: Generators for subrings and Ideals		
	8	Chapter 2 – Section 2.4: Basic Properties of Ideals		
	9	Chapter 2 – Section 2.5: Algebra of Ideals		
III		**Homomorphisms of Rings**	12	
	10	Chapter 2 – Section 2.6 & 2.7 : Quotient rings and Ideals in Quotient rings		
	11	Chapter 3 – Section 3.1: Definition and Basic Properties		
	12	Chapter 3 – Section 3.2 : Fundamental Theorems of Homomorphisms		
	13	Chapter 3 – Section 3.3: Endomorphism Rings		
	14	Chapter 3 – Section 3.4: Field of Fractions		
	15	Chapter 3 – Section 3.5: Prime Fields		
IV		**Modules**	12	
	16	Chapter 5: Modules: Section 5.1: Definition and Examples		
	17	Chapter 5: Section 5.2 to 5.4: Direct sums, Free Modules and Vector spaces		
	18	Chapter 5: Section 5.4 to 5.3: Direct sums and Free Modules		
	19	Chapter 5: Section 5.6: Quotient Modules		
	20	Chapter 5: Section 5.7: Homomorphisms		
	21	Chapter 5: Section 5.8: Simple Modules		
V		**Open Ended**	12	
		Artinian Modules and Rings, Noetherian Modules and Rings, Nil Radical, Jacobson Radical		
References	1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Edition, 2002 2. M. Artin: Algebra, Prentice Hall, 1991 3. Thomas W. Hungerford, Algebra, Springer, 2003 4. Joseph Gallian, Contemporary Abstract Algebra, 7th Edition, Cengage Learning, 2009. 5. D.M. Burton, A First Course in rings and ideals, Addison- Wesley, 1970.			

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	1	2	1	3	0	1
CO 2	2	3	2	1	3	1	3	1	3	0	1
CO 3	2	2	2	1	3	1	3	1	3	0	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT8EJ404
Course Title	**CODING THEORY**
Type of Course	**Elective**
Semester	VIII
Academic Level	400-499

Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60

Pre-requisites	Linear Algebra, Algebra
Course Summary	The course helps the student to understand various algebraic codes, - their encoding and decoding methods and the mathematical tools used in their design.

Course Outcomes (CO):

CO	**CO Statement**	**Cognitive Level***	**Knowledge Category#**	**Evaluation Tools used**
CO1	Construct the parity check/generator matrix of a linear code.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Calculate bounds on rate and distance of a given linear code using various bounds.	An	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Design cyclic codes of a given rate and distance parameters and decode it using various standard decoding procedures.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text	Huffman, W. Cary, and Vera Pless. Fundamentals of error-correcting codes. Cambridge university press, 2010.			
Module	**Unit**	**Content**	**Hrs (48+12)**	**External Marks (70)**
I	**Linear Codes** Text Sections: 1.1, 1.2, 1.4, 1.5.1 to 1.5.3, 1.8, 1.10, 1.11.2		**12**	
	1	Binary and Prime Fields		
	2	Linear Codes - Generator and Parity Check Matrix		
	3	Weights and Distances		
	4	Punchuring, Shortening and Extension		
	5	Hamming Codes		
	6	Reed Muller Codes		
	7	Encoding Linear Codes		
II	**Bounds on Linear Codes** **Text Sections: 2.2, 2.4, 2.8**		**5**	
	8	Plotkin Bound		
	9	Singleton Bound and MDS codes		
	10	Gilbert - Varshamov Lower Bound		
	11	Asymptotic Singleton and Plotkin Bounds		
III	**Finite Fields and Cyclic Codes** **Text Sections: 3.1 to 3.7 and 4.1, 4.2, 4.5.**		**15**	
	12	Finite fields and elementary properties		
	13	Polynomials and Euclid’s Algorithm		
	14	Primitive Elements		
	15	Construction of Finite fields		

	16	Cyclotomic Polynomials		
	17	Basic Theory of Cyclic Codes		
	18	BCH Bound.		
IV	**BCH and Reed Solomon Codes** **Text Sections: 5.1, 5.2, 5.3, 5.4.1 to 5.4.3**		**16**	
	18	BCH Codes		
	19	Reed Solomon Codes and their generalization.		
	20	Peterson–Gorenstein–Zierler Decoding Algorithm		
	21	Berlekamp Massey Decoding Algorithm		
	22	Sugiyama Decoding Algorithm (Euclid's Algorithm)		
V	**OPEN ENDED**		**12**	**-**
	1	List decoding and Guruswami Sudan Algorithm		
	2	Weight Distributions of Codes and McWilliams Identities		
	3	Self-dual codes.		
	4	Codes on Projective Planes		
	5	Codes over Z4		
	6	Convolutional Codes		
References	1. E. F. Assmus, Jr. and J. D. Key, Designs and Their Codes. London: Cambridge University Press, 1993. 2. R. E. Blahut, Theory and Practice of Error Control Codes. Reading, MA: Addison-Wesley, 1983.			

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module

Mapping of COs with PSOs and POs:

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	0	3	1	2	1	3	0	1
CO 2	3	2	2	0	3	1	3	1	3	0	1
CO 3	3	3	2	0	3	1	3	1	3	0	1

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT8EJ405				
Course Title	**FOUNDATIONS OF MATHEMATICS**				
Type of Course	**Elective**				
Semester	VIII				
Academic Level	400-499				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Nil				
Course Summary	The course goes into the philosophy of mathematics, modern axiom methods, controversies in set theory around axiom of choice, its implications and various philosophical alternative approaches to the foundations of mathematics.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse Axiomatic Systems and Logical Deductions	An	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO2	Explore Axioms and their Interpretation of Mathematical Structures	Ap	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO3	Investigate Properties of standard sets in Mathematics and obtain their axiomatic constructions	E	P	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

TEXT: R. Wilder, Introduction to the Foundations of Mathematics (2/e), John Wiley & Sons, 1967				
Module	**Unit**	**Content**	**Hrs (60)**	**Ext. Marks (70)**
I	**Axiomatic Method** (Up to Chapter 3 Section 5 of Text Book)		**12**	
	1	Description - undefined terms, axioms, logical deductions and proofs. Case study with axioms of points and lines.		
	2	Axioms and Interpretation (models): consistency (satisfiability), completeness, categorically and independence.		
	3	Case Study with axioms of order and equivalence.		
	4	Sets and Russal's Paradox.		
	5	Finite and Infinite Sets,		
	6	Review of Mathematical Induction.		
II	**Set Theory: Cardinals** (Chapter 3, Section 6 to Chapter 4 of Text Book)		12	
	7	Infinite Sets - Ordinary and Dedekind Infinity and their equivalence		
	8	Axiom of Choice		
	9	Countable Sets and their properties		
	10	Diagonalization and Uncountable Sets, Irrational Numbers		
	11	Cardinal Numbers and Bernstein's Equivalence Theorem		
	12	Well Ordered Sets and Transfinite Induction		
III	**Set Theory: Ordering (**Chapter 5)		**12**	
	13	Well Ordering Theorem		
	14	Ordinals and Burali-Forti Paradox		
	15	Properties of Ordinals and Continuum Hypothesis		
	16	Equivalence of Axiom of Choice, Well Ordering Theorem.		
	17	Zorn's Lemma and Equivalence with Axiom of Choice		
IV	**Real Numbers** (Chapter 6 of Text Book)		**12**	

	18	Ordering and Separability of Reals, and Dedekind Cuts.		
	19	Axiomatization of Real Numbers: Constituency, Independence and		
	20	Categoricalness of Real Number Axioms.		
	21	Definition of Real numbers from Peano's Axioms		
	22	Complex Numbers.		
V	**Discussions in Mathematical Philosophy**			
	1	Abstractions: Groups/Rings/Fields/Vector Spaces		
	2	Zermelo Fraenkel Axiomatization of Set Theory		
	3	Frege-Russell Thesis Set Theory using Predicate Calculus		
	4	Brower's Intuitionist Theory		
	5	Formal Deductions and Godel's Theorems.		

References:

1. I. M. Copi, Symbolic Logic (5/e), Pearson, 2015.
2. U. C. Merzbach and C. B. Boyer, A History of Mathematics, (3/e), 2011.
3. I. Stewart and D. Tall, The foundations of Mathematics, (2/e), Oxford University Press 2015.

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	1	3	3	3	3	0	0	3
CO 2	3	3	2	1	3	3	3	3	0	0	3
CO 3	3	3	2	1	3	3	3	3	0	0	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT8EJ406				
Course Title	**OPERATIONS RESEARCH**				
Type of Course	**Major**				
Semester	VIII				
Academic Level	400-499				
Course Details	Credit	Lecture/Tutorial per week	**Practical per week**	**Total Hours**	
	4	4	**-**	**60**	
Pre-requisites	Basic Mathematical and Statistical knowledge.				
Course Summary	This paper on Operation Research introduces the concepts like minimum path problem in network analysis, integer linear programming problem and dynamic programming problem. Kuhn Tucker condition to solve nonlinear programming problem is also discussed.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Solve Minimum Path Problem, Maximum flow problem	Ap	C	Internal Exam/ Assignment / Seminar/ Viva / End Sem Exam
CO2	Understand and solve ILP and MILP	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply Kuhn-Tucker Conditions to solve nonlinear programming problem	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text: Optimization Methods in Operation Research and System Analysis (4th edition), KV Mittal, C Mohan, New Age International (P) Limited (2016)

Module	Unit	Content	Hrs (48 +12)	Ext. Marks (70)
I		**Flow and Potential in Networks**	14	
	1	5.1,5.2 - Graphs Definitions and Notation		
	2	5.3- Minimum Path Problem		
	3	5.4- Spanning tree of minimum length		
	4	5.5- Problem of Potential Difference		
	5	5.6- Scheduling of sequential activities		
	6	5.7 Maximum flow problem		
	7	Generalized Problem of Maximum flow		
II		**Integer Programming**	10	
	8	6.1, 6.2-Introduction, ILP in two dimensional space		
	10	6.3-General ILP and MILP problems		
	11	6.4- Examples of ILP in two dimensional space		
	12	6.5,6.6, 6.7- Cutting planes, Example, Remarks on Cutting plane method		
III		**Kuhn-Tucker Theory and Nonlinear Programming**	11	
	14	8.1, 8.2-Introduction , Lagrangian Function: Saddle Point,		
	15	8.3- Relation between Saddle Point of F(X,Y) and Minimal point of f(X)		
	16	8.4- Kuhn-Tucker Conditions		
	17	8.5- Primal and Dual Problems		
	18	8.6-Quadratic Programming		
IV		**Dynamic Programming**	13	
	19	10.1,10.2- Introduction, Problem 1: A Minimum Path Problem		

	20	10.3-Problem II: Single Additive Constraint, Additively Separable Return		
	21	10.4, 10.5-Problem III: Single Multiplicative Constraint, Additively Separable Return, Problem IV: Single Additive Constraint, Multiplicatively Separable Return		
	22	10.6,10.7-Computational Economy in DP, Serial Multistage Model		
	23	10.8, 10.9-Examples of Failure, Decomposition		
	24	10.10-Backward and Forward Recursion		
V	**Open Ended**		**12**	
	Sensitivity Analysis, Changes in b_i, c_j, and a_{ij}, Introduction of new variable, Introduction of new constraint, Deletion of variables, Deletion of constraints, Parametric linear programming, goal programming			

References:

1. G. Hadley: Linear Programming Addison-Wesley Pub Co Reading, Mass (1975)
2. G. Hadley : Non-linear and Dynamic Programming Wiley Eastern Pub Co. Reading, Mass (1964)
3. S.S. Rao : Optimization – Theory and Applications (2nd Edn.) Wiley Eastern (P) Ltd. New Delhi.
4. Russel L Ackoff and : Fundamentals of Operation Research Maurice W.Sasioni Wiley Eastern Ltd. New Delhi. (1991)

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	2	1	1	1	2	0	1
CO 2	3	3	1	1	2	1	1	1	2	0	1
CO 3	2	3	2	1	2	1	1	1	2	0	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8EJ407			
Course Title	**CRYPTOGRAPHY**			
Type of Course	**Elective**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Elementary number theory, algebra, combinatorics, basic linear algebra			
Course Summary	Cryptography is a fundamental aspect of information security that involves creating secure communication by encoding messages to make them unintelligible to unauthorised users and Cryptography relies heavily on mathematical concepts. This course covers a wide range of topics, starting with Classical Cryptography, which includes simple cryptosystems. It also delves into cryptanalysis of these systems. Moreover, the course includes a section on Cryptographic Hash Functions, focusing on their role in ensuring data integrity. Students gain a comprehensive understanding of these concepts and techniques, equipping them with the knowledge and skills needed to analyze and implement secure cryptographic systems.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Construct the parity check/generator matrix of a linear code. Design cyclic codes of a given rate and distance parameters.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Calculate bounds on rate and distance of a given linear code using various bounds.	An	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Decode a cyclic code using various standard decoding procedures.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Cryptography Theory and Practice 3rd Edition, Douglas R. Stinson, , Chapman & Hall,			
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Classical Cryptography**	**12**	**Min.15**
	1	Chapter 1: Section 1.1-1.1.1: Some SimpleCryptosystems, Shift Cipher		
	2	Chapter 1: Sections 1.1.2 & 1.1.3: The SubstitutionCipher, Affine Cipher		
	3	Chapter 1: Sections 1.1.4 & 1.1.5: The VigenereCipher, The Hill Cipher		
	4	Chapter 1: Sections 1.1.6 : The Permutation Cipher		
	5	Chapter 1: Sections 1.1.7 : Stream Ciphers		
II		**Cryptanalysis**	**12**	**Min.15**
	6	Chapter 1: Section 1.2 & 1.2.1 : Cryptanalysis:Cryptanalysis of the Affine Cipher		
	7	Chapter 1: Section 1.2.2 : Cryptanalysis of theSubstitution Cipher		
	8	Chapter 1: Section 1.2.3 : Cryptanalysis of theVigenere Cipher		
	9	Chapter 1: Section 1.2.4 : A known plain textattack on the Hill Cipher		
	10	Chapter 1: Section 1.2.5 : Cryptanalysis of theLFSR-based Stream Cipher.		
III		**Shannon's Theory**	**10**	**Min.15**
	11	Chapter 2 : Sections 2.1, 2.2 : Introduction,Elementary Probability Theory		
	12	Chapter 2 : Sections 2.3: Perfect Secrecy		
	13	Chapter 2 : Sections 2.4: Entropy, HuffmanEncodings		
	14	Chapter 2 : Sections 2.5: Properties of Entropy		
	15	Chapter 2 : Sections 2.6: Spurious Keys andUnicity Distance		
	16	Chapter 2 : Sections 2.7: Product Cryptosystems		
IV		**Block Ciphers and Advanced Encryption Standard**	**14**	**Min.15**
	17	Chapter 3: Sections 3.1 and 3.2 : Introduction,Substitution - Permutation Networks		
	18	Chapter 3: Sections 3.3 (3.3.1 to 3.3.3): LinearCryptanalysis		
	19	Chapter 3: Sections 3.4 : Differential Cryptanalysis		
	20	Chapter 3: Sections 3.5 (3.5.1,3.5.2) : Data Encryption Standard (DES), Description of DES,Analysis of DES		
V		**Open Ended**	**12**	
		Cryptographic Hash Functions		
References		**1.** Jeffrey Hoffstein: Jill Pipher, Joseph H. Silverman, An Introduction to Mathematical Cryptography, Springer International Edition. **2.** Koblitz, N. (1994) A course in Number Theory and Cryptography, (SecondEd.), Springer- Verlag **3.** Yan, S. Y. (2003) Primality Testing and Integer Factorization in Public-Key Cryptography, Springer **4.** H. Deffs & H. Knebl: Introduction to Cryptography, Springer Verlag, 2002 **5.** Alfred J. Menezes, Paul C. van Oorschot and Scott A. Vanstone: Handbook of Applied Cryptography, CRC Press, 1996. **6.** William Stallings: Cryptography and Network Security Principles and		

	Practice, Third Edition, Prentice-hall India, 2003. 7. D. Boneh and V. Shoup: A Graduate Course in Applied Cryptography (V 0.5) **8.** J. Katz and Y. Lindell. *Introduction to Modern Cryptography* (2nd edition)

Note: 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	3	3	3	3	0	0	3
CO 2	3	3	1	1	3	3	3	3	0	0	3
CO 3	2	3	2	1	3	3	3	3	0	0	3

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT8EJ408			
Course Title	**INTRODUCTION TO FRACTALS**			
Type of Course	**Elective**			
Semester	VIII			
Academic Level	400 - 499			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	0	60
Pre-requisites	1. Calculus 2. Geometry			
Course Summary	This course equips students with a thorough understanding of metric spaces and the mathematical foundations of fractal geometry, blending theoretical insights with practical applications.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the basic concepts to build fractals	U	C	Internal Examination/ Assignment/ End Sem examination
CO2	Interpret the dimension of fractals	An	P	Internal Examination/Seminar/ Assignment/ Report/ End Sem examination
CO3	To understand how to construct fractals and apply them	Ap	M	Internal Examination/Seminar/ Report/ End Sem examination
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	Fractals Everywhere, (2/e), Michael F Barnsley, Dover Publications, 2012			
Module	**Unit**	**Content**	**Hrs (48+12)**	**External Marks(70)**
I		**Metric spaces**	**15**	**18**
	1	Chapter II, Section 2:- Metric spaces		
	2	Section 3: - Cauchy Sequences, Limit Points, Closed Sets, Perfect Sets, and Complete Metric Spaces		
	3	Section 4: - Compact Sets, Bounded Sets, Open Sets, and Boundaries		
	4	Section 5: - Connected Sets, Disconnected Sets, and Pathwise-Connected Sets		
II		**Space of Fractals**	**15**	**17**
	5	Section 6: - The Metric Space (H(X), h): The Space Where Fractals Live		
	6	Section 7: - The Completeness of the Space of Fractals – up to Theorem 7.1		
	7	Section 7: - The Completeness of the Space of Fractals – From Theorem 7.1 onwards.		
	8	Chapter III, Section 1 – Transformations on the Real line – up to definition 1.3		
	9	Section 1: – Transformations on the Real line – from definition 1.3 onwards.		
	10	Section 2: – Affine Transformations in the Euclidean Plane		
	11	Section 6: – The Contraction Mapping Theorem		
III		**Fractal Dimension**	**8**	**18**
	12: - Section 7: - Contraction Mappings on the Space of Fractals - up to definition 7.1			
	13: - Section 7: – Contraction Mappings on the Space of Fractals – from definition 7.1 onwards			
	14: - Section 8: – Two Algorithms for Computing Fractals from Iterated Function Systems			
	15: - Section 10: – How to Make Fractal Models with the Help of the Collage Theorem.			
	16: - Chapter V, Section 1: – Fractal Dimension – up to Theorem 1.2			
	17: - Chapter V, Section 1: – Fractal Dimension – from Theorem 1.2 onwards.			
IV		**Determination of Dimensions**	**10**	**17**
	18	Section 2: – The Theoretical Determination of the Fractal Dimension – up to Theorem 2.1(including)		
	19	Section 2: – The Theoretical Determination of the Fractal Dimension – rest of the section.		
	20	Section 3: – The Experimental Determination of the Fractal Dimension.		
	21	Section 4: – The Hausdorff-Besicovitch Fractal Dimension – up to and including Theorem 4.2		

	22	Section 4: – The Hausdorff-Besicovitch Fractal Dimension – rest of the section		
V	**OPEN ENDED**		**12**	
	Applications of Fractal functions, Fractal interpolation functions, Space filling curves, Construction of Iterated function systems, Applications of Fractals in medical imaging			
References	1. The Fractal Geometry of Nature**,** Benoît B. Mandelbrot, W.H. Freeman and Company, 1982. 2. Chaos and Fractals: New Frontiers of Science, (2/e), Heinz-Otto Peitgen, Hartmut Jürgens, Dietmar Saupe, Springer, 2004 3. Fractals: Form, Chance, and Dimension, Benoît B. Mandelbrot, W.H. Freeman and Company,1977. 4. Fractals Everywhere, (2/e), Michael F. Barnsley, Academic Press, 1993. 5. An Introduction to Fractals and Chaos, Michael F. Barnsley, Cambridge University Press, 2021.			

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	2	1	2	2	2	1	1
CO 2	3	3	1	1	2	1	2	2	2	1	1
CO 3	3	2	2	1	2	1	2	2	2	1	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

RESEARCH METHODOLOGY

Programme	B. Sc. Mathematics Honours
Course Code	MAT8CJ489
Course Title	**RESEARCH METHODOLOGY IN MATHEMATICS**
Type of Course	**Major**
Semester	VII
Academic Level	400 – 499

Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60

Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Research Aptitude
Course Summary	MAT8CJ489, "Research Methodology in Mathematics," is designed to equip students with the essential skills and knowledge required for conducting research in mathematics effectively. This course focuses on various aspects of mathematical research, including axiomatic set theory, writing mathematics, researching and presenting findings, and using LaTeX for mathematical typesetting. Additionally, students explore open-ended research topics, allowing them to delve into specific areas of interest within mathematics. Throughout the course, students engage with key texts and resources, enabling them to develop a comprehensive understanding of research methodologies in mathematics.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Set Theory and Mathematical Writing: Students will demonstrate proficiency in axiomatic set theory, including concepts such as relations, functions, and Peano axioms. Students will exhibit competence in mathematical writing.			Internal Examination/ Assignment/ End Sem examination
CO2	Research Skills and Presentation Techniques: Students will acquire research skills, including identifying research topics. Students will develop effective presentation techniques, giving talks.			Internal examination/ Seminar/ Assignment/ End Sem examination
CO3	Mathematical typesetting: to use LaTeX to create and typeset documents. Beamer Presentations and PSTricks also included.			Internal Examination/Seminar/ Assignment/End Sem examination
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	(1): Naive set theory: Paul R. Halmos, Courier Dover Publications, 2017. (2): A student's guide to the study, practice, and tools of modern mathematics, Donald Bindner and Martin Erickson. CRC Press, ISBN: 978-1-4398-4606-3			
Module	**Unit**	**Content**	**Hrs (48+12)**	**External Marks (70)**
I		**Axiomatic Set Theory**	**12**	
		(Sections 1 to 12 from the Text 1.) 1: The axiom of extension 2: The axiom of specification 3: Unordered pairs 4: Unions and intersections 5: Complements and powers 6: Ordered pairs 7: Relations 8: Functions 9: Families 10: Inverses and composites 11: Numbers 12: The Peano axioms		
II		**Writing Mathematics (Text 2)**	**12**	
		Chapter 1: How to Learn Mathematics (A quick review – not part of evaluation)		
		Chapter 2: How to Write Mathematics - 2.1: What is the goal of mathematical writing? 2.2: General principles of mathematical writing 2.3: Writing mathematical sentences 2.4: Avoiding error		

		2.5: Writing mathematical solutions and proofs 2.6: Writing longer mathematical works 2.7: The revision process		
III	**Researching and Presenting** **(Text 2)**		**12**	
		Chapter 3: How to Research Mathematics - 3.1: What is mathematical research? 3.2: Finding a research topic 3.3: General advice 3.4: Taking basic steps 3.5: Fixing common problems 3.6: Using computer resources 3.7: Practicing good mathematical judgment Chapter 4: How to Present Mathematics - 4.1: Why give a presentation of mathematics? 4.2: Preparing your talk 4.3: DOs and DON'Ts 4.4: Using technology 4.5: Answering questions 4.6: Publishing your research		
IV	**LATEX** **(Text 2)**		**12**	
		LaTeX 9.4 How to create and typeset a simple LATEX document 9.5 How to add basic information to your document 9.6 How to do elementary mathematical typesetting 9.7 How to do advanced mathematical typesetting 9.8 How to use graphics		
		PsTricks		

		10.1 What is PSTricks? 10.2 How to make simple pictures 10.3 How to plot functions 10.4 How to make pictures with nodes		
		Beamer 11.1 What is Beamer? 11.2 How to think in terms of frames 11.3 How to set up a Beamer document 11.4 How to enhance a Beamer presentation		
V	**OPEN ENDED** **(General Mathematical Research)**		**12**	
	Lecturer’s choices from the following Reference 1 (Princeton Companion), Section 1.4: General Goals of Mathematical Research, p.48 to 78. 1. Solving Equations 2. Classifying 3. Generalizing 4. Discovering Patterns 5. Explaining Apparent Coincidences 6. Counting and Measuring 7. Determining Whether Different Mathematical Properties are Compatible 8. Working with Arguments that are not Fully Rigorous 9. Finding Explicit Proofs and Algorithms 10. What do you find in a Mathematical Paper? Reference 2 (Math Unlimited), any chapters of the lecturer's choices. Reference 3 (Krantz, Mathematical Writing), any topics of lecturer’s choice.			

MULTI-DISCIPLINARY COURSES

(MDC)

Programme	B. Sc. Mathematics Honours				
Course Code	MAT1FM105(1)				
Course Title	**MATRICES AND BASICS OF PROBABILITY THEORY**				
Type of Course	**MDC**				
Semester	I				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Basic Arithmetic and Computational Skill.				
Course Summary	The course "Matrices and Basics of Probability Theory" provides students with a comprehensive understanding of two fundamental mathematical concepts: matrices and probability. The syllabus begins with a focus on the algebra of matrices, covering operations such as addition, subtraction, multiplication, determinants, and inverses, followed by applications in solving systems of equations. Transitioning to probability theory, students delve into basic concepts, conditional probability, the addition and multiplication rules, and various counting methods. Additionally, the course introduces basic statistics, including frequency distributions, measures of central tendency and variation, and measures of position.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the concepts of matrices and determinants.	U	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO2	Apply matrix theory to solve systems of equations.	Ap	P	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO3	Understand concepts like measures of central tendency, measures of variation, measures of position and probability.	U	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Texts: 1. John Bird, Bird's Higher Engineering Mathematics 9/e, Routledge, ISBN: 978-0-367-64373-7, 2021. 2. Ron Larson & Betsy Farber, Elementary Statistics, Picturing the World 6/e, Pearson Education, ISBN: 978-0-321-91121-6, 2015.				
Module	**Unit**	**Content**	**Hrs** **(36+ 9)**	**Ext. Marks** **(50)**
I		**Algebra of Matrices (from text 1)**	**9**	**Min 10**
	1	Section 20.1 - Matrix notation		
	2	Section 20.2 - Addition, subtraction and multiplication of matrices		
	3	Section 20.3 to 20.4 - The unit matrix, The determinant of a 2 by 2 matrix.		
	4	Section 20.5 - The inverse or reciprocal of a 2 by 2 matrix.		
	5	Section 20.6 - The determinant of a 3 by 3 matrix		
	6	Section 20.7 - The inverse or reciprocal of a 3 by 3 matrix		
II		**System of Equations From Text 1**	**9**	**Min 10**
	7	Section 21.1 - Solution of simultaneous equations by matrices		
	8	Section 21.2 - Solution of simultaneous equations by determinants		
	9	Section 21.3 - Solution of simultaneous equations using Cramer's rule		
	10	Section 21.4 - Solution of simultaneous equations using the Gaussian elimination method.		
III		**Basic Statistics From Text 2**		
	11	Section 1.1 to 1.2 - An Overview of Statistics, Data Classification		

	12	Section 2.1 - Frequency Distributions and their Graphs	**9**	**Min 10**
	13	Section 2.3 - Measures of Central Tendency		
	14	Section 2.4 - Measures of Variation		
	15	Section 2.5 - Measures of Position		
IV	**Basics of Probability (from text 2)**		**9**	**Min 10**
	16	Section 3.1 - Basic Concepts of Probability and Counting.		
	17	Section 3.2 - Conditional Probability and the Multiplication Rule.		
	18	Section 3.3 - The Addition Rule.		
	19	Section 3.4 - Additional topics in probability and counting.		
V	**Open Ended**		**9**	
	Data Collection and Experimental Design, More Graphs and Displays (for instance refer sections from Text 2: 1.3 and 2.2)			

References:

1. Advanced engineering mathematics, 10/e, Erwin Kreyszig, Wiley, 2011.

2. Introduction to Linear Algebra with Applications, Jim DeFranza and Daniel Gagliardi, Waveland Press, 2015.

3. Elementary Statistics, 13/e, Mario F. Triola, Pearson Education, 2018.

4. Elementary Statistics, 8/e, Neil A. Weiss, Pearson Education, 2012.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	0	3	1	3	2	2	1	2
CO 2	3	0	3	1	3	2	3	1	2
CO 3	3	0	3	1	2	2	3	1	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT2FM106(1)				
Course Title	**GRAPH THEORY AND LPP.**				
Type of Course	**MDC**				
Semester	II				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Basic Arithmetic and Geometry.				
Course Summary	The course "Graph Theory and Linear Programming" introduces fundamental concepts in graph theory focusing initially on graph definitions, properties, and structures such as vertex degrees, subgraphs, paths, and cycles. The discussion extends to trees, bridges, spanning trees, cut vertices, and connectivity, emphasizing essential properties and theorems while providing proofs for brevity. Transitioning to linear programming, the course employs graphical methods for solving linear inequalities and optimization problems, progressing to the simplex method for more complex maximization and minimization problems, including duality and nonstandard scenarios. Additionally, the syllabus offers open-ended exploration into graph modellingmixture, matrix representations, and connector problems.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand and apply the fundamental concepts in graph theory.	U	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO2	Analyse properties of graphs and trees.	An	P	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO3	Solve linear programming problems by geometrically and Simplex method.	Ap	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Texts:
1. John Clark & Derek Allan Holton, A First Look at Graph Theory: Allied Publishers, First Indian Reprint 1995.
2. Margaret L. Lial, Raymond N, Finite Mathematics and Calculus with Applications 9/e, Greenwell & Nathan P. Ritchey Pearson Education, Inc, ISBN 0-321-74908-1, 2012.

Module	Unit	Content	Hrs (36 +9)	Ext. Marks (50)
I		**Basics of Graph Theory (from text 1)**	**9**	**Min 10**
	1	Section 1.1 - Definition of a graph.		
	2	Section 1.3 - More definitions.		
	3	Section 1.4 - Vertex degrees.		
	4	Section 1.5 - Sub Graphs.		
	5	Section 1.6 - Paths and Cycles (Theorem 1.4 statement only).		
II		**Basics of Graph Theory From Text 1**	**9**	**Min 10**
	6	Section 2.1 - Definitions and Simple Properties of trees (Proof of Theorem 2.1, 2.2 and 2.4 omitted).		
	7	Section 2.2 - Bridges: up to and including Theorem 2.8 (Theorem 2.6 and 2.7 are statement only).		
	8	Section 2.2 - Bridges (Theorem 2.9 statement only) contd.		
	9	Section 2.3 - Spanning trees (Theorem 2.12 statement only).		
	10	Section 2.6 - Cut Vertices and Connectivity (Theorem 2.20 and Theorem 2.21 are statements only).		
III		**Linear Programming - The Graphical Method From Text 2**	**9**	**Min 10**
	11	Section 3.1 - Graphing Linear Inequalities.		
	12	Section 3.2 - Solving Linear Programming Problems Graphically; up to and including Example 2.		
	13	Section 3.2 - Solving Linear Programming Problems Graphically contd.		

	14	Section 3.3 - Applications of Linear Programming; up to and including Example 2.		
	15	Section 3.3 - Applications of Linear Programming contd.		
IV	**Linear Programming - The Simplex Method** (from text 2)		**9**	**Min 10**
	16	Section 4.1- Slack Variables and the Pivot.		
	17	Section 4.2- Maximization Problems.		
	18	Section 4.3- Minimization Problems; Duality.		
	19	Section 4.4- Nonstandard Problems.		
V	**Open Ended**		**9**	
	Graphs as models, Matrix representation of graphs, Connector problems (for instance refer sections from 1.2, 1.7 and 2.4 of Text 1).			

References:

1. Introduction to Graph Theory, 4th ed., R.J. Wilson, LPE, Pearson Education, 1996.
2. Graph Theory with Applications, J .A. Bondy & U.S.R. Murty, North-Holland,1982
3. Linear Programming: Foundations and Extensions, 2/e, Robert J. Vanderbei, Springer Science+Business Media LLC, 2001.
4. An Introduction to Linear Programming and Game Theory (3/e), Paul R. Thie and G. E. Keough, John Wiley and Sons, 2008.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	3	2	3	1	2
CO 2	3	2	3	1	3	2	3	1	2
CO 3	3	2	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT1FM105(2)				
Course Title	**MATHEMATICS FOR COMPETITIVE EXAMINATIONS - PART I**				
Type of Course	**MDC**				
Semester	I				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Basic Arithmetic and Computational Skill				
Course Summary	The course is designed to equip students with essential arithmetic and problem-solving skills required for competitive exams. It covers topics ranging from fundamental arithmetic operations such as number systems, fractions, and roots to more advanced concepts like financial mathematics, time-speed-distance calculations, and problem-solving techniques..				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply mathematical methods to solve problems	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply numerical skills in competitive examinations	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Manage time in competitive examinations.	C	M	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (36+ 9)	Ext. Marks (50)
I		**Fundamentals of Arithmetic**	**9**	**Min 10**
	1	Number System		
	2	Number Series		
	3	Simple and Decimal Fractions		
	4	HCF and LCM		
	5	Square root and Cube root		
II		**Basic Arithmetic Operations**	**9**	**Min 10**
	6	Simplification		
	7	Average		
	8	Ratio and Proportion		
	9	Problems based on ages		
	10	Percentage		
III		**Financial Mathematics**	**9**	**Min 10**
	11	Profit and Loss		
	12	Discount		
	13	Simple Interest		
	14	Compound Interest		
	15	Work and Time		
IV		**Time, Speed, and Distance**	**9**	**Min 10**
	16	Speed, Time and Distance		
	17	Problems based on trains		
	18	Boats and Streams		
	19	Clock and Calendar		

V	**Open Ended**	**9**	
	Mixture or Allegation, Partnership, Pipes and Cisterns		

References: 1. Fast Track Objective Arithmetic, Rajesh Verma, Arihant Publications India limited, 2018 (Primary Reference).
2. Objective Arithmetic for Competitive Examinations, Dinesh Khattar, Pearson Education, 2020.
3. Quicker Objective Arithmetic, Dr Lal, Jain, Upkar's publication, 2010.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	0	3	2	3	2	3	1	2
CO 2	2	0	3	1	3	2	3	1	2
CO 3	2	0	2	2	2	2	2	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT2FM106(2)				
Course Title	**MATHEMATICS FOR COMPETITIVE EXAMINATIONS - PART II**				
Type of Course	**MDC**				
Semester	II				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Basic Arithmetic and Computational Skill				
Course Summary	The course "Mathematics for Competitive Examinations - Part II" is designed to prepare students for competitive exams by focusing on various reasoning and problem-solving skills. It covers a range of topics including non-verbal reasoning, verbal reasoning, spatial reasoning, and abstract reasoning, each module addressing different aspects of these skill sets.				

Course Outcomes (CO):

CO	**CO Statement**	**Cognitive Level***	**Knowledge Category#**	**Evaluation Tools used**
CO1	Apply mathematical methods to solve problems	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Understand the basic concepts of logical reasoning Skills	U	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Manage time in competitive examinations	C	M	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (36+ 9)	Ex Marks (50)
		Non-Verbal Reasoning		
I	1	Similarity of Pairs	**9**	**Min 10**
	2	What come Next		
	3	Odd One out		
	4	Coding and Decoding		
	5	Ranking Test		
II	**Reasoning Contd.**		**9**	**Min 10**
	6	Blood relations		
	7	Blood relations Contd.		
	8	Direction Sense Test		
	9	Direction Sense Test contd.		
	10	Logical Venn Diagram		
III	**Spatial Reasoning**		**9**	**Min 10**
	11	Figure analogy		
	12	Figure series		
	13	Figure Classification		
	14	Mirror and Water Images		
	15	Counting of figures		
IV	**Abstract Reasoning**		**9**	**Min 10**
	16	Cube and Dice		
	17	Logical and Analytical Reasoning		
	18	Geometry mensuration		
	19	Data Interpretation		
V	**Open Ended**			

	Alphabet and Number Sequence Test, Paper folding and paper cutting	**9**	

References:

1. A Fast Track Course in MENTAL ABILITY, Amogh Goel, Arihant Publications India limited, 2016. (Primary Reference).
2. The Mental Ability, Logical Reasoning & Problem-Solving Compendium for IAS Prelims General Studies Paper 2 & State PSC Exams, Disha Experts, Disha Publications, 2018.
3. The Pearson Guide to Verbal Ability and Logical Reasoning for the CAT, Nishit K. Sinha, Pearson Education, 2014.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	2	1	2	0	1	1	0
CO 2	2	0	2	1	2	0	1	1	0
CO 3	0	1	2	1	2	0	1	1	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

SKILL ENHANCEMENT COURSES

(SEC)

Programme	B. Sc. Mathematics Honours				
Course Title	**MATHEMATICAL TYPE SETTING SYSTEM - LATEX**				
Course Code	MAT5FS112				
Type of Course	**SEC**				
Semester	V				
Academic Level	300-399				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	1. Fundamental Mathematics Concepts				
Course Summary	The course will cover topics such as document formatting, mathematical typesetting, graphics and tables, bibliography management, beamer presentation and understanding the Indian language transliteration package for typesetting Sanskrit or Hindi or Malayalam using LaTeX.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Preparing a LaTex document with title page including contents, references and index	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
CO2	To Display documents with bullets, numbering and aligning or ordering and adding rows and tables	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
CO3	Use mathematical typesetting and equation environments to create professional looking equations and mathematical notation	U	F	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Text 1: LATEX TUTORIAL, A PRIMER by Indian TEX Users Group, Edited by E. Krishnan, 2003. Text 2: George Gratzer, More Math Into LaTeX-Springer 2016 (5th Edition),			
Module	**Unit**	**Content**	**Hrs (36+ 9)**	**Ex. Marks (50)**
I		**Getting Started with LaTeX (Text-1)**	**8**	**Min 10**
	1	The basics- Tutorial I		
	2	The documents – Tutorial II		
	3	Bibliographic Database- Tutorial III & IV		
	4	Table of contents and Index- Tutorial V(Omit glossary)		
II		**Styling Pages**	**6**	**Min 10**
	5	Displayed Text – Tutorial VI		
	6	Rows and columns – Tutorial VII		
	7	Tables – Tutorial VII .2		
III		**Typesetting Mathematics**	**10**	**Min 10**
	8	Basic Mathematical equation- Tutorial VIII.1, VIII.2		
	9	Groups of Equations and numbering – Tutorial VIII.3		
	10	Matrices, dots, delimiters and affixing symbols- Tutorial VIII.4		
	11	Operators, Equations, Symbols, notations, Greek letters etc. Tutorial VIII.5, VIII.6, VIII.7, VIII.8(In VIII.8 focus only on usual symbols, Greek letters, operations etc. commonly used in mathematics)		
IV		**Theorems, figures, Cross references and Presentation(Text-1 and 2)**	**12**	**Min 10**
	12	Theorem in Latex – Tutorial IX.1		
	13	The AMS theorem package- Tutorial IX.2 (Omit IX.2.2 , IX.2.3)		
	14	Boxes – Tutorial X (Section X.1 , X.2 Only)		

	15	Floating Images- Tutorial XI (Section XI.I.I , XI.I.2 and XI.I.5 Only)		
	16	Cross Reference – Tutorial XII (Section XII.1, XII.2 Only)		
	17	Footnotes- Tutorial XIII (Section XIII.1 Only)		
	18	Presentation – Text 2, Section 12.1 to 12.2.4		
	19	Presentation – Text 2, Section 12.2.6 to 12.2.9 (Omit 12.2.5 and 12.2.7)		
V	**Open Ended**		**9**	
	1	Installation of LaTeX		
	2	Familiarising Overleaf Platform		
	3	Write a chapter in a book that you are studying in any semester having mathematical symbol theorems and figures.		
	4	Create Slides with beamers and posters		
	5	Transliteration symbols with Illustrative examples of the Indian Languages, such as Sanskrit, Hindi (Devanagari) and Malayalam.		

References:

1) Tobias Oetiker, Hubert Partl, Irene Hyna and Elisabeth Schlegl, The Not So Short Introduction to LATEX 2ε (Online Link:- The Not So Short Introduction to LaTeX (oetiker.ch))
2) Harvey J. Greenberg, A simplified introduction to LaTeX (Online version)
3) Leslie Lamport (second edition. Addison Wiley,1994)- LaTeX, a Document Preparation System.
4) Donald Knuth (Addison-Wesley, 1984), The TeX book
5) Frank Mittelbach and Michel Goossens (second edition), Addison-Wesley, 2004).

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1	0	1	1	2	2	1	0	2	3	0
CO 2	2	3	1	0	1	1	1	3	1	0	2	3	0
CO 3	3	2	1	0	1	1	2	1	1	0	2	2	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT6FS113				
Course Title	**DATA SCIENCE WITH PYTHON**				
Type of Course	**SEC**				
Semester	VI				
Academic Level	300 - 399				
Course Details	Credit	Lecture per week	Tutorial per week	Practical per week	Total Hours
	3	3	-	0	60
Pre-requisites	A basic course in Python programming with the understanding of using looping, conditionals, creating variables, writing functions, and importing modules.				
Course Summary	This course is an advanced course for those who have learned the basics of Python. It will enable the students to learn more features of Python with a specific focus on how to use them to analyse data and arrive at conclusions in practical situations with the help of a reasonable knowledge of statistics.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Learn to rearrange and manipulate various data structures in Python to make it more meaningful	U	F	Internal Exam/ Assignments / End Semester Examination
CO2	Understand fundamentals of Statistics from a real life point of view	U	F	Internal Exam/ Assignments / Quiz / End Semester Examination
CO3	Learn how to visualise data for clearer understanding of practical situations	Ap	C	Internal Exam / Quiz / End Semester Examination
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Note : Python IDLE (with necessary modules like pandas, scipy), Anaconda/Spyder package, Jupyter notebook interface or Google colab (free to use) interface, Pydroid 3 for android (along with Pydroid repository plugin) can be used for training purposes. Python version 3.10 or above should be used to avoid errors with some of the functionalities we discuss in the course.

Textbook	1 Mastering Python for Data Science, Samir Madhavan, PACKT Publishing, 2015 2 Data Science from Scratch, Second Edition ,Joel Grus, O'Reilly, 2019			
Module	**Unit**	**Content**	**Hrs (36+ 9)**	**Ext. Marks (50)**
I	**Python Tools for Handling and Manipulating Data (Text 2, Chapter 2)**		**8**	**Min 10**
	1	Exceptions, Lists.		
	2	Tuples, Dictionaries.		
	3	Counters, Sets, List Comprehensions,		
	4	Truthiness, Automated Testing and assert Iterables and Generators		
	5	Randomness, Regular Expressions, zip and Argument Unpacking		
II	**More Tools for Data Handling – Numpy and Pandas (Text 1, Chapter 1)**		**8**	**Min 10**
	6	NumPy: Mathematical operations, Array subtraction, squaring an array, A trigonometric function performed on the array, Conditional operations.		
	7	NumPy : Matrix multiplication, Indexing and slicing, Shape manipulation.		

	8	Pandas : Inserting and exporting data, CSV, Data cleansing, Checking the missing data.		
	9	Pandas : Filling the missing data, String operations, Merging data		
	10	Data operations: Aggregation operations, Joins, The inner join		
	11	Data operations: The left outer join, The full outer join, The groupby function		
III		**Inferential Statistics** **(Text 1, Chapter 2)**	**12**	**Min 10**
	12	Various forms of distribution, A normal distribution, A normal distribution from a binomial distribution.		
	13	A Poisson distribution, A Bernoulli distribution.		
	14	A z-score, A p-value, One-tailed and two-tailed tests.		
	15	Type 1 and Type 2 errors, confidence interval.		
	16	Correlation, Z-test vs T-test, The F distribution.		
	17	The chi-square distribution, Chi-square for the goodness of fit, The chi-square test of independence, ANOVA.		
IV		**Applying the Theory to Problems** **(Text 1, Chapter 3)**	**8**	**Min 10**
	18	What is data mining? Presenting an analysis.		
	19	Studying the Titanic – with all the required analysis		
V		**Open Ended** **Visualizing Data** **(Text 1, Chapter 4)**	**10**	
	1	Making Sense of Data through Advanced Visualization - Controlling the line properties of a chart		

	2	Using keyword arguments, Using the setter methods, Using the setp() command.		
	3	Creating multiple plots, Playing with text, Styling your plots.		
	4	Box plots, Heatmaps, Scatter plots with histograms.		
	5	A scatter plot matrix, Area plots.		
References	1 Thomas Nield, Essential Math for Data Science - Take Control of Your Data with Fundamental Linear Algebra, Probability, and Statistics, O'Reilly Media, 2022 2 Wes McKinney, Python for Data Analysis_ Data Wrangling with pandas, NumPy, and Jupyter-O'Reilly Media, Third Edition, 2022 3 Fabio Nelli, Python Data Analytics- With Pandas, NumPy, and Matplotlib, Apress, Second Edition, 2018 4 https://www.kaggle.com/datasets/yasserh/titanic-dataset 5 https://www.w3schools.com/datascience/ds_python.asp 6 https://realpython.com/python-for-data-analysis/ 7 https://www.geeksforgeeks.org/data-science-with-python-tutorial/ 8 https://learn.microsoft.com/en-us/training/modules/explore-analyze-data-with-python/1-introduction 9 https://onlinecourses.nptel.ac.in/noc24_cs54/preview 10 https://onlinecourses.nptel.ac.in/noc20_cs46/preview			

Note: For detailed understanding of the topics given in Module II, additional reference 1 can also be used, though it is not very essential.

Roadmap:

Being a practice-oriented course, the teachers may introduce the students to more problems so as to familiarize them with the tools in which they have been trained through this course. Many good examples on how to use these in real life situations can be found in Chapter 13 of additional reference 2 and the URLs provided in the additional references section.

Mapping of COs with PSOs and POs :

	PSO 1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	3	3	1	3	2	3	3	1	1	1
CO 2	3	2	3	2	3	2	1	1	1	1	1
CO 3	3	2	2	1	3	1	3	3	1	-	1

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Quiz	End Semester Examinations
CO 1	√	√		√
CO 2	√	√	√	√
CO 3	√		√	√

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Internal Exam
- Assignment
- Quiz
- End Semester Examinations

VALUE-ADDED COURSES

(VAC)

Programme	B. Sc. Mathematics Honours				
Course Code	MAT3FV109(1)				
Course Title	**HISTORY OF MATHEMATICS**				
Type of Course	**VAC**				
Semester	III				
Academic Level	200 - 299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Aptitude for Mathematics and its History.				
Course Summary	The course goes into the philosophy of mathematics, modern axiom methods, controversies in set theory around axiom of choice, its implications and various philosophical alternative approaches to the foundations of mathematics.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse Key Mathematical Theorems and Concepts from Ancient to Early Modern Times	An	C	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
CO2	Evaluate and Compare Methods of Addressing Infinity and Large Cardinal Numbers	E	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Ensure students gain a comprehensive understanding of the historical development and foundational concepts of mathematics	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Mathematics & Its History, 3rd Edition, John Stillwell, Springer (2010) ISBN: 978-1-4419-6052-8.			
Module	**Unit**	**Content**	**Hrs (36+9)**	**Ext. Marks (50)**
I	**Ancient Origins & Foundations**		**9**	**Min 10**
	Quick Review of Ancient Mathematics			
	1	Chapter 1: Pythagoras Theorem		
	2	Chapter 2: Greek Geometry		
	3	Chapter 3: Greek Number Theory		
	Infinity in Greek Mathematics – Chapter 4			
	4	Section 4.1, 4.2-Fear of Infinity, Eudoxus' Theory of Proportions		
	5	Section – 4.3, 4.4-The Method of Exhaustion, Area of a Parabolic Segment		
	Sets & Logic – Chapter 24			
	6	Sections 24.1, 24.2, 24.4- Sets, Ordinals, Axiom of Choice & Large Cardinals		
	7	Section 24.3- Measure		
	8	Section 24.5-The Diagonal Argument		
	Biographical Notes: Pythagoras, Euclid, Diophantus, Archimedes			
II	**Calculus – Chapter 9**		**9**	**Min 10**
	9	Section 9.1, 9.2-What is Calculus, Early Results on Areas & Volumes		
	10	Section 9.3-Maxima, Minima & Tangents		
	11	Section 9.4-The *Arithemetica Infinitorum* of Wallis		
	12	Section 9.5-Newton's Calculus of Series		
	13	Section 9.6-The Calculus of Leibnitz		

		Biographical Notes: Wallis, Newton & Leibnitz		
III		**Algebraic Equations & Numbers**	**9**	**Min 10**
		Polynomial Equations – Chapter 6		
	14	Section 6.1, 6.2- Algebra, Linear Equations & Elimination		
	15	Section 6.3, 6.4 Quadratic Equations, Quadratic Irrationals		
	16	Section 6.5-The Solution of the Cubic		
	17	Section 6.6-Angle Division		
	18	Section 6.7-Higher Degree Equations		
		Biographical Notes: Tartaglia, Cardano & Viete		
		Complex Numbers – Chapter 14		
	19	Section 14.1, 14.2, 14.3- Impossible Numbers, Quadratic & Cubic Equations		
	20	Section 14.4- Wallis' Attempt at Geometric Representation		
	21	Section 14.5, 14.6- The Fundamental Theorem of Algebra, The Proofs of d'Alembert & Gauss		
		Biographical Notes: d'Alembert		
IV		**Topology – Chapter 22**	**10**	**Min 10**
	22	Section 22.1, 22.2- Geometry & Topology, Polyhedron Formulas of Descartes & Euler		
	23	Section 22.3-The Classification of Surfaces		
	24	Section 22.4- Descartes & Gauss-Bonnet		
	25	Section Euler 22.5-Characteristic & Curvature		
	26	Section 22.7, 22.8- The Fundamental Group, The Poincare Conjecture		
		Biographical Notes: Poincare		
V		**Open Ended Module**	**9**	
	1	Hypercomplex Numbers – Chapter 20		

	2	Number Theory in Asia – Chapter 5		
	3	Mechanics – Chapter 13		
	4	Complex Numbers & Functions – Chapter 16		
	5	Non-Euclidean Geometry – Chapter 18		
	6	Group Theory – Chapter 19		

References:

1. Mathematics, The Queen & Handmaiden of Sciences, E. T. Bell, McGraw Hill.
2. Men of Mathematics, E. T. Bell, Simon & Schuster, 1986.
3. What is Mathematics?, Richard Courant & Herbert Robbins,
4. History of Mathematics, 7^{th} Edition, David M. Burton, McGraw Hill.
5. Mathematics In India, Kim Plofker, Princeton University Press, 2009.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	1	0	3	2	2	0	3	2	1
CO 2	3	2	1	0	2	1	2	0	2	1	0
CO 3	1	1	0	0	3	2	2	0	3	2	1

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT3FV109(2)				
Course Title	**COMPUTATIONAL LOGIC**				
Type of Course	**VAC**				
Semester	III				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	Nil				
Course Summary	The course will cover the basics of propositional and predicate logic, Compactness, and the Resolution Theory.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Determine the Satisfiability of a Propositional Formula Set.	Ap	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO2	Analyse Theorems of Propositional Logic	Ap	C	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
CO5	Remember Proofs of Major Theorems of Logic	An	M	Internal Exam/Assignment / Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text book	Logic for Computer Scientists, U. Schoning, Birkhauser, 2008 (Reprint).			
Module	**Unit**	**Content**	**Hrs (45 = 36 +9)**	**Ext. Marks (50)**
I	**Propositional Logic (Chapter 1 of Text Book).**		**10**	**Min 10**
	1	Syntax and Semantics, Truth Tables, Satisfiability and Validity.		
	2	Equivalence and Normal Forms, Substitution Theorem		
	3	DNF and CNF forms		
	4	Horn Formulas,		
	5	Compactness Theorem for Propositional Calculus		
	6	Resolution Theorem and Resolution Algorithm		
II	**Introduction to Predicate Logic: Section 2.1, 2.2,** Subsection on Mathematical Theories of Section 2.3		**9**	**Min 10**
	7	Syntax of Predicate Logic		
	8	Semantics - Structures and Models, Satisfiability and Validity		
	9	Equivalence of formulas - Substitution, Variable Renaming.		
	10	Skolem Normal Form		
	11	Mathematical Theories - Axioms and Models.		
III	**Herbrand Theory for Predicate Logic: Section 2.4**		**9**	**Min 10**
	12	Herbrand Universe and Structures		
	13	Herbrand Model and Satisfiability Theorem		
	14	Skolem Lowenheim Theorem		
	15	Herbrand Expansion and Godel-Herbrand-Skolem Theorem		
	16	Compactness and Herbrand's Theorem		
IV	**Resolution for Predicate Logic: Section 2.5**			

	17	Ground Resolution and Resolvants	**8**	**Min 10**
	18	Ground Resolution Theorem		
	19	Robinson's Unification Theorem and Algorithm		
	20	Lifting Lemma		
	21	Resolution Theorem for Predicate Logic		
V	**Logic Programming**			
	1	Unsolvability of Predicate Logic (Section 2.3 on Text Book)	**9**	
	2	SLD Resolution (Section 2.6 of Text Book)		
	3	Introduction to Logic Programming		
	4	Horn Clause Programs		
	5	Evaluation Strategies for Horn Clause Programs.		

References:

1. J. H. Gallier, Logic for Computer Science - Foundations of Automatic Theorem Proving, Dower, 2015.
2. S. Reeves, M Clarke, Logic for Computer Science, Addition Wesley, 1990. coding

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	1	0	3	2	2	0	3	2	1
CO 2	3	2	1	0	2	1	2	0	2	1	0
CO 3	1	1	0	0	3	2	2	0	3	2	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT4FV110(1)				
Course Title	**STATISTICS AND MATHEMATICS WITH R**				
Type of Course	**VAC**				
Semester	IV				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours	
	3	3	-	45	
Pre-requisites	1. Basic School (+2) Level Statistics 2. Basic Programming Experience				
Course Summary	The "Statistics and Mathematics with R" course is designed to provide an understanding of R programming for statistical analysis and mathematical computation. The curriculum begins with an introduction to R, covering basic features, data storage, and manipulation techniques. Subsequent modules explore graphical visualization, programming constructs such as flow control and functions, and computational linear algebra. Each unit offers hands-on exercises and references to relevant sections in the textbook by Braun and Murdoch, supplemented by further reading materials for deeper exploration. This course helps students with practical skills in utilizing R for statistical analysis and mathematical modeling.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate Proficiency in Basic and Intermediate R Programming	Ap	P	Internal Exam/ Seminar/Assignment / End Sem Exam
CO2	Create and Interpret Various Types of Graphs Using R	C	C	Internal Exam/ Seminar/Assignment / End Sem Exam
CO3	Apply Advanced Mathematical and Statistical Functions in R	Ap	P	Internal Exam/ Seminar/Assignment / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	A First Course in Statistical Programming with R, , W. John Braun and Duncan J. Murdoch, Cambridge University Press, 3rd Ed., 2021, ISBN 978-1-108-99514-6.			
Module	**Unit**	**Content**	**Hrs (36+9)**	**External Marks (50)**
I		**Introduction to R**	**12**	**Min 10**
	1	R Studio. R Command Line. R as calculator. Named Storage. Quitting R.		
	2	Basic Features of R.		
	3	Vectors in R.		
	4	Data Storage in R. Packages,		
	5	Libraries and Repositories.		
	6	Getting Help. Useful Features of R.		
	7	Data Frames, tibbles, and lists		
	8	Data Input and Output		
	Reference: Chapter 2, Sections 1 to 10			
II		**Graphics with R**	**4**	**Min 10**
	9	Bar Charts and Dot Charts. Pie Charts.		
	10	Histograms. Box Plots. Scatter Plots.		
	11	Plotting from Data Frames. Quantiles. QQ Plots.		
	Reference: Section 3.1.			
III		**Programming in R**	**13**	**Min 10**
	12	Flow Control. For Loop. Examples 4.1 to 4.4.		
	13	If Statement. Examples.		
	14	Eratosthenes Sieve.		
	15	While Loop. Examples. Newton’s Method.		

	16	Repeat loop. Break and Next Statements. Examples and Exercises.		
	17	Functions.		
	18	General Programming Guidelines		
	Reference: Chapter 4, Sections 1-4.			
IV	**Computational Linear Algebra**		**7**	**Min 10**
	21	Vectors and Matrices in R		
	12	Matrix Multiplication and Inversion		
	19	Eigenvalues and Eigenvectors		
	20	Singular Value Decomposition		
	Reference: Sections 7.1, 7.2, 7.3, 7.4.1.			
V	**OPEN ENDED**		**9**	
	Suggestions: Section 3.2 - 3.4: Higher Level Graphics with ggplot Section 4.6: Debugging and Maintenance Section 4.7: Efficient Algorithms. Section 6.1: Monte Carlo, 6.2: Pseudo-Random Numbers Appendix A: Overview of Random Variables and Distributions Section 6.3: Simulation of Random Variables Section 8.3: Newton-Raphson Section 8.5: Linear Programming			
Reference	1. Roger D. Peng, R Programming for Data Science, LeanPub, 2022, ISBN 9781365056826. https://bookdown.org/rdpeng/rprogdatascience/ 2. Garrett Grolemund, Hands-On Programming with R, O'Reilly, 2014, ISBN 1449359019. https://rstudio-education.github.io/hopr/ 3. Ruriko Yoshida, Linear Algebra and its Applications in R, Chapman and Hall, 2021, ISBN 9780367486846			

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	2	2	2	2	2	2	1
CO 2	2	3	1	0	2	2	2	2	2	1	1
CO 3	1	1	3	2	2	2	2	2	2	1	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT4FV110(2)				
Course Title	**THE MATHEMATICAL PRACTICES OF MEDIEVAL KERALA**				
Type of Course	**VAC**				
Semester	IV				
Academic Level	200 - 299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	3	3	-	45	
Pre-requisites	1. Fundamental Mathematics Concepts: Number system,Basic Mathematical operations, Plane Geometry. 2. Convergence of series of numbers and functions.				
Course Summary	This course familiarises students with the traditional Indian Mathematics practised in the Medieval Kerala School of Astronomy and Mathematics.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Uncover the underlying fundamental principles of the traditional mathematics practised in medieval Kerala.	U	C	Seminar Presentation/ Group Tutorials
CO2	Appreciate the role of thought process and working rules in mathematics.	U	C	Seminar Presentation/ Group Tutorials
CO3	Appreciate the usage of infinite series in mathematical analysis.	U	C	Seminar Presentation/ Group Tutorials
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book		1. **Lilavati of Bhaskaracarya** Translated by K.S.Patwardhan, S.A.Naimpally and S.L.Singh, Motilal Banarsidass Publishers, Delhi. 2006. 2. **Ganita Yukti Bhasa of Jyesthadeva**. Volume I. English Translation by K.V.Sarma with explanatory notes by K.Ramasubramanian, M.D.Srinivas and M.S.Sriram. Hindustan Book Company, 2008.		
Module	**Unit**	**Content**	**Hours (36 + 9)**	**Ext. Marks (50)**
I		**Measurement of sides and areas of triangles, quadrilaterals and circles.**	**9**	**14**
	1	Computation of sides of a right triangle when one side is given.		
	2	Computation of area of triangles and quadrilaterals.		
	3	Computation of the perpendicular below the intersection of diagonals.		
	4	Approximating the surface area and volume of spheres.		
	5	Computation of sides of polygons inscribed in a circle.		
	6	Computation of the arcs and chords of circles.		
		Chapter 28 from Text I (Treatment based on English translations of Sanskrit verses in Lilavati).		
II		**Rules concerned with Solids, Shadow of Gnomon and Pulverizer.**	**9**	**12**
	7	Volume of Solids		
	8	Volume of a heap of Grain		
	9	Shadows of Gnomon.		
	10	Pulverization		
		Chapters 29, 30, 31, 32 and 33 from Text I (Treatment based on English translations of Sanskrit verses in Lilavati).		
III		**Circle and Circumference as in Yuktibhasa.**	**10**	**14**
	11	Circumference of a circle approximated by regular polygons.		
	12	Circumference of a circle without calculating square roots.		
	13	Circumference of a circle in terms of the hypotenuses.		
	14	Summation of Series.		
	15	Calculation of circumference.		
	16	Conversion of the Rsine to Arc.		
		Sections 6.1 to 6.6 of Chapter 6 from Text II.		
IV		**Sine and Cosine series as in Yuktibhasa.**	**8**	**10**
	17	Some technical terms and derivation of Rsines.		
	18	Computation of Rsines.		
	19	Computation of Jya and Sara by sankalita and accurate circumference.		
		Sections 7.1 to 7.6 of Chapter 7 from Text II.		
V (Open Ended)		**From Ancient Mathematical Rules to Modern Computer Algorithms.**	**9**	
	20	Decoding of important Sanskrit verses discussed in Modules I and II from Lilavati (Text I).		

	21	Decoding of important Sanskrit verses discussed in Modules III and IV from Yuktibhasa (Text II).		
	22	Conversion of selected Rules discussed in Modules I to IV into Computer Algorithms.		
	Relevant Topics from Text I, Text II and References.			

References:

1.The Mathematics of India - Concepts, Methods, Connections. P.P.Divakaran, Hindustan Book Agency, New Delhi, 2018.

2. A Passage to Infinity - Medieval Indian Mathematics from Kerala and its Impact. George Ghevarghese Joseph, Sage Publications, New Delhi, 2009.

3. On an Untapped Source of Medieval Keralese Mathematics. C.T.Rajagopal and M.S.Rangachari, Archive for the History of Exact Sciences, 35 (2), (1986), 91 - 99.

4. Yukthibhasha. Rama Varma Maru Thampuran and A.R.Akhileswara Iyer (Editors)}, Mangalodayam Press, Trichur 1948.

5. Tantrasangraha of Nilakantha Somayaji with Yuktidipika and Laghuvivrti of Sankara. K.V.Sarma, Vishveshvaranand Visva Bandhu Institute of Sanskrit and Indological Studies, Punjab University, Hoshiarpur 1977.

6. Colebrook's translation of the Lilavati with Notes by Haran Chandra Banerji. The Book Company, Calcutta, 1927.

7. Mathematical Treasures – Lilavati of Bhaskara. Frank J.Swetz and Victor J.Katz. Loci. 2011.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1	1	3	2	1	0	2	3	0
CO 2	2	3	1	2	2	3	1	0	2	3	0
CO 3	2	2	2	2	2	1	1	0	2	2	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

VOCATIONAL MINORS

Programme	B. Sc. Mathematics Honours				
Course Code	MAT1VN101				
Course Title	**PYTHON PROGRAMMING**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	I				
Academic Level	100-199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Nil				
Course Summary	Course aims to provide basic programming skills in Python and Python libraries like NumPy etc.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools
CO1	Understand the basics of Python Data structures and Programming constructs	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Understand the basics of Python Programming constructs	U	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply Python Libraries for Data Science and Machine Learning	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Module	Unit	Content	Hrs (45+ 30)	Ext. Marks (70)
1		**Data Types and Data Structures**	10	Min.15
	1	Introduction to Python: - using the Python interpreter, Overview of programming in Python		
	2	Expressions and Variables-String Operations.		
	3	Python Data Structures: lists & Tuple –Sets - Dictionaries		
	4	Programming Fundamentals: Conditions and Branching- Loops		
	5	Functions: formal arguments, variable-length arguments		
II		**Classes, files and modules**	12	Min.15
	6	Introduction to Classes and Objects: -classes, class attributes, instances, instance attributes		
	7	Binding and method invocation, inheritance, polymorphism,		
	8	Built-in functions for classes and instances.		
	9	Files and input/output, reading and writing files		
	10	Methods of file objects, using standard library functions		
	11	Exception Handling		
III		**Introduction to Data Science using Python**	12	Min.15
	12	Python libraries: Numpy- Scikit- Pandas.		
	13	Importing Datasets: Importing and Exporting Data in Python, Basic Insights from Datasets		
	14	Data cleansing and pre-processing: Identify and Handle Missing Values		
	15	Descriptive Statistics		
	16	ANOVA Correlation		

	17	Dealing with Outliers		
IV		**Data Visualization Packages - Matplotlib and Seaborn**	**11**	**Min.15**
	18	Overview of data visualization concepts		
	19	Introduction to Matplotlib and Seaborn		
	20	Basic Plotting and Customization with Matplotlib		
	21	Basic Plotting and Statistical Visualization with Seaborn		
	22	Other Visualization Libraries – Case Studies		
		Practical's	**30**	
	1	a) Write a program to calculate compound interest when principal, rate and number of periods are given b) Read name, address, email and phone number of a person through keyboard and print the details		
	2	Write a program to check whether the given input is digit or lowercase character or uppercase character or a special character (use 'if-else-if' ladder)		
	3	a) Print the below triangle using for loop. 5 4 4 3 3 3 2 2 2 2 1 1 1 1 1 b) Python Program to Print the Fibonacci sequence using while loop		
	4	Python program to print all prime numbers in a given interval (use break)		
	5	Write a function called GCD that takes parameters a and b and returns their greatest common divisor		

	6	Write a function called palindrome that takes a string argument and returns True if it is a palindrome and False otherwise. Remember that you can use the built-in function len to check the length of a string		
	7	Define a new class called Circle with appropriate attributes and instantiate a few Circle objects. Write a function called draw_circle that draws circles on the canvas		
	8	Write a python program that defines a matrix and prints		
	9	Write a python program to perform addition of two square matrices		
	10	Python program to perform read and write operations on a file.		
	11	Use the structure of exception handling all general-purpose exceptions		
	12	Write a Python program that calculates basic statistics measures using NumPy		
	13	Create a CSV file named sales_data.csv, which contains sales data for a company. The file has the following columns: Date, Product, Units Sold, and Revenue. Write a Python program using Pandas to perform the following tasks: a) Read the data from the CSV file into a DataFrame. b) Calculate the total revenue generated by each product. c) Determine the total units sold for each product. d) Find the date with the highest revenue. e) Plot a bar chart showing the total revenue generated by each product.		

	14	Create a CSV file named student_grades.csv, which contains the grades of students in different subjects. The file has the following columns: Student_ID, Maths, Science, English, and History. Write a Python program using Matplotlib to perform the following tasks: a) Read the data from the CSV file into a DataFrame. b) Calculate the average score for each subject. c) Plot a bar chart showing the average scores for each subject. d) Plot a histogram showing the distribution of scores in Maths.		
	15	Visualizing Titanic Dataset You are given a dataset containing information about passengers on the Titanic, including their survival status, age, sex, class, and fare. Write a Python program using Seaborn to perform the following tasks: a) Load the Titanic dataset into a DataFrame. b) Plot a count plot to visualize the number of passengers in each class. c) Plot a bar plot to visualize the survival rate of passengers based on their class and sex. d) Plot a heatmap to visualize the correlation matrix of numerical features (e.g., age, fare, and survival status).		

References:

1. Core Python Programming by Wesley J. Chun, 2nd Edition , Pearson Education.
2. An Introduction to Python by Guido Van Russom, Fred L.Drake, Network Theory Limited.
3. Python for Data Science, Dr. Mohd. Abdul Hameed, Wiley Publications - 1st Ed. 2021
4. Python Programming: A Modern Approach, Vamsi Kurama, Pearson
5. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython ,2nd edition, Wes McKinney, O'Reilly Media (2017)

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	3	3	2	1	2
CO 2	2	1	3	1	3	3	2	1	2
CO 3	3	2	3	2	3	3	3	1	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT2VN101				
Course Title	**LINEAR ALGEBRA FOR MACHINE LEARNING**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	II				
Academic Level	100-199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Foundations in Mathematics				
Course Summary	Course aims to provide basics of linear algebra which is useful in understanding machine learning problems				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Solve system of linear equations	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply vector spaces and its properties	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Understand basics of matrix algebra and its applications	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Introduction to Linear Algebra" by Gilbert Strang, Wellesley-Cambridge Press, 2016, ISBN: 978-0980232776			
Module	**Unit**	**Content**	**Hrs (45+ 30)**	**Marks (70)**
I		**Solving Linear Equations**	**12**	**Min.15**
	1	Vectors and Linear Equation		
	2	The Idea of Elimination		
	3	Elimination Using Matrices		
	4	Rules for Matrix Operations		
	5	Inverse Matrices		
	6	Elimination = Factorization: A = L U		
	7	Transposes and Permutations		
II		**Vector Spaces and Subspaces**	**12**	**Min.15**
	8	Spaces of Vectors		
	9	The Nullspace of A: Solving Ax = 0		
	10	The Rank and the Row Reduced Form		
	11	The Complete Solution to Ax = b		
	12	Independence, Basis and Dimension		
	13	Dimensions of the Four Subspaces		
III		**Orthogonality**	**8**	**Min.15**
	14	Orthogonality of the Four Subspaces		
	15	Projections		
	16	Least Squares Approximations		
	17	Orthogonal Bases and Gram-Schmidt		
IV		**Eigenvalues and Eigenvectors**	**13**	**Min.15**
	18	Introduction to Eigenvalues		
	19	Diagonalizing a Matrix		
	20	Symmetric Matrices		

	21	Positive Definite Matrices		
	22	Similar Matrices		
	23	Singular Value Decomposition (SVD)		
		Practical using Python	**30**	
	1	Write Python function for vector operations: addition, scalar multiplication, norm,		
	2	Write Python function for matrix operations: addition, multiplication, inverse, transpose		
	3	Implement a Python function to solve a system of linear equations using NumPy's linear algebra module.		
	4	Implement matrix factorization techniques such as LU decomposition in Python using NumPy		
	5	Write a Python function to check if a set of vectors forms a vector space. And to determine if a set of vectors forms a subspace of a given vector space.		
	6	Write a Python function to find the basis of the column space, null space of a matrix, to calculate the rank, dimension of a matrix using NumPy,		
	7	Write a function to determine if a set of vectors is linearly independent, to find the span of a set of vectors. and to check if a set of vectors forms a basis for a given vector space.		
	8	Create a function to determine if two given vectors are orthogonal to each other and to calculate the projection of one vector onto another vector.		
	9	Use orthogonalization to find the least squares approximation of a vector that does not lie in the span of a given set of vectors.		
	10	Implement the Gram-Schmidt process in Python to orthogonalize a given set of vectors and to orthogonalize columns of a given matrix		
	11	Implement a function to perform a change of basis operation on a given vector.		
	12	Write a Python script to verify the rank-nullity theorem by computing the rank and nullity of a matrix and		

		comparing with the dimensions of its domain and codomain.		
	13	Write a Python function to compute the eigenvalues and eigenvectors of a square matrix using SciPy.		
	14	Write a Python function to check if a given square matrix is diagonalizable, to diagonalize a matrix using its eigenvectors and eigenvalues.		
	15	Write a Python function to compute the singular value decomposition of a matrix using NumPy, Use Singular Value Decomposition (SVD) to find the rank and dimension of a matrix, and discuss how it can be used for dimensionality reduction.		
		Reference		
	1	"Linear Algebra and Its Applications" by David C. Lay, Steven R. Lay, and Judi J. McDonald, Pearson, 2020,ISBN: 978-0134860244		
	2	Linear Algebra: Concepts and Applications" by Charles R. Johnson and Dean E. Riess, Wiley, 2017,ISBN: 978-1118612596		
	3	Linear Algebra: A Modern Introduction" by David Poole, Cengage Learning, 2016, ISBN: 978-1305658004		
	4	Linear Algebra for Machine Learning" by Jason Brownlee, Machine Learning Mastery, 2021		
	5	Numerical Python: Scientific Computing and Data Science Applications with Numpy, SciPy, and Matplotlib" by Robert Johansson, Apress, 2018, ISBN: 978-1484242452		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	2	2	3	1	1
CO 2	3	2	3	1	2	2	3	1	1
CO 3	3	3	3	1	2	2	3	1	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT3VN201				
Course Title	**INTRODUCTION TO MACHINE LEARNING**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	III				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Minor 1, Minor 2 (Code)				
Course Summary	Course aims to provide basic concepts of machine learning including paradigms of supervised, unsupervised and reinforcement learning.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Machine Learning concepts and basic parameter estimation methods.	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Distinguish between Supervised, Unsupervised and semi supervised learning and evaluate the performance measures	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply the algorithms identifying problem situations	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Introduction to Machine Learning**	10	Min.15
	1	Introduction: Machine Learning - Machine Learning Foundations		
	2	Machine Learning Paradigms- Supervised, Unsupervised, Reinforcement		
	3	Applications of Machine Learning, Case studies		
	4	Basics of parameter estimation - maximum likelihood estimation (MLE) and maximum a posteriori Estimation (MAP).		
	5	Introduction to Bayesian formulation.		
II		**Supervised Learning & SVM**	14	Min.15
	6	Regression – Simple Linear regression and Multiple Linear Regression		
	7	Gradient Descent algorithm and Matrix method, Overfitting in regression.		
	8	Methods for Classification- Logistic regression, Naive Bayes, Decision tree algorithm- ID3		
	9	SVM - Introduction, Maximum Margin Classification, Mathematics behind Maximum Margin Classification		
	10	Maximum Margin linear separators, soft margin SVM classifier, non-linear SVM		
	11	Kernels for learning non-linear functions, polynomial kernel, Radial Basis Function (RBF)		
		Performance Measures & Unsupervised Learning		
	12	Regression Evaluation Metrics – Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), R-squared (Coefficient of Determination)		

III	13	Classification Evaluation Metrics - Precision, Recall, Accuracy, F-Measure, Receiver Operating Characteristic Curve (ROC), Area Under Curve (AUC)	11	Min.15
	14	Bootstrapping, Cross Validation, Ensemble methods, Bias-Variance decomposition.		
	15	Clustering - Similarity measures, Hierarchical Agglomerative Clustering, K-means partitional clustering		
	16	Expectation maximization (EM) for soft clustering		
	17	Dimensionality reduction –Principal Component Analysis, t-Distributed Stochastic Neighbour Embedding (t-SNE)		
IV		**Introduction to Advanced Machine Learning**	10	Min.15
	18	Introduction to Reinforcement Learning, Learning Task		
	19	Learning Models for Reinforcement – (Markov Decision process, Q Learning - Q Learning function, Q Learning Algorithm), Application of Reinforcement Learning		
	20	Introduction to Neural Network, Perceptron, Multilayer feed forward network,		
	21	Activation functions (Sigmoid, ReLU, Tanh), Back - propagation algorithm.		
	22	Case Study: Applying Reinforcement Learning in Autonomous Vehicle Navigation Case Study: Predicting Customer Churn in Telecommunications Industry using Neural Networks		
		Practical's	30	
	1	Create a dataset containing measurements of the heights of students in a class. Estimate the parameters of a normal distribution that best describes the distribution of heights using Maximum Likelihood Estimation (MLE)		

	2	The probability that it is Friday and that a student is absent is 3 %. Since there are 5 school days in a week, the probability that it is Friday is 20 %. What is the probability that a student is absent given that today is Friday? Apply Baye's rule in python to get the result		
	3	Implement Simple Linear regression using python		
	4	Implement Multiple Linear regression using python		
	5	Implement the Logistic regression algorithm		
	6	Write a program to implement the naïve Bayesian classifier for a sample training data set stored as a .CSV file. Compute the accuracy of the classifier, considering few test data sets		
	7	Write a program to demonstrate the working of the decision tree based ID3 algorithm. Use an appropriate data set for building the decision tree and apply this knowledge to classify a new sample.		
	8	Create a dataset containing information about the prices of houses in a certain city. The dataset includes various features such as the size of the house, number of bedrooms, location, and age of the house, as well as the corresponding sale prices. Your task is to build a regression model to predict the sale price of houses based on their features and evaluate the model's performance using appropriate evaluation metrics (MAE, MSE, RMSE, R-squared)		
	9	Implement the support vector machine algorithm		
	10	Create a dataset containing information about customers of a telecommunications company. The dataset includes features such as customer demographics, service usage, and contract details, as well as a binary target variable indicating whether each customer churned (1) or not (0). Your task is to build a classification model to predict customer churn based on the available features. Evaluate the trained model's performance on the testing data using the following evaluation metrics: Accuracy, Precision, Recall, F1-score and ROC Curve. Use SVM Classification		
	11	Program to implement K-Means clustering Algorithm		

	12	Create dataset containing information about customers of a retail store, including features such as age, income, and spending score. Your task is to perform clustering on the dataset to identify distinct groups of customers based on their purchasing behaviour. Use K-means Algorithm		
	13	Implement Dimensionality reduction using Principal Component Analysis (PCA) method		
	14	Implementing a simple reinforcement learning algorithm		
	15	Create a dataset containing information about patients with diabetes, including features such as age, BMI, blood pressure, and glucose levels, as well as an indication of whether each patient has diabetes or not. Your task is to build a simple neural network classifier to predict whether a patient has diabetes based on their features		
		References		
	1.	M. Gopal, “Applied Machine Learning”, McGraw Hill Education		
	2.	Tom M Mitchell, ―Machine Learning, First Edition, McGraw Hill Education, 2013		
	3.	Machine Learning: A Probabilistic Perspective by Kevin P. Murphy		
	4.	Ethem Alpaydin, Introduction to Machine Learning, 2nd edition, MIT Press 2010.		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	2	3	2	3	1	2
CO 2	2	3	3	2	3	2	3	1	2
CO 3	2	3	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours
Course Code	MAT8VN401
Course Title	**INTRODUCTION TO ARTIFICIAL INTELLIGENCE**
Type of Course	**Vocational Minor – Data Analytics**
Semester	VIII
Academic Level	400-499

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	3	2	75

Pre-requisites	Python Programming, Foundation of Mathematics, Machine Learning
Course Summary	This course on "Introduction to Artificial Intelligence" offers a thorough exploration of AI fundamentals and techniques. Covering topics like representation, search algorithms, and intelligent agents, students' progress to advanced concepts including knowledge representation, neural networks, and practical implementations. With hands-on sessions focusing on algorithm implementation and machine learning models, students gain both theoretical understanding and practical skills essential for AI development.

Course Outcome

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand foundation principles, mathematical tools and program paradigms of AI and Apply problem solving through search for AI applications	U	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO2	Understand formal methods of knowledge representation and Apply logic and reasoning techniques to AI applications	U	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO3	Apply intelligent agents for Artificial Intelligence programming techniques	Ap	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Introduction to Artificial Intelligence**	10	Min.15
	1	Introduction to AI, History and Evolution of AI, Applications		
	2	Introduction to representation and search		
	3	The Propositional calculus, Predicate Calculus, Calculus expressions and Applications		
	4	State Space Search, Production Systems, Problem Characteristics, types of production systems, Graph theory		
	5	Intelligent Agents: Agents and Environments, The nature of environments, The structure of agents. concept of rationality, the nature of environments, structure of agents, problem solving agents, problem formulation		
II		**Search Strategies**	14	Min.15
	6	Uninformed Search Strategies - Breadth First Search, Depth First Search, Depth Limited Search, Iterative Deepening Depth First Search		
	7	Bidirectional Search, Comparison of Uninformed search Strategies, Searching with partial information		
	8	Sensor-less problems, Contingency problems		
	9	Informed Search Strategies - Generate& test, Hill Climbing, Best First Search		
	10	A* and AO* Algorithm, Constraint satisfaction, Backtracking Search		
	11	Game playing: Minimax Search, Alpha-Beta Cutoffs		
	12	Optimal Decisions in Games, Stochastic Games		
III		**Knowledge Representation**	13	Min.15
	13	Knowledge Representation -Knowledge based agents, Wumpus world		
	14	Knowledge Representation -issues, The frame problem.		
	15	First order Logic: Representation, Inference, Reasoning Patterns, Resolution, Forward and Backward Chaining		

	16	Propositional Logic: Representation, Inference, Reasoning Patterns, Resolution, Forward and Backward Chaining		
	17	Agent based and distributed problem solving		
	18	Introduction to Expert System Technology, Bayes Rule,Bayesian Network, Hidden Markov Model, Decision Network		
IV		**Introduction to ANN**	8	Min.15
	19	Introduction ANN, biological neuron, Artificial neuron		
	20	Perceptron Learning		
	21	Back Propagation algorithm		
	22	Introduction to Natural Language Processing, Pattern recognition Case study - Enhancing Customer Service with AI-Powered Chatbots		
		Practical's	30	
	1	Write a program to implement depth first search algorithm.		
	2	Write a program to implement breadth first search algorithm.		
	3	Write a program to simulate 4-Queen / N-Queen problem.		
	4	Write a program to solve tower of Hanoi problem.		
	5	Write a program to implement alpha beta search.		
	6	Write a program for Hill climbing problem.		
	7	Write a program to implement A*algorithm		
	8	Write a program to implement AO*algorithm		
	9	Design the simulation of tic–tac–toe game using min-max algorithm		
	10	Write a program to shuffle Deck of cards		
	11	Write a program to derive the predicate.		
	12	Solve constraint satisfaction problem (a) Derive the expressions based on Associative law		

		(b)Derive the expressions based on Distributive law.		
	13	Develop a simple text-based game using Python that simulates a classic "Guess the Number" game. The game should generate a random number between 1 and 100 and prompt the player to guess the number. After each guess, the game should provide feedback to the player (e.g., "Too high", "Too low", or "Correct!") and keep track of the number of attempts it takes for the player to guess the correct number. Once the player guesses the correct number, the game should display the number of attempts and ask if the player wants to play again		
	14	Train a simple machine learning model, such as a linear regression or logistic regression classifier, using a dataset of your choice and evaluate its performance using appropriate metrics.		
	15	Implement a decision tree classifier from scratch and apply it to a classification task with a real-world dataset		
		References		
	1	S. Russel and p. Norvig, Artificial intelligence – A Modern Approach, 3rdEdn, Pearson		
	2	Artificial Intelligence: Elaine Rich, Kevin Knight, Mc-GrawHill		
	3	Artificial Intelligence by Luger (Pearson Education)		
	4	D W Patterson, introduction to Artificial Intelligence and Expert Systems, PHI, 1990		
	5	Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville:		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	2	3	2	3	2	3	1	2
CO 3	2	3	3	2	3	2	3	1	2

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT1VN102				
Course Title	**STATISTICS FOR DATA SCIENCE**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	I				
Academic Level	100-199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Foundations in mathematics				
Course Summary	Course aims to provide basic concepts such as central tendency, probability, sampling and testing				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand measures of central tendency , dispersion, regression	U	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO2	Distinguish discrete and continuous distributions and its properties	U	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO3	Analyse data using testing hypothesis	An	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Descriptive statistics**	**11**	**Min.15**
	1	Measures of central tendency: - mean, median, mode		
	2	Measures of dispersion: Range, Mean deviation, Quartile deviation and Standard deviation		
	3	Moments, Skewness and Kurtosis,		
	4	Correlation - Linear correlation		
	5	Karl Pearson's coefficient of Correlation, Rank correlation		
	6	Linear regression- Simple and Multiple		
II		**Probability**	**7**	Min.15
	7	Sample space, Events, Different approaches to probability		
	8	Addition and multiplication theorems on probability		
	9	Independent events, Conditional probability		
	10	Bayes Theorem		
III		**Probability Distributions**	**12**	Min.15
	11	Random variables, Probability density functions and distribution functions		
	12	Marginal density functions, Joint density functions		
	12	Mathematical expectations		
	14	Moments and moment generating functions		
	15	Discrete probability distributions – Binomial, Poisson distribution		
	16	Continuous probability distributions- uniform distribution and normal distribution.		
III		**Sampling and Testing**		
	17	Theory of Sampling: - Population and sample, Types of sampling Theory of Estimation: - Introduction, point estimation		

	18	methods of point estimation-Maximum Likelihood estimation and method of moments, Central Limit Theorem(Statement only)	**15**	Min.15
	19	Null and alternative hypothesis, types of errors, level of significance, critical region		
	20	Large sample tests – Testing of hypothesis concerning mean of a population and equality of means of two populations		
	21	Small sample tests – t Test for single mean, difference of means. Paired t-test		
	22	Chi-square test (Concept of test statistic ns2/σ2), F test - test for equality of two population variances		
	23	ANOVA – one-way & two-way classification		
		Practical using MS Excel	**30**	

1. Calculate the mean, median, and mode of a dataset.
2. Calculate the range of a dataset.
3. Calculate the mean deviation of a dataset.
4. Calculate the quartile deviation of a dataset.
5. Calculate the standard deviation of a dataset.
6. Calculate skewness and kurtosis of a dataset.
7. Compute the Karl Pearson's coefficient of correlation between two variables.
8. Calculate rank correlation (e.g., Spearman's rank correlation) between two variables.
9. Perform simple linear regression analysis.
10. Perform multiple linear regression analysis.
11. Calculate probabilities of events using different approaches (e.g., classical, relative frequency, subjective).
12. Apply addition and multiplication theorems of probability to solve problems.
13. Calculate conditional probabilities and use Bayes' Theorem.
14. Generate random samples from various probability distributions (e.g., binomial, Poisson, normal) and calculate relevant statistics.
15. Conduct hypothesis testing using Excel functions for large sample tests (e.g., z-test, t-test), small sample tests (e.g., t-test for single mean, paired t-test), chi-square test, F-test, and ANOVA.

		References		
	1	Fundamentals of statistics: S. C. Gupta, 6th Revised and enlarged edition April 2004, Himalaya Publications		

	2	Fundamentals of Mathematical Statistics- S. C. Gupta,V. K. Kapoor. Sultan Chand Publications		
	3	Introduction to Mathematical Statistics - Robert V. Hogg & Allen T. Craig. Pearson education		
	3	Probability and Statistics for Engineering and the Sciences, Jay L. Devore, Cengage Learning, January 2022, ISBN for the 10th Edition: 978-1305251809		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	3	3	3	1	2
CO 2	2	1	3	1	3	3	3	1	2
CO 3	3	2	3	2	3	3	3	2	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT2VN102				
Course Title	**R PROGRAMMING**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	II				
Academic Level	100-199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Foundations in Mathematics, Programming Fundamentals				
Course Summary	Course aims to provide R programming fundamentals and algorithm writing				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the basic programming structure of R, visualization of models and their inference.	U	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO2	Apply statistical functions, models and their Inferences	Ap	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO3	Design data model, visualization and inference of dataset to gain insights	C	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Introduction to R**	10	Min.10
	1	Introduction to R: R Studio, Basic components in R Studio.		
	2	Basic R syntax: variables, data types, operators		
	3	Working with Data structures Vectors, List, Matrices & Arrays, Factors and Data frame		
	4	Control structures (if-else statements, Loops) & Functions		
	5	Measures of Central Tendency & Dispersion		
II		**Data Manipulation and Visualization with R**	13	Min.20
	6	Importing and exporting data in R (CSV, Excel, Xml, Json, databases)		
	7	Data Cleaning: Exploring raw data, Missing values, Zeros and NAs – Separating, Uniting Columns, String Manipulation, Filling Missing values		
	8	Data manipulation with dplyr: filtering, selecting, mutating, summarizing		
	9	Basic Charts: Pie, Bar, Histogram, Boxplot and Scatterplot		
	10	Data visualization with ggplot2: creating plots (scatter plots, bar plots, line plots)		
	11	Customizing plots and Introduction to other Visualization Packages (ggplot2 extensions, plotly)		
III		**Statistical Analysis with R**	9	Min.15
	12	Overview of statistical analysis in R		
	13	Descriptive statistics: mean, median, standard deviation, variance		
	14	Probability distributions and random variables		
	15	Hypothesis testing: t-tests, chi-square tests, ANOVA		

	16	Linear regression analysis: simple and multiple regression		
	17	Introduction to statistical modelling with R		
IV		**Introduction to Machine Learning with R**	**13**	**Min.15**
	18	Introduction to machine learning concepts and algorithms		
	19	Supervised learning techniques: classification and regression		
	20	Unsupervised learning techniques: clustering and dimensionality reduction		
	21	Case study – Explore Diamond dataset for prize prediction		
	22	Applied Analytics – HR, Finance & Marketing, Case studies		
		Practical's	**30**	
	1	Write a R program to take input from user (name, age, occupation, salary) and display the values with datatypes. Also print version of R installation.		
	2	Write a R program to calculate the sum of numbers from 1 to 10.		
	3	Write a R Program to create a list containing a vector, a matrix and a list and write a code for the following. 1) Give names to the elements in the list 2) Add element at the end of the list 3) Remove the second element		

	4	R program to create a data frame of student with four given vectors and write a code 1) to get the structure of a given data frame. 2) to get the statistical summary and nature of the data of a given data frame. 3) to extract specific column from a data frame using column name. 4) to extract first two rows from a given data frame. 5) to extract 3rd and 5th rows with 1st and 3rd columns from a given data frame. 6) to add a new column in a given data frame. 7) to add new row(s) to an existing data frame. 8) to drop column(s) by name from a given data frame. 9) to drop row(s) by number from a given data frame. a) 10) to extract the records whose grade is greater than 9
	5	Write a R program to find biggest of 3 number (if -else)
	6	Write a R program to find sum of elements of vector and to find minimum and maximum elements of vector (loop)
	7	Write a R program to Import a CSV file named 'data.csv' into a data frame named 'data_df'. a) Display the structure of the 'data_df' data frame using the 'str()' function. b) Print the first few rows of the data frame to inspect the data using the 'head()' function. c) Calculate summary statistics (mean, median, min, max) for numerical variables in the data frame using the 'summary()' function.

	8	Write a Program in R for Missing value imputation 1) Load the 'iris' dataset into a data frame named 'iris_df'. 2) Introduce missing values into the 'iris_df' dataset by randomly replacing a certain percentage of values with NA. 3) Display the summary of missing values in the dataset using the 'is.na()' and 'colSums()' functions. 4) Impute missing values in the dataset using a simple technique (e.g., replacing missing values with the mean or median of the corresponding column). 5) Verify that there are no missing values remaining in the dataset after imputation. 6) Compare summary statistics (mean, median, min, max) of the dataset before and after missing value imputation.
	9	Import a dataset from a CSV file and use dplyr to filter rows based on a condition.
	10	Write a R Program to print data in different graph formats (Histogram, Pie, Bar, Boxplot, Scatterplot)
	11	Write a R program to visualize different plot using ggplot 1) Load the 'iris' dataset into a data frame named 'iris_df'. 2) Create a scatter plot of 'Sepal.Length' against 'Sepal.Width' with points colored by 'Species'. 3) Generate a box plot of 'Petal.Length' for each 'Species'. 4) Create a histogram of 'Sepal.Length' with customized bin widths and colors. 5) Generate a density plot of 'Petal.Width' for each 'Species' overlaid on the same plot. 6) Create a bar plot showing the count of each 'Species' in the dataset. 7) Generate a violin plot of 'Petal.Length' for each 'Species' with custom fill colors. 8) Create a line plot showing the trend of 'Sepal.Length' over 'Petal.Length' for each 'Species'. 9) Combine multiple plots into a single visualization using facets based on 'Species'. 10) Customize the appearance of the plots by adding titles, axis labels, legends, and adjusting plot aesthetics (e.g., colors, transparency).
	12	Write a Program to find mean, median, standard deviation and variance

	13	The heights of 6 randomly chosen sailors are 63,65,68,69,71,72 inches. Those of 10 randomly chosen soldiers are 61,62,65,66,69,69,70,71,72,73 inches. Discuss whether this data gives a suggestion that the sailors are taller than soldiers. Aim: To test the claim that sailors are taller than soldiers (t-test)		
	14	Write a R Program to Apply Simple Linear Regression and Multiple Linear Regression		
	15	Write a R Program to Apply K-means clustering algorithm to the data and visualize the clusters.		
		References		
	1	Hands-On Programming with R by Garrett Grolemund		
	2	R Cookbook by Winston Chang, Paul Teetor, and Joseph Adler		
	3	Beginning R: The Statistical Programming Language by Mark Gardener		
	4	The Art of R Programming by Norman Matloff		
	5	Advanced R by Hadley Wickham		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	3	2	3	3	3	2	2
CO 2	3	3	3	2	3	3	3	2	2
CO 3	3	3	3	2	3	3	3	2	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Code	MAT3VN202				
Course Title	**DATA MINING**				
Type of Course	**Vocational Minor – Data Analytics**				
Semester	III				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	Basic Knowledge in MS Excel				
Course Summary	Course aims to provide basic data mining techniques using Weka tool				

Course Outcome:

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the fundamental concepts and principles of data mining	U	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO2	Understand the mining techniques like association, classifications and clustering on datasets	U	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO3	Apply data mining techniques to real-world datasets	Ap	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Introduction to Data Mining**	**8**	**Min 15**
	1	Data Warehousing - Data warehousing architecture, Warehouse Schema, Data warehouse backend process, Multidimensional Data Model		
	2	OLAP Operations, Introduction to KDD process, Data mining		
	3	Data mining Functionalities, Classification of Data Mining Systems.		
	4	Data Warehousing Case Study: Government, Tourism and Industry		
	5	Data Preprocessing - Data Cleaning, Data Integration and Transformation, Data Reduction, Data discretization		
II		**Association Analysis**	**7**	**Min 15**
	6	Association Analysis - Basic Concepts, Frequent Item set Mining Methods: Apriori Algorithm, generating association Rules from Frequent Item sets, Improving the Efficiency of Apriori.		
	7	Evaluation of Association Patterns, Visualization, Partition algorithm A Case Study on Association using Orange Tool		
	8	Dynamic Item set Counting algorithm- FP-tree growth algorithm-Incremental Algorithm-Border algorithm		
III		**Classification & Prediction**	**14**	**Min 15**
	9	Classification Technique: Introduction, Decision Trees: Tree Construction Principle – Attribute Selection measure – Tree Pruning - Decision Tree construction Algorithm – CART – ID3		
	10	Bayesian Classification: Bayes' theorem, Naïve Bayesian Classification		
	11	K- Nearest Neighbour Classifiers, Support Vector Machine. Evaluating the performance of a Classifier, Methods for comparing classifiers, Visualization		
	12	Case Study of Classification using Orange Tool		

	13	Linear Regression, Nonlinear Regression, Other Regression-Based Methods		
IV		**Clustering**	16	Min 15
	14	Clustering techniques: Data Attribute Types – Data Similarity and Dissimilarity		
	15	Partitioning Methods: k-Means and k- Medoids, CLARANS		
	16	Hierarchical Method: Agglomerative and Divisive Hierarchical Clustering		
	17	Density-based Clustering - DBSCAN, Grid based clustering-STING		
	18	Evaluation of Clustering Method		
	19	Case Study of Clustering using Orange Tool		
	20	Introduction to Web Mining - Basic concepts, Web content mining, Web structure mining, Web usage mining		
	21	Introduction to Text mining, Text Preprocessing, Text clustering		
	22	Case Study – Web Mining: Analysing User Behaviour on E-commerce Website Case Study - Sentiment Analysis of Customer Reviews		
		Practical's	30	
	1	Installation of WEKA Tool		
	2	Creating new Arff File		
	3	Pre-Processes Techniques on Data Set		
	4	Pre-process a given dataset based on Handling Missing Values		
	5	Generate Association Rules using the Apriori Algorithm		
	6	Generating association rules using FP growth algorithm		
	7	Build a Decision Tree by using ID3 algorithm		
	8	Build a Naïve Bayesian Classifier		
	9	Build a K- Nearest Neighbour Classifiers		
	10	Build a Support Vector Machine		

	11	Build a Linear Regression		
	12	Build K-Means Algorithm		
	13	Build K-Medoids Algorithm		
	14	Build Hierarchical Clustering Algorithms		
	15	Create Student. ariff file to suggest better college using Decision tree		
		References		
	1	Arun K Pujari, “Data Mining Techniques”, Universities Press. 2012		
	2	Pang-Ning Tan, Michael Steinbach, Vipin Kumar, ‘Introduction to Data Mining’		
	3	G. K. Gupta, “Introduction to Data Mining with Case Studies”, Easter Economy Edition, Prentice Hall of India, 2006.		
	4	Data Mining: Practical Machine Learning Tools and Techniques" by Ian H. Witten, Eibe Frank, Mark A. Hall, and Christopher J. Pal:		
	5	Data Mining: Concepts and Techniques" by Jiawei Han, Micheline Kamber, and Jian Pei:		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	2	3	2	3	1	2
CO 2	2	3	3	2	3	2	3	1	2
CO 3	2	3	3	2	3	2	3	1	2

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours			
Course Code	MAT8VN402			
Course Title	**DATA VISUALIZATION**			
Type of Course	**Vocational Minor – Data Analytics**			
Semester	VIII			
Academic Level	400-499			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	3	2	75
Pre-requisites	Minor 1 and minor 2			
Course Summary	Course aims to provide data visualization techniques using R programming and interactive chart building			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the methods for visualizing data	U	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO2	Apply Visualization methods for different data domains	Ap	P	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment
CO3	Design an Interactive data visualization story board for data	C	C	Internal exam/ Assignment/ Seminar/ External/ Practical Assessment

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Ext. Marks (70)
I		**Introduction to Data Visualization**	**8**	**Min.10**
	1	Definition, Methodology, Data Visualization and Theory, Visualization Design objectives		
	2	Key Factors – Purpose, visualization function and tone, visualization design options – Data representation, Data Presentation		
	3	Seven stages of data visualization, widgets, and introduction to different data visualization tools		
	4	Computational Statistics and Data Visualization, Presentation and Exploratory Graphics		
	5	Graphics and Computing, Statistical Historiography		
II		**Visualizing Data Methods**	**13**	**Min.15**
	6	Mapping, Time series, Connections and correlations - Scatter plot maps		
	7	Hierarchies and Recursion – introduction to Networks and Graphs, Info graphics		
	8	Complete Plots, Customization of plots -Parameters, Arranging Plots, Annotation,		
	9	Extensibility-Building Blocks, Combining Graphical Elements, 3-D Plots, Data Handling		
	10	Data and Graphs, Graph Layout Techniques, Graph Drawing		
	11	Bipartite Graphs, Hierarchical Trees, Spanning Trees, Networks, Directed Graphs, Tree maps		
III		**Data visualization using R**	**12**	**Min.20**
	12	Environment setup - R and RStudio, Basic plotting functions in R		
	13	Creating scatter plots, histograms, pie chat, bar charts, Boxplot, violin plot, line chart, heatmap, Customizing plot appearance,		
	14	Introduction to ggplot2, Grammar of graphics, creating static plots with ggplot2, Customizing plots with themes and scales		

	15	Introduction to plotly for interactive plotting, Creating interactive scatter plots, line plots, and bar charts, Adding interactivity with tooltips, zooming, and brushing		
	16	Designing interactive dashboards with Shiny and plotly, Other Visualization Pacakges		
IV		**Introduction to Tableau**	**12**	**Min.15**
	17	Environment Setup, Design flow, Data Types, File Types		
	18	Data Source - Custom Data View, Extracting Data, Field operations, Metadata, Data Joining and Blending		
	19	Worksheets- Adding, renaming, reordering Worksheet, Workbook Calculations		
	20	Sort and Filters- Sorting, Quick filtering, Context filtering, Condition filtering, Filter operations		
	21	Tableau Charts ─ Bar Chart, Line Chart, Multiple Measure Line Chart, Pie Chart		
	22	Scatter Plot, Bubble Chart, Bullet Graph, Box Plot, Dashboard – Formatting – Forecasting – Trend Lines		
		Practical's using R	**30**	
	1	Exploring Data with Basic Plots • Load a dataset (e.g., Iris dataset) into R. • Create scatter plots, histograms, and box plots to explore the distribution of variables. • Label axes, add titles, and customize colors and styles		
	2	Visualizing Relationships • Choose a dataset with multiple variables. • Create scatter plots to visualize relationships between pairs of variables. • Use color or shape to represent categorical variables. • Analyze patterns and correlations in the data		

	3	Time Series Visualization · Load a time series dataset (e.g., stock prices, weather data) into R. · Create line plots to visualize trends and fluctuations over time. · Use different line styles or colors to represent multiple time series. · Add labels, titles, and annotations to the plot		
	4	Bar and Pie Charts: · Load a dataset with categorical variables (e.g., survey responses, product categories). · Create bar charts and pie charts to visualize the distribution of categories. · Customize the appearance of the charts (e.g., colors, labels, legends).		
	5	Heatmaps and Correlation Plots: · Load a dataset with numerical variables (e.g., correlation matrix). · Create heatmaps to visualize correlations between variables. · Customize the color scheme and add annotations to the heatmap. · Interpret the patterns of correlation in the data		
	6	Box Plots and Violin Plots: · Load a dataset with numerical and categorical variables (e.g., Iris dataset). · Create box plots and violin plots to visualize the distribution of numerical variables across different categories. · Compare the use of box plots and violin plots for data visualization		

	7	Interactive Visualizations with ggplot2 and Shiny: • Create interactive plots using ggplot2 and Shiny. • Design a Shiny app with interactive controls (e.g., sliders, checkboxes) to explore different aspects of the data.		
	8	Geospatial Visualization: • Load a dataset with geographical information (e.g., map coordinates, regions). • Create maps using packages like ggmap, leaflet, or tmap to visualize spatial data. • Add layers, markers, and tooltips to the map to provide additional information		
	9	Faceted Plots: • Load a dataset with multiple groups or categories. • Create faceted plots using ggplot2 to display subsets of the data in separate panels. • Customize the appearance of each panel (e.g., axis limits, labels, titles		
	10	Network Visualization: • Load a dataset representing a network or graph (e.g., social network, co-authorship network). • Create network visualizations using packages like igraph or networkD3. • Customize the layout, node colors, and edge weights to convey information about the network structure.		
	11	Word Clouds and Text Visualization: • Load a dataset containing text data (e.g., tweets, reviews). • Create word clouds to visualize word frequency and importance. • Customize the appearance of the word cloud (e.g., colors, fonts, word sizes).		

	12	Dashboards with Plotly and Shiny: • Design an interactive dashboard using Plotly and Shiny. • Incorporate interactive plots, tables, and controls to explore and analyze data dynamically.		
	13	Dynamic Visualizations • Load a dataset with time-varying data (e.g., stock prices, sensor readings). • Create animated plots using package plotly. • Customize the animation settings (e.g., frame rate, transition effects) to enhance data visualization.		
	14	Visualizing Hierarchical Data • Load a dataset with hierarchical or nested structure (e.g., organizational hierarchy, file directories). • Create tree maps, dendrograms, or sunburst plots to visualize hierarchical data structures. • Customize the appearance of the plots to highlight different levels of hierarchy.		
	15	Dashboard Design • Design a dashboard layout with multiple visualizations and interactive components. • Arrange the visualizations in a coherent and informative manner. • Add text annotations, titles, and summaries to provide context and insights.		
		References		
	1	Ben Fry, “Visualizing Data”, O‟Reilly Media, Inc., 2007.		
	2	Scott Murray, “Interactive data visualization for the web”, O‟Reilly Media, Inc., 2nd edition, 2017		
	3	Fundamentals of Data Visualization" by Claus O. Wilke		
	4	Data Visualization: A Practical Introduction" by Kieran Healy		
	5	Learning tableau by Joshua N. Milligan		

Note: Proofs of all the results are exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	2	3	2	3	2	3	1	2
CO 3	2	3	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

MINOR COURSES

Programme	B. Sc. Mathematics Honours			
Course Code	MAT1MN101			
Course Title	**CALCULUS**			
Type of Course	**Minor**			
Semester	I			
Academic Level	100 –199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic Idea of Functions, Limits and Continuity			
Course Summary	This course covers fundamental concepts in calculus: It begins with introducing the idea of tangent lines, rates of change, and the derivative, illustrating their application in describing motion and finding instantaneous rates of change. Basic rules of differentiation, including the product, quotient, and power rules, as well as techniques for finding higher-order derivatives are discussed. It also covers related rates, differentials, extrema of functions, the mean value theorem, concavity, inflection points, curve sketching, indefinite and definite integrals, integration by substitution, and the geometric interpretation of the definite integral. These sections explore various calculus techniques for analysing functions, determining areas under curves, and solving real-world problems.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate proficiency in finding derivatives using various differentiation techniques and apply them to describe motion, rates of change, and related rates problems.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse functions to determine extrema, concavity, and inflection points using the Mean Value Theorem, First and Second Derivative Tests, leading to effective curve sketching.	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply integration techniques to compute areas between curves, volumes of solids of revolution, arc lengths, and surface areas, culminating in understanding the Fundamental Theorem of Calculus and its applications.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (48 +12)	Ext. Marks (70)
Text Book		Calculus, Soo T. Tan, Brooks/Cole Cengage Learning (2010) ISBN-13: 978-0-534-46579-7.		
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Introduction to Differentiation**	**14**	**Min 15**
	1	A Quick Review of Functions, Limits, and Continuity (This unit is optional)		
	2	Section 1.5: Tangent Lines and Rates of Change - An intuitive Look, Defining a Tangent Line, Tangent lines, Secant lines and Rates of Change.		
	3	Section 2.1**:** The Derivative - The Derivative, Using the Derivative to Describe the Motion of the Maglev, Differentiation, Finding the Derivative of a Function, Differentiability, Differentiability and Continuity		
	4	Section 2.2**:** Basic Rules of Differentiation - Some Basic Rules		
	5	Section 2.3**:** The Product and Quotient Rules - The Product and Quotient Rules(Example 6 is optional), Extending the Power Rule, Higher- Order Derivatives		
	6	Section 2.6: The Chain Rule – Composite Functions, The Chain Rule, Applying The Chain Rule		
	7	Section 2.7 : Implicit Differentiation – Implicit Functions, Implicit Differentiation		
	8	Section 2.8**:** Related Rates - Related Rates Problems, Solving Related Rates Problems.		
II		**Applications of Differentiation**	**12**	**Min 15**
	9	Section 2.9**:** Differentials and Linear Approximations - Increments, Differentials, Linear Approximations		
	10	Section 3.1: Extrema of Functions - Absolute Extrema of Functions, Relative Extrema of Functions, Finding the Extreme Values of a Continuous Function on a Closed Interval		
	11	Section 3.2: The Mean Value Theorem - Rolle's Theorem, Some Consequences of the Mean Value Theorem, Determining the Number of Zeros of a Function.		
	12	Section 3.3: Increasing and Decreasing Functions and the First Derivative Test - Increasing and Decreasing Functions, Finding the Relative Extrema of a Function		
	13	Section 3.4: Concavity and Inflection Points - Concavity, Inflection Points(Example 6 is optional), The Second Derivative Test, The roles of $f'$and f'' in Determining the Shape of a Graph.		
III		**Introduction to Integration**		
	14	Section 3.6: Curve Sketching -		

		The Graph of a Function, Guide to Curve Sketching(Up to and including Example 2)	**10**	**Min 15**
	15	Section 4.1: Indefinite Integrals - Antiderivatives, The indefinite Integral, Basic Rules of Integration.		
	16	Section 4.2: Integration by Substitution - How the method of Substitution Works, The Technique of Integration by Substitution (Example 8 is optional)		
	17	Section 4.3: Area - An Intuitive Look, Sigma Notation, Summation Formulas, Defining the Area of The Region Under the Graph of a Function (Example 9 is optional)		
	18	Section 4.4: The Definite Integral - Definition of the Definite Integral (Examples 2,3, and 4 are optional), Geometric Interpretation of the Definite Integral, The Definite Integral and Displacement, Properties of the Definite Integral.		
IV	**The Main Theorem and Applications of Integration**		**12**	**Min 15**
	19	Section 4.5: The Fundamental Theorem of Calculus - The Mean Value Theorem for Definite Integrals, The Fundamental Theorem of Calculus - Part 1, Fundamental Theorem of Calculus - Part 2, Evaluating Definite Integrals using Substitution, Definite Integrals of Odd and Even Functions		
	20	Section 5.1**:** Areas Between Curves - A Real- Life Interpretation, The Area Between Two Curves, Integrating with Respect to y		
	21	Section 5.2: Volumes: Disks, Washers, and Cross Sections - Solids of Revolution, The Disk Method, The Method of Cross Sections.		
	22	Section 5.4: Arc Length and Areas of Surfaces of Revolution - Definition of Arc Length, Length of a Smooth Curve, Surfaces of Revolution		
V	**Open Ended**		**12**	
	1	Limits Involving Infinity; Asymptotes		
	2	Derivatives of Trigonometric Functions		
	3	The General Power Rule and using the Chain Rule		
	4	Volumes Using Cylindrical Shells		
	5	Work , Moments and Centre of Mass		
	6	Taylor & Maclaurin's Series		
	7	Approximation by Taylor Series		
	8	Transcendental Functions		
	9	Improper Integrals		
	10	Numerical Integration		

References:

1. Calculus & Analytic Geometry, 9th Edition, George B. Thomas & Ross L. Finney, Pearson Publications.
2. Thomas' Calculus, 14th Edition, Maurice D. Weir, Christopher Heil, & Joel Hass, Pearson Publications.

3. Calculus, 7th Edition, Howard Anton, Biven, & Stephen Davis, Wiley India.
4. Advanced Engineering Mathematics, 10th Ed, Erwin Kreyszig, John Wiley & Sons.
5. Calculus, 4th Edition, Robert T Smith and Roland B Minton, McGraw-Hill Companies
6. Calculus, 9th Edition, Soo T Tan, Brooks/Cole Pub Co.
7. Calculus, Vol 1, Tom M. Apostol, John Wiley & Sons.
8. Michael Van Biezen Calculus Lectures: https://youtu.be/YZYxPclo2rg?si=qKCt6ty8m5dBR4DG

Note: 1) Optional topics are exempted for end semester examination.

2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	1	2	1	3	1	1
CO 2	2	1	3	1	3	1	3	1	2
CO 3	3	2	3	1	3	1	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT2MN101			
Course Title	**DIFFERENTIAL EQUATIONS AND MATRIX THEORY**			
Type of Course	**Minor**			
Semester	II			
Academic Level	100 –199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic Calculus			
Course Summary	This course covers a range of topics. It starts with introducing fundamental terminology and methods for solving differential equations, including separable equations, linear equations, exact equations, and equations with constant coefficients. Then it proceeds into more specialized topics such as homogeneous linear equations with constant coefficients and Cauchy-Euler equations, providing methods for their solution. Laplace transforms, including their definition, properties, and applications in solving differential equations and transforming derivatives are explored. The course concludes with an introduction to vector spaces matrix theory the eigenvalue problem, Fourier series, and separable partial differential equations, providing a comprehensive foundation in advanced calculus and its applications to engineering and physics.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Solve basic ordinary differential equations using separation of variables, linear methods, and Laplace transforms.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply concepts from linear algebra, including matrices, determinants, and eigenvalues, to solve systems of equations and analyse linear systems.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Analyse periodic functions using Fourier series and solve separable partial differential equation	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text		Advanced Engineering Mathematics, 6th Edition, Dennis G. Zill, Jones & Bartlett Learning LLC (2018) ISBN: 978-1-284-10590-2		
Module		**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
		Differential Equations	**11**	Min 15
I	1	Introduction to Differential Equations - Section 1.1**:** Definitions and Terminology - A Definition, Classification by Type, Notation, Classification by Order , Classification by Linearity, Solution.		
	2	Section 2.2: Separable Equations - Introduction, A Definition, Method of Solution.		
	3	Section 2.3: Linear Equations - Introduction, A Definition, Standard Form, Method of Solution, An Initial Value Problem (Examples 4 & 5, ref section 1.1)		
	4	Section 2.4: Exact Equations - Introduction, Differential of a Function of Two Variables, Method of Solution.		
	5	Section 3.3**:** Homogeneous Linear Equations with Constant Coefficients - Introduction, Auxiliary Equation.		
	6	Section 3.6: Cauchy-Euler Equations - Cauchy-Euler Equation (Second Order Only), Method of Solution.		
		Laplace Transforms	**14**	Min 15
II	7	Section 4.1: Definition of the Laplace Transform - Basic Definition (Definition 4.1.1 onwards)		
	8	Section 4.1: Definition of the Laplace Transform - L is a Linear Transform.		
	9	Section 4.2: The Inverse Transform and Transforms of Derivatives - Inverse Transforms		
	10	Section 4.2:The Inverse Transform and Transforms of Derivatives - Transforms of Derivatives		
	11	Section 7.6: Vector Spaces - Vector Space (Example 2 is optional), Subspace.		
	12	Section 7.6: Vector Spaces - Basis, Standard Bases, Dimension, Span		
		Matrix Theory	**13**	Min 15
III	13	Section 8.2: Systems of Linear Algebraic Equations - Introduction, General Form, Solution, Augmented Matrix, Elementary Row Operations, Elimination Methods.		
	14	Section 8.2: Systems of Linear Algebraic Equations - Homogeneous Systems, Notation		
	15	Section 8.3: Rank of a Matrix -		

		Introduction, A Definition, Row Space, Rank by Row Reduction, Rank and Linear Systems.		
	16	Section 8.4: Determinants - Introduction, A Definition (Topics up to and including Example 2).		
	17	Section 8.8: The Eigenvalue Problem - Introduction, A Definition (Topics up to and Including Example 2)		
	18	Section 8.8: The Eigenvalue Problem - A Definition (Topics from Example 3 onwards), Eigenvalues and Eigenvectors of A^{-1}.		
IV		**Fourier Series and PDE**	**10**	Min 15
	19	Section 12.2: Fourier Series - Trigonometric Series (Definition 12.2.1 onwards), Convergence of a Fourier Series.		
	20	Section 12.3: Fourier Cosine and Sine Series - Introduction, Even and Odd Functions, Properties, Cosine and Sine Series (Definition 12.3.1 onwards).		
	21	Section 13.1: Separable Partial Differential Equations - Introduction, Linear Partial Differential Equation, Solution of a PDE, Separation of Variables.		
	22	Section 13.1: Separable Partial Differential Equations - Classification of Equations.		
		Open Ended		
	1	Initial-Value Problems	**12**	
	2	Differential Equations as Mathematical Models		
	3	Second Order Non-Homogeneous Equations-Method of Undetermined Coefficients, Variation of Parameters.		
	4	Linear Models – IVP		
	5	Linear Models - BVP		
	6	Non-linear Models		
	7	Half- Range Fourier Series		
	8	Classical PDEs and Boundary- Value Problems		

	1	Advanced Engineering Mathematics, Erwin Kreyszig, 10th Edition, Wiley India.
	2	Calculus & Analytic Geometry, 9th Edition, George B. Thomas & Ross L. Finney, Pearson Publications.
	3	Calculus, 7th Edition, Howard Anton, Biven, & Stephen Davis, Wiley India.

Note: 1) Optional topics are exempted for end semester examination.

2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	3	3	3	1	2
CO 2	2	1	3	1	3	3	3	1	2
CO 3	3	2	3	2	3	3	3	2	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT3MN201			
Course Title	**CALCULUS OF SEVERAL VARIABLES**			
Type of Course	**Minor**			
Semester	III			
Academic Level	200 - 299			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Calculus of Single Variable			
Course Summary	This course provides a comprehensive study of advanced calculus topics, including partial derivatives, limits, continuity, the chain rule, and vector-valued functions. Students will explore directional derivatives, tangent planes, and extrema of functions of multiple variables, as well as integral calculus techniques such as line integrals, double integrals (including those in polar coordinates), surface integrals, and the applications of these concepts in vector calculus and field theory			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply Multivariable Calculus Concepts to Vector Valued Functions	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply Techniques of Multivariable Integration	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply Advanced Theorems in Multivariable Calculus	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	Calculus, Soo T. Tan, Brooks/Cole Cengage Learning (2010) ISBN-13: 978-0-534-46579-7			
Module	Unit	Content	Hrs (48 +12)	**Ext. Marks (70)**
I		**Partial Derivatives**	14	Min 15
	1	12.1: Vector Valued Functions & Space Curves		
	2	12.2: Differentiation & Integration of Vector Valued Functions		
	3	13.1: Functions of Two or More Variables		
	4	13.2: Limits & Continuity		
	5	13.3: Partial Derivatives		
	6	13.4: Differentials		
	7	13.5: The Chain Rule		
	8	13.6: Directional Derivatives		
	9	13.7: Tangent Planes & Normal Lines		
	10	13.8: Extrema of Functions of Two Variables		
II		**Vector Derivatives – Calculus of Scalar & Vector Fields**	11	Min 15
	11	13.6: Gradient Vector of a Scalar Field		
	12	15.1, 15.2: Divergence & Curl of Vector Fields		
	13	15.3: Line Integrals		
	14	15.4: Path Independence & Conservative Vector Fields		
		(Fundamental Theorem of Line Integration- Gradients)		
III		**Multiple Integration**	14	Min 15
	15	14.1: Double Integrals		
	16	14.2: Iterated Integrals		
	17	14.3: Double Integrals in Polar Coordinates		
	18	14.4: Applications of Double Integrals		
	19	14.5: Surface Area		

	20	14.6: Triple Integrals		
	21	14.7: Triple Integrals in Cylindrical & Spherical Coordinates		
	22	14.8: Change of Variables in Multiple Integrals		
IV	**Integral Calculus of Fields & Fundamental Theorems**		11	Min 15
	23	15.5: Green's Theorem		
	24	15.6: Parametric Surfaces		
	25	15.7: Surface Integrals		
	26	15.8: Divergence Theorem		
	27	15.9: Stoke's Theorem		
V	Open Ended Module – Complex Analysis		12	
	1	Algebra of Complex Numbers, Complex Functions, Complex Differentiation		
	2	Cauchy-Riemann Equations, Analytic Functions		
	3	Complex Line Integrals		
	4	Cauchy's & Cauchy-Goursat Theorems		
	5	Cauchy's Integral Formula, Derivative Formula		
	6	Morera's & Liouville's Theorem, Fundamental Theorem of Algebra		
	7	12.3: Arc Length & Curvature		
	8	12.4: Velocity & Acceleration		
	9	12.5: Tangential & Normal Components		
	10	13.9: Lagrange Multipliers		

. References:

1. Advanced Engineering Mathematics, Erwin Kreyzsig, 10th Edition, Wiley India.

2. Advanced Engineering Mathematics, 6th Edition, Dennis G. Zill, Jones & Bartlett Learning LLC (2018) ISBN: 978-1-284-10590-2.

3. Calculus & Analytic Geometry, 9th Edition, George B. Thomas & Ross L. Finney, Pearson Publications.

4. Thomas' Calculus, 14th Edition, Maurice D. Weir, Christopher Heil, & Joel Hass, Pearson Publications.

5. Calculus, 7th Edition, Howard Anton, Biven, & Stephen Davis, Wiley India.

. **Note: 1) Optional topics are exempted for end semester examination.**

2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	2	3	3	3	1	2
CO 2	3	0	3	2	3	3	3	1	2
CO 3	3	2	3	2	3	3	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT1MN102			
Course Title	**DIFFERENTIAL CALCULUS**			
Type of Course	**MINOR**			
Semester	I			
Academic Level	100-199			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Set theory along with an understanding of the real number system.			
Course Summary	This course provides a foundational understanding of calculus concepts: From the beginning sections students learn about limits (including one-sided limits and limits at infinity), continuity (definitions and properties), and the intermediate value theorem. Modules II and III cover differentiation techniques, including tangent lines, the definition of derivatives, rules of differentiation (product, quotient, chain), implicit differentiation, and advanced topics like L'Hopital's Rule for indeterminate forms. Module IV focuses on the analysis of functions, discussing concepts such as increasing/decreasing functions, concavity, inflection points, and techniques for identifying relative extrema and graphing polynomials.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse limit, continuity and differentiability of a function	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply rules and techniques of differentiation to solve problems, also find limit in indeterminate forms involving transcendental functions	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Draw a polynomial function by analysing monotonicity, concavity and point of inflection using derivatives test	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

<table>
<tr><td colspan="2">Text book</td><td colspan="3">Anton, Howard, Irl C. Bivens, and Stephen Davis. Calculus: early transcendentals. 10th Edition, John Wiley & Sons, 2021.</td></tr>
<tr><td>Module</td><td>Unit</td><td>Content</td><td>Hrs 60</td><td>External Marks (70)</td></tr>
<tr><td rowspan="7">I</td><td colspan="2">Fundamentals of Limits and Continuity</td><td rowspan="7">14</td><td rowspan="7">Min.15</td></tr>
<tr><td>1</td><td>Section 1.1: Limits (An Intuitive Approach) -
Limits, One-Sided Limits, The Relationship Between One-Sided and Two Sided Limits</td></tr>
<tr><td>2</td><td>Section 1.2: Computing Limits -
Some Basic Limits, Limits of Polynomials and Rational Functions as $x \to a$</td></tr>
<tr><td>3</td><td>Section 1.2: Computing Limits -
Limits involving Radicals, Limits of Piecewise-Defined Functions</td></tr>
<tr><td>4</td><td>Section 1.3: Limits at Infinity; End Behaviour of a Function Limits of Rational Functions as $x \to \pm\infty$ - A Quick Method for Finding Limits of Rational Functions as $x \to +\infty$ or $x \to -\infty$</td></tr>
<tr><td>5</td><td>Section 1.5: Continuity -
Definition of Continuity, Continuity on an interval, Some Properties of Continuous Functions,</td></tr>
<tr><td>6</td><td>Section 1.5: Continuity -
Continuity of Polynomials and Rational Functions, Continuity of Compositions, The Intermediate- Value Theorem.</td></tr>
<tr><td rowspan="7">II</td><td colspan="2">Differentiation</td><td rowspan="7">14</td><td rowspan="7">Min.15</td></tr>
<tr><td>7</td><td>Section 2.1: Tangent Lines and Rates of Change -
Tangent lines, Slopes and Rate of Change</td></tr>
<tr><td>8</td><td>Section 2.2: The Derivative Function -
Definition of the Derivative Function-Topics up to and including Example 2.</td></tr>
<tr><td>9</td><td>Section 2.3: Introduction to Techniques of Differentiation -
Derivative of a Constant, Derivative of Power Functions, Derivative of a Constant Times a Function, Derivatives of Sums and Differences, Higher Derivatives</td></tr>
<tr><td>10</td><td>Section 2.4: The Product and Quotient Rules -
Derivative of a Product, Derivative of a Quotient, Summary of Differentiation Rules.</td></tr>
<tr><td>11</td><td>Section 2.5: Derivatives of Trigonometric Functions -
Example 4 and Example 5 are optional</td></tr>
<tr><td>12</td><td>Section 2.6: The Chain Rule
Derivatives of Compositions, An Alternate Version of the Chain Rule, Generalized Derivative Formulas</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Differentiation contd :</td><td rowspan="2">10</td><td rowspan="2"></td></tr>
<tr><td>13</td><td>Section 3.1: Implicit Differentiation -
Implicit Differentiation (sub section)</td></tr>
</table>

III	14	Section 3.2: Derivatives of Logarithmic Functions - Derivative of Logarithmic Functions (sub section) Logarithmic Differentiation, Derivatives of Real Powers of x.		**Min.15**
	15	Section 3.3: Derivatives of Exponential and Inverse Trigonometric Functions - Derivatives of Exponential Functions		
	16	Section 3.3: Derivatives of Exponential and Inverse Trigonometric Functions - Derivatives of the Inverse Trigonometric Functions		
	17	Section 3.6: L'Hopital's Rule; Indeterminate Forms - Inderminate Forms of Type 0/0, Indeterminate Forms of Type ∞/∞		
	18	Section 3.6: L'Hopital's Rule; Indeterminate Forms - Inderminate Forms of Type $0 \cdot \infty$, Indeterminate Forms of Type $\infty - \infty$		
IV		**Applications of Differentiation**	**10**	**Min 15**
	19	Section 4.1: Analysis of Functions I: Increase, Decrease, and Concavity - Increasing and Decreasing Functions		
	20	Section 4.1: Analysis of Functions I: Increase, Decrease, and Concavity - Concavity, Inflection Points		
	21	Section 4.2: Analysis of Functions II: Relative Extrema; Graphing Polynomials - Relative Maxima and Minima, First Derivative Test, Second Derivative Test		
	22	Section 4.2: Analysis of Functions II: Relative Extrema; Graphing Polynomials Geometric Implications of Multiplicity, Analysis of Polynomials		
V		**Module V (Open Ended)**	**12**	
		Infinite Limits		
		Differentiability, Relation between Derivative and Continuity		
		Parametric Equations, Parametric Curves		
		Inverse Trigonometric Functions and their derivatives		
		Taylor series expansion of functions		
		Maclaurin series of sin x, cos x, tan x, log(1+x), log(1-x) etc		
		Binomial expansion of $\frac{1}{(1+x)}$, $\frac{1}{(1-x)}$, $\frac{1}{\sqrt{1+x}}$, $\frac{1}{\sqrt{1-x}}$ etc		
		Different coordinate systems: - Cartesian, Spherical, and Cylindrical coordinates		
		Conic sections with vertex other than the origin		
		Indeterminate Forms of Type $0^0, \infty^0, 1^\infty$		
		Graphing Rational Functions		
References				
	1	Calculus and Analytic Geometry, 9 th Edition, George B. Thomas Jr and Ross L. Finney, Pearson Publications.		

	2	Calculus, Soo T. Tan, Brooks/Cole Cengage Learning (2010) ISBN-13: 978-0-534-46579-7.
	3	Marsden, Jerrold, and Alan Weinstein. *Calculus I*. Springer Science & Business Media, 1985.
	4	Stein, Sherman K. *Calculus in the first three dimensions*. Courier Dover Publications, 2016.

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam. (3) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	1	2	1	3	1	2
CO 2	3	1	3	1	2	1	3	1	2
CO 3	2	1	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT2MN102			
Course Title	**CALCULUS AND MATRIX ALGEBRA**			
Type of Course	**MINOR**			
Semester	II			
Academic Level	100-199			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Basic Calculus			
Course Summary	Students learn about antiderivatives, the indefinite and definite integrals, Riemann sums, and the Fundamental Theorem of Calculus. Course explores the average value of functions, evaluating definite integrals by substitution, calculating areas between curves, and finding the length of plane curves. Next it introduces functions of multiple variables, including notation, graphs, limits, continuity, and partial derivatives for functions of two or more variables. Course also focuses on matrix algebra, determinants, eigenvalue problems (including complex eigenvalues), and orthogonal matrices and their properties.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Demonstrate proficiency in applying calculus techniques to solve analytical and geometrical problems involving indefinite and definite integrals, substitution methods, and integration by parts.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply multivariable calculus concepts, including functions of multiple variables, limits, continuity, and partial derivatives, to model and analyse real-world phenomena and mathematical problems.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply linear algebra principles, such as matrix operations, determinants, and eigenvalue problems, to analyze and solve systems of equations and geometric problems.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book	1. Howard Anton, Bivens and Stephen Davis, Calculus- Early Transcendentals (10th Edition). 2. Advanced Engineering Mathematics(6/e): Dennis G Zill Jones & Bartlett, Learning, LLC (2018) ISBN: 9781284105902			
Module	**Unit**	**Content**	**Hrs 60**	**External Marks (70)**
I		**Indefinite and Definite Integrals**	**12**	**Min 15**
	1	Section 5.2: The Indefinite Integral - Antiderivatives, The Indefinite Integral, Integration Formulas, Properties of the Indefinite Integral, Integral Curves		
	2	Section 5.3: Integration by Substitution - u-Substitution, Easy to Recognize Substitutions, Less Apparent Substitutions		
	3	Section 5.5: The Definite Integral - Riemann Sums and the Definite Integral, Properties of the Definite Integral.		
	4	Section 5.6: The Fundamental Theorem of Calculus - The Fundamental Theorem of Calculus (sub section), The Relationship Between Definite and Indefinite Integrals.		
II		**Techniques and Applications**	**13**	**Min 15**
	5	Section 5.8: Average Value of a Function and its Applications - Average Value of a Continuous Function (up to and including Example 2 only)		
	6	Section 5.9: Evaluating Definite Integrals by Substitution - Two Methods for Making Substitutions in Definite Integrals		
	7	Section 6.1: Area Between Two Curves - Area Between $y = f(x)$ and $y = g(x)$, Reversing the Roles of x and y		
	8	Section 6.4: Length of a Plane Curve - Arc Length		
	9	Section 7.2: Integration by Parts - The Product rule and Integration by Parts, Guidelines for Integration by Parts, Repeated Integration by Parts		
	10	Section 7.5: Integrating Rational Functions by Partial Fractions - Partial Fractions, Finding the form of a Partial Fraction Decomposition, Linear Factors, Quadratic Factors (Example 4 is optional), Integrating Improper Rational Functions.		
III		**Multivariable Calculus**	**10**	**Min 15**
	11	Section 13.1: Functions of Two or More Variables: Notation and Terminology, Graphs of Functions of Two Variables.		
	12	Section 13.1: Functions of Two or More Variables: Level Curves, Level Surfaces.		
	13	Section 13.2: Limits and Continuity - Limit along Curves		
	14	Section 13.2: Limits Continuity - Continuity		
	15	Section 13.3: Partial Derivatives -		

		Partial Derivatives of Functions of Two Variables, The Partial Derivative Function, Partial Derivative Notation, Implicit Partial Differentiation, Partial Derivatives and Continuity		
	16	Section 13.3: Partial Derivatives Partial Derivatives of Functions with more than Two Variables, Higher order Partial Derivatives, Equality of Mixed Partials.		
IV		**Linear Algebra Essentials**	**13**	**Min 15**
	17	Section 8.1: Matrix Algebra		
	18	Section 8.2: Systems of Linear Algebraic Equations		
	19	Section 8.8: The Eigenvalue Problem - Topics up to and including Example 4		
	20	Section 8.8: The Eigenvalue Problem - Topics from Complex Eigenvalues onwards		
	21	Section 8.10: Orthogonal Matrices - Topics up to and including Theorem 8.10.3		
	22	Section 8.10: Orthogonal Matrices - Topics from Constructing an Orthogonal Matrix onwards		
V		**Module V (Open Ended)**	**12**	
		Fundamental theorems in Vector Calculus such as Green's theorem, divergence theorem, and the Stokes' theorem.		
		Trigonometric Substitutions		
		Integrating Trigonometric Functions		
		Volume of Solids of Revolution, Area of Surfaces of Revolution		
		The Chain Rule in Partial Differentiation		
		Directional Derivatives and Gradients, Tangent Planes and Normal Vectors		
		Basics of Vector Calculus including the differential operators such as gradient, divergence and curl.		
		Simpsons Rule, Trapezoidal rule in Numerical Integration		
		Algebra of Complex Numbers		
References				
	1	Calculus and Analytic Geometry, 9 th Edition, George B. Thomas Jr and Ross L. Finney, Pearson Publications.		
	2	Calculus, Soo T. Tan, Brooks/Cole Cengage Learning (2010) ISBN-13: 978-0-534-46579-7.		
	3	Marsden, Jerrold, and Alan Weinstein. *Calculus I*. Springer Science & Business Media, 1985.		
	4	Stein, Sherman K. *Calculus in the first three dimensions*. Courier Dover Publications, 2016.		
	5	Kreyszig, Erwin. *Advanced Engineering Mathematics 9th Edition with Wiley Plus Set*. Vol. 334. US: John Wiley & Sons, 2007.		
	6	Elementary Linear Algebra, Applications version, 9 th edition, Howard Anton and Chriss Rorres		

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	1	1	3	0	0
CO 2	2	1	2	1	2	1	2	0	0
CO 3	2	1	2	1	2	1	2	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT3MN202
Course Title	**DIFFERENTIAL EQUATIONS AND FOURIER SERIES**
Type of Course	**Minor**
Semester	III
Academic Level	200-299

Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60

Pre-requisites	Basic Calculus and familiarity with Real Numbers
Course Summary	In Module I students are introduced to various types of differential equations, including linear, separable, exact equations, and Bernoulli's equation. Module II delves deeper into linear equations, both homogeneous and nonhomogeneous. Module III introduces Fourier series, including trigonometric series, Fourier cosine and sine series, and half-range expansions. Module IV transitions into algebra of complex numbers, , and functions of complex variables, including analytic functions and the Cauchy-Riemann equations, which are fundamental in complex analysis.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply various methods, such as separation of variables, linear, and exact equations, integrating factors, and substitution, to solve differential equations, including those with constant coefficients and Cauchy-Euler equations.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Analyse and solve partial differential equations, including separable ones, and comprehend Fourier series and their applications in solving differential equations and understanding periodic function	An	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply complex number theory, including arithmetic operations, polar forms, powers, roots, sets in the complex plane, functions of a complex variable, and Cauchy-Riemann equations, to analyze and solve real-world problems in various fields.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
\# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text Book	Advanced Engineering Mathematics(6/e) : Dennis G Zill, Jones & Bartlett, Learning, LLC(2018)ISBN: 978-1-284-10590-2			
Module	**Unit**	**Content**	**Hrs 60**	**External Marks (70)**
I		**Foundations of Differential Equations**		Min 15
	1	Introduction to Differential Equations Section 1.1: Definitions and Terminology Introduction, A Definition, Classification by Type, Notation, Classification by Order, Classification by Linearity, Solution.	10	
	2	Section 2.2: Separable Equations Introduction, A Definition, Method of Solution.		
	3	Section 2.3: Linear Equations Introduction, A Definition, Standard Form, Method of Solution, An Initial Value Problem		
	4	Section 2.4: Exact Equations Introduction, Differential of a Function of Two Variables (Definition 2.4.1 and Theorem 2.4.1 only), Method of Solution.		
	5	Section 2.4: Exact Equations Integrating Factors		
	6	Section 2.5: Solutions by Substitutions Bernoulli's Equation		
II		**Linear Differential Equations**		Min 15
	7	Section 3.1: Theory of Linear Equations 3.1.2 Homogenous Equations, Linear Dependence and Independence, Solutions of Differential Equations,	11	
	8	Section 3.1: Theory of Linear Equations 3.1.3 Nonhomogeneous Equations, Complementary Function		
	9	Section 3.3: Homogeneous Linear Equations with Constant Coefficients Introduction, Auxiliary Equation.		
	10	Section 3.4: Undetermined Coefficients Introduction, Method of Undetermined Coefficients (Topics up to and including Example 4.)		
	11	Section 3.6: Cauchy-Euler Equations Cauchy-Euler Equation (Second Order Only), Method of Solution.		
III		**Fourier Series**		Min 15
	12	Section 12.2: Fourier Series Trigonometric Series (Definition 12.2.1 onwards), Convergence of a Fourier Series, Periodic Extension	13	
	13	Section 12.3: Fourier Cosine and Sine Series Introduction, Even and Odd Functions, Properties, Cosine and Sine Series (Definition 12.3.1 onwards).		
	14	Section 12.3: Fourier Cosine and Sine Series Half-Range Expansions.		

	15	Section 13.1: Separable Partial Differential Equations Introduction, Linear Partial Differential Equation, Solution of a PDE, Separation of Variables.		
	16	Section 13.1: Separable Partial Differential Equations Classification of Equations.		
IV		**Introduction to Complex Analysis**		**Min 15**
	17	Section 17.1: Complex Numbers Introduction, A definition, Terminology, Arithmetic Operations, Conjugate, Geometric Interpretation	**14**	
	18	Section 17.2: Powers and Roots Introduction, Polar Form, Multiplication and Division, Integer Powers of z.		
	19	Section 17.2: Powers and Roots DeMoivre's Formula, Roots.		
	20	Section 17.3: Sets in the Complex Plane Introduction, Terminology.		
	21	Section 17.4: Functions of a Complex Variable Introduction, Functions of a Complex Variable, Limits and Continuity, Derivative, Analytic Functions.		
	22	Section 17.5: Cauchy- Riemann Equations Introduction, A Necessary Condition for Analyticity, Harmonic Functions, Harmonic- Conjugate Functions.		
V		**Module V (Open Ended)**	**12**	
		Initial Value Problems		
		Differential Equations as Mathematical Models		
		Method of Variation of Parameters in solving DE		
		Solving DE with the Runge-Kutte Method		
		Interpolation, Extrapolation		
		Classical PDEs and Boundary Value Problems		
		Heat Equation		
		Wave Equation		
		Fourier Transform		
References				
	1	Advanced Engineering Mathematics, Erwin Kreyszig, 8^{th} Edition, Wiley Student Edition.		
	2	Mathematics For Engineers and Scientist, Alan Jeffrey, Sixth Edition		
	3	Complex Analysis A First Course with Applications (3/e), Dennis Zill & Patric Shanahan Jones and Bartlett, Learning (2015) ISBN 1-4496-9461-6		

Note: Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	3	3	1	2
CO 2	3	1	3	2	3	3	3	1	2
CO 3	3	2	3	2	3	3	3	1	2

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT1MN103			
Course Title	**BASIC CALCULUS**			
Type of Course	**Minor**			
Semester	I			
Academic Level	100 – 199			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Basic Set Theory including functions and their algebraic operations .			
Course Summary	This course provides a comprehensive exploration of calculus and its applications: It begins with fundamental concepts of graphs, linear models, inverse functions, laying the groundwork for calculus. Modules II and III delve into differentiation techniques, including product and quotient rules, implicit differentiation, derivatives of inverse functions, and applications like extrema, theorems (such as Rolle's and Mean Value Theorems), and curve sketching. Module IV explores integral calculus, covering the fundamental theorem of calculus, numerical integration techniques (like the Trapezoidal Rule and Simpson's Rule), and introduces hyperbolic functions and their derivatives and integrals.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply graphical analysis skills to mathematical models**:**	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Evaluate and solve calculus problems involving limits and continuity	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Apply differentiation and integration techniques to analyse functions**:**	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (48 +12)	Ext. Marks (70)
Text Book		Calculus: Early Transcendental Functions (6edn), Ron Larson and Bruce Edwards Cengage Learning ISBN-13: 978-1-285-77477-0.		
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Foundations of Calculus: Graphs, Functions, and Limits**		
	1	A quick review of sections 1.1 and 1.2 (not for external exam) Section 1.3 – Functions and their Graphs	**13**	**Min 15**
	2	Section 1.5: Inverse Functions - Inverse Functions, Existence of an Inverse Function		
	3	Section 1.6: Exponential and Logarithmic Functions - Exponential Functions, The Number e, The Natural Logarithmic Function		
	4	Section 2.2: Finding Limits Graphically and Numerically - An Introduction to Limits, Limits That Fail to Exist, A Formal Definition of Limit (examples are optional topics)		
	5	Section 2.3: Evaluating Limits Analytically - Properties of Limits, A Strategy for Finding Limits,		
	6	Section 2.3: Evaluating Limits Analytically - Dividing Out Technique, Rationalizing Technique, The Squeeze Theorem		
II		**Continuity, Derivatives, and Differentiation Rules**		
	7	Section 2.4: Continuity and One-Sided Limits - Continuity at a Point and on an Open Interval, Properties of Continuity, The Intermediate Value Theorem.	**12**	**Mn 15**
	8	Section 3.1: The Derivative and the Tangent Line Problem - The Derivative of a Function, Differentiability and Continuity		
	9	Section 3.2: Basic Differentiation Rules and Rates of Change – The Constant Rule, The Power Rule, The Constant Multiple Rule, The Sum and Difference Rules		
	10	Section 3.2 : Basic Differentiation Rules – rest of the section.		
	11	Section 3.3: Product and Quotient Rules and Higher Order Derivatives - The Product Rule, The Quotient rule, Higher- Order Derivatives		
	12	Section 3.4 The Chain Rule.		
	13	Section 3.5: Implicit Differentiation Implicit and Explicit Functions, Implicit Differentiation, Logarithmic Differentiation		
III		**Applications of Derivatives: Extrema, Concavity, and Curve Sketching**		
	14	Section 4.1: Extrema on an Interval - Extrema of a Function, Relative Extrema and Critical Numbers, Finding Extrema on a Closed Interval	**12**	**Min 15**
	15	Section 4.2: Rolle's Theorem and The Mean Value Theorem - Rolle's Theorem, The Mean Value Theorem		
	16	Section 4.3: Increasing and Decreasing Functions and The First Derivative Test - Increasing and Decreasing Functions, The First Derivative Test		
	17	Section 4.4: Concavity and the Second Derivative Test -		

		Concavity, Points of Inflection, The Second Derivative Test		
	18	Section 4.6: A summary of Curve Sketching - Analyzing the Graph of a Function		
IV		**Integral Calculus: Fundamental Theorems and Applications"**		
	19	Section 5.1: Antiderivatives and Indefinite Integration – Antiderivatives, Basic Integration Rules, Initial Conditions and Particular Solutions.	11	**Min 15**
	20	Section 5.3: Reimann Sums and Definite Integrals – Reimann Sums, Definite Integrals, Properties of Definite Integrals.		
	21	Section 5.4: The Fundamental Theorem of Calculus - The Fundamental Theorem of Calculus, The Mean Value Theorem for Integrals.		
	22	Section 5.4: The Fundamental Theorem of Calculus - Average Value of a Function, The Second Fundamental Theorem of Calculus, Net Change Theorem		
V	**Open Ended**			
	One Sided Limits and Discontinuity, Derivatives of Inverse Functions, Derivatives of Trigonometric functions, Limits at Infinity and Horizontal Asymptotes, Numerical Integration, Area problems using Riemann Sums, Hyperbolic Functions.		**12**	

References:

1. Calculus, Soo T. Tan, First Edition, Brooks/Cole, Cengage Learning, 2011.
2. Calculus & Analytic Geometry, (9/e), George B. Thomas & Ross L. Finney, Pearson Publications
3. Calculus, (7/e), Howard Anton, Biven, & Stephen Davis, Wiley India
4. Calculus, (7/e)., Howard Anton, Biven, & Stephen Davis, Wiley India.
5. Calculus: Early Transcendentals, (4/e), Dennis G. Zill and Warren S. Wright

Note: 1) Optional topics are exempted for end semester examination.
2) Proofs of all the results are also exempted for the end semester exam.,

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	1	3	1	3	1	3	1	2
CO 3	2	1	3	1	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B.Sc. Mathematics Honours			
Course Code	MAT2MN103			
Course Title	**ANALYSIS AND SOME COUNTING PRINCIPLES**			
Type of Course	**Minor**			
Semester	II			
Academic Level	100 – 219			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	4	-	60
Pre-requisites	Basic Calculus and familiarity with Real Number system.			
Course Summary	This course covers fundamental topics in calculus and complex analysis, beginning with sequences and series in Module I, exploring convergence tests like the nth-term test, comparison tests, and alternating series. Module II delves into complex numbers and functions, discussing the arithmetic and geometric properties of complex numbers, along with polar and exponential forms. In Module III, the focus shifts to limits, continuity, and differentiability of complex functions, including the Cauchy-Riemann equations and harmonic functions. Finally, Module IV introduces counting principles, including permutations, combinations, the pigeonhole principle, and basic elements of probability.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Describe and apply convergence tests for sequences and series.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Demonstrate proficiency in manipulating complex numbers and functions.	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Evaluate limits, continuity, and differentiability of real and complex functions.	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text Book	1. Calculus: Early Transcendental Functions (6/e), Ron Larson and Bruce Edwards, Cengage Learning ISBN 13: 978-1-285-77477-0. 2. Complex Analysis A First Course with Applications (3/e), Dennis Zill & Patric Shanahan Jones and Bartlett, Learning (2015) ISBN 1-4496-9461-6 3. Discrete Mathematical Structures (6/e), Bernard Kolman, Robert Busby, Sharon C. Ross, Pearson ISBN 978-93-325-4959-3

Module	Unit	Content	Hrs (48 +12)	Ext. Marks (70)
I		**Sequences and Series (Text 1)**		
	1	Section 9.1: Sequences - Sequences (sub section), Limit of a Sequence, Monotonic Sequences and Bounded Sequences.	13	Min 15
	2	Section 9.1: Sequences Monotonic Sequences and Bounded Sequences		
	3	Section 9.2: Series and Convergence - Infinite Series, Geometric Series, nth-Term Test for Divergence		
	4	Section 9.3: The Integral Test and p-Series - The Integral Test, p-series and Harmonic Series		
	5	Section 9.4: Comparisons of Series - Direct Comparison Test, Limit Comparison Test		
	6	Section 9.5: Alternating Series - Alternating Series (sub section), Alternating Series Remainder, Absolute and conditional Convergence		
II		**Complex Numbers (Text 2)**		
	7	Section 1.1: Complex numbers and their Properties - The Imaginary Unit, Terminology, Arithmetic Operations, Zero and Unity, Conjugate, Inverses	13	Min 15
	8	Section 1.2: Complex Plane - Complex Plane, Vectors, Properties, Distance Again, Inequalities		
	9	Section 1.3: Polar Form of Complex Numbers - Polar Form, Principal Argument, Multiplication and Division, Integer Powers of z, de Moivre's Formula		
	10	Section 1.4: Powers and Roots - Roots, Principal nth Root		
	11	Section 1.5: Sets of Points in the Complex Plane - Circles, Disks and Neighborhoods, Open Sets, Annulus, Domain, Regions, Bounded Sets		
	12	Section 2.1: Complex Functions - Introduction, Function, Real and Imaginary Parts of a Complex Function, Exponential Function		
III		**Complex Analysis (Text 2)**		
	13	Section 3.1: Limits and Continuity - Introduction, Real Limits, Complex Limits (definition only), Real Multivariable Limits (Example 2 and Problems Using Epsilon Delta Definition are optional)		
	14	Section 3.1: Limits and Continuity -		

		Continuity of Real Functions, Continuity of Complex Functions (Example 6 is optional), Properties of Continuous Functions.	**12**	Min 15
	15	Section 3.2: Differentiability and Analyticity - Introduction, The Derivative, Rules of Differentiation		
	16	Section 3.2: Differentiability and Analyticity - Analytic Functions, Entire Functions, Singular Points, An Alternate Definition of $f'(z)$.		
	17	Section 3.3: Cauchy -Riemann Equations - Introduction, A Necessary Condition for Analyticity, A Sufficient Condition for Analyticity		
	18	Section 3.4: Harmonic Functions Introduction, Harmonic Functions, Harmonic Conjugate Functions		
IV	**Introduction to Counting and Probability Theory (Text 3)**			
	19	Chapter 3: Counting Section 3.1 - Permutations	**10**	Min 15
	20	Chapter 3: Counting Section 3.2 - Combinations		
	21	Chapter 3: Counting Section 3.3 – Pigeonhole Principle		
	22	Chapter 3: Counting Section 3.4 – Elements of Probability		
V	**Open Ended**			
	Pattern Recognition for Sequences, Rearrangement of Series, The Ratio Test, The Root Test, Taylor Polynomials and Approximations, Power Series, Taylor Series, Maclaurin Series, Complex Functions as Mappings, Linear Mappings, Special Power Functions, Relations and Di Graphs.		**12**	

References:

1. Calculus, Soo T. Tan, First Edition, Brooks/Cole, Cengage Learning, 2011.
2. Calculus & Analytic Geometry, (9/e)., George B. Thomas & Ross L. Finney, Pearson Publications.
3. Calculus, (7/e), Howard Anton, Biven, & Stephen Davis, Wiley India.
4.Calculus: Early Transcendentals, (4/e)., Dennis G. Zill and Warren S. Wright.
5. Advanced Engneering Mathematics, (10/e), Erwin Kreyszig, John Wiley and Sons.
6.Complex Variables and Applications, (8/e), James Brown and Ruel Churchill, McGraw-Hill International (UK) Ltd
7.Discrete Mathematics, (6/e), Richard Johnsonbaugh, Pearson

Note: 1) Optional topics are exempted for end semester examination.

2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	1	1	3	0	0
CO 2	2	1	2	1	1	1	2	0	0
CO 3	2	1	2	1	1	1	3	0	0

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Title	**MATRIX ALGEBRA AND VECTOR CALCULUS**				
Course Code	**MAT3MN203**				
Type of Course	**Minor**				
Semester	III				
Academic Level	200 – 299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Basic Calculus and familiarity with Euclidian Geometry.				
Course Summary	This course covers fundamental concepts in vectors, vector calculus, and matrices. Students will explore vectors in 2-space and 3-space, including dot and cross products, as well as lines and planes in 3-space. The vector calculus portion includes vector functions, partial and directional derivatives, tangent planes, normal lines, curl, divergence, line integrals, double integrals, surface integrals, and triple integrals. Additionally, the course delves into matrix algebra, systems of linear equations, matrix rank, and the eigenvalue problem.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Discuss the geometry of Vectors in two- and three-dimensional spaces	U	C	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
CO2	Discuss the basic concepts of matrices, and evaluate the solutions of system of linear equations using matrices.	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Describe the idea of eigen values and eigen vectors.	U	C	Internal Exam/ Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (60)	Ext. Marks (70)
		Text: Advanced Engineering Mathematics, 6th Edition, Dennis G. Zill, Jones & Bartlett Learning LLC (2018) ISBN: 978-1-284-10590-2.		
I		**Vectors**	**11**	**Min. 15**
	1	Section 7.1-Vectors in 2 -Space (quick review)		
	2	Section 7.2-Vectors in 3-Space (quick review)		
	3	Section 7.3- Dot Product up to and including Example 5		
	4	Section 7.4- Cross Product up to and including Example 3		
	5	Section 7.5- Lines and Planes in 3-space- upto and including Example 6		
	6	Section 7.5- Lines and Planes in 3-space- From Planes: Vector Equation onwards		
II		**Vector Calculus**	**15**	**Min. 15**
	7	Section 9.1 – Vector Functions		
	8	Section 9.4 – Partial Derivatives		
	9	Section 9.5 – Directional Derivative – upto and including Example 4.		
	10	Section 9.5 – Functions of Three Variables onwards.		
	11	Section 9.6 – Tangent Planes and Normal Lines – upto and including Example 4		
	12	Section 9.6 – Topics from Normal Line onwards		
	13	Section 9.7 – Curl and Divergence -		
III		**Vector Calculus – contd.**		**Min. 15**
	14	Section 9.8 – Line Integrals – upto and including Example 5.		

	15	Section 9.10 – Double Integrals – upto and including Example 2	**12**	
	16	Section 9.13 – Surface Integrals – upto and including Example 4		
	17	Section 9.15 – Tripple Integrals (Examples 5 and 7 are optional)		
IV		**Matrices**		
	18	Section 8.1- Matrix Algebra.		
	19	Section 8.2-Systems of Linear Algebraic Equations. Up to and including Example 7	**10**	**Min. 15**
	20	Section 8.2-Systems of Linear Algebraic Equations. From Homogeneous Systems onwards till end omit chemical equations		
	21	Section 8.3 -Rank of a Matrix.		
	22	Section 8.8-The Eigenvalue Problem.-Up to and including Example 4		
V		**Open Ended**	**12**	
		Vector Spaces, Gram- Schmidt Orthogonalization (for instance, refer sections 7.6 and 7.7) Green's Theorem, Stocke's Theorem and Divergence Theorem (for instance, refer sections 9.12, 9.14 and 9.16) Complex Eigen Values Eigen Values and Singular Matrices. Eigen Values and Eigen Vectors of inverse of A Improper Integrals, Beta and Gama Functions		
		References: **1.** Calculus and Analytic Geometry (9th Edn), George B Thomas, Jr. and Ross L Finney, Addison -Wesley Publishing Company. 2. A Freshman Honors Course in Calculus and Analytic Geometry, Emil Artin (Author), Marvin J Greenberg (Foreword).		

		3. Advanced Engineering Mathematics (10^{th} Edn), Erwin Kreyszig, John Wiley and Sons. 4. Improper Riemann Integrals*:* Ioannis M. Roussos CRC Press by Taylor & Francis Group, LLC(2014) ISBN: 978-1-4665-8808-0 (ebook -pdf)		

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	1	3	2	3	3	3	1	2
CO 3	3	2	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B.Sc Mathematics Honours				
Course Code	MAT1MN104				
Course Title	**MATHEMATICAL LOGIC, SET THEORY AND COMBINATORICS**				
Type of Course	**Minor**				
Semester	I				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Higher Secondary Mathematics.				
Course Summary	This course explores mathematical logic, set theory, and combinatorics, covering fundamental ideas like propositions, logical equivalences, and quantifiers. It introduces set theory concepts such as sets, operations with sets, and cardinality. Additionally, it delves into functions and matrices, along with topics like permutations, combinations, and discrete probability in combinatorics.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse propositional logic and equivalences	An	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply set theory and operations	Ap	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Implement functions, matrices, and combinatorics	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text: Discrete Mathematics with Applications, (1/e), Thomas Koshy, Academic Press (2003), ISBN: 978-0124211803.				
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Mathematical Logic**	**15**	**Min. 15**
	1	1.1 Propositions: Conjunction, Disjunction.		
	2	1.1 Propositions: Converse, Inverse and Contrapositive.		
	3	1.1 Propositions: Biconditional Statement, Order of Precedence, Tautology, Contradiction and Contingency (Switching network and Example 1.16 are optional).		
	4	1.2 Logical Equivalences (Equivalent Switching Networks, Example 1.23, Fuzzy Logic and Fuzzy Decisions are optional)		
	5	1.3 Quantifiers (Example 1.28, De Morgan's Laws and example 1.29 are optional)		
	6	1.4 Arguments: Valid and Invalid arguments, (Example 1.33 is optional)		
II		**Set Theory**	**12**	**Min. 15**
	7	2.1 The Concept of a Set - up to and including example 2.7 (Example 2.6 is optional).		
	8	2.1 The Concept of a Set - finite and infinite sets (Topics from the Hilbert Hotel paradoxes onwards are optional).		
	9	2.2 Operations with Sets – up to and including example 2.21.		
	10	2.2 Operations with Sets – Cartesian product (Fuzzy sets, Fuzzy subsets and operations on fuzzy sets are optional).		
	11	2.4 The Cardinality of a Set (Theorem 2.2 and Algorithm subsets are optional).		
III		**Functions and Matrices**		

	12	3.1. The Concept of Functions - up to and including example 3.2	**10**	**Min. 15**
	13	3.1. The Concept of Functions – Piecewise definition, sum and product (Example 3.7 is optional).		
	14	3.2 Special Functions – up to and including example 3.13 (Proof of Theorems 3.1 and 3.2 are optional).		
	15	3.2 Special Functions- Characteristic function, Mod and Div functions (Theorem 3.3, Code dealing and The two Queens Puzzle are optional).		
	16	3.7 Matrices (Proof of theorem 3.12, algorithm product are optional).		
IV	**Combinatorics and Discrete Probability**		**11**	**Min. 15**
	17	6.1 The Fundamental Counting Principles (Example 6.7 is optional)		
	18	6.2 Permutations - up to and including example 6.13 (Proof of theorem 6.4 is optional)		
	19	6.2 Permutations - Cyclic permutations (Theorem 6.7 and Fibonacci numbers revisited are optional)		
	20	6.4 Combinations (Proof of theorem 6.10, example 6.22, theorem 6.12 and example 6.26 are optional)		
	21	6.8 Discrete Probability- up to and including example 6.49 (Examples 6.45 and 6.47 are optional)		
	22	6.8 Discrete Probability- Mutually exclusive events (Proof of theorem 6.20 is optional)		
V	**Open Ended**		**12**	
	1. Basic calculus concepts such as limits, continuity, differentiation and integration. Relations and Digraphs, Conditional Probability, Multiplication theorem of Probability, Dependent and Independent Events, Probability Distributions, Correlation and Regression, Bisection Method, Regula-Falsie Method, Gauss-Jordan Method.			

References:

1. Discrete Mathematics and Its Applications (7/e), Kenneth H. Rosen, McGraw-Hill, NY (2007).
2. Discrete Mathematics with Applications(4/e), Susanna S Epp, Brooks/ Cole Cengage Learning (2011).
3. Discrete Mathematics, Gary Chartrand, Ping Zhang, Waveland Press (2011).

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	3	2	3	1	2
CO 2	3	2	3	2	3	2	3	1	2
CO 3	2	1	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B.Sc Mathematics Honours				
Course Code	MAT2MN104				
Course Title	**GRAPH THEORY AND AUTOMATA**				
Type of Course	**Minor**				
Semester	II				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Higher Secondary Mathematics				
Course Summary	This course introduces students to Graph Theory and Automata, covering topics such as graphs, adjacency matrices, and isomorphic graphs in Module I. In Module II, it explores Eulerian and Hamiltonian graphs, including paths, cycles, and connected graphs. Module III focuses on Planar Graphs, Graph Coloring, Trees, and Spanning Trees. Finally, Module IV delves into Automata, covering concepts like formal languages, grammars, and finite state automata.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse Graph Structures and Properties	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply Algorithms to Eulerian and Hamiltonian Graphs	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Explore Formal Languages and Finite State Automata	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text: Discrete Mathematics with Applications, Thomas Koshy, Academic Press (2003), ISBN: 978-0124211803.				
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I	**Graphs**		**14**	**Min. 15**
	1	8.1 Graphs - Graph, Simple Graph (Example 8.3 is optional).		
	2	8.1 Graphs - Adjacency and Incidence, Degree of a Vertex, Adjacency Matrix (Example 8.5 and proof of Theorem 8.2 are optional).		
	3	8.1 Graphs – Subgraph of a Graph.		
	4	8.1 Graphs - Complete Graph, Cycle and Wheel Graphs (Fibonacci and Paraffins, Lucas and Cycloparaffins are optional).		
	5	8.1 Graphs - Bipartite graph, Complete Bipartite Graph, Weighted Graph (Graphs and Telecommunications, Graphs and Local Area Networks and A Generalised Handshake Problem are optional).		
	6	8.3 Isomorphic Graphs.		
II	**Eulerian and Hamiltonian graphs**		**10**	**Min. 15**
	7	8.4 Paths, Cycles and Circuits – Path, Independent Subsets of the Vertex set, Cycle and Circuit (Proof of theorem 8.3, 8.5, example 8.20 and example 8.21 are optional).		
	8	8.4 Paths, Cycles and Circuits – Connected Graphs (Proof of theorem 8.3, 8.5, example 8.20 and example 8.21 are optional).		
	9	8.5 Eulerian and Hamiltonian graphs- Eulerian Graph (Proof of theorem 8.7, example 8.26, Algorithm Eulerian graph, example 8.27, Algorithm Eulerian circuit, proof of theorem 8.8, example 8.31).		

	10	8.5 Eulerian and Hamiltonian graphs- Hamiltonian Graph (Knight's tour problem, example 8.34, Travelling Salesperson Problem, Example 8.35 are optional)		
III	**Planar Graphs and Trees**		**11**	**Min. 15**
	11	8.6 Planar Graphs- Planar Graph (Proofs of theorems 8.11 and 8.12 are optional).		
	12	8.6 Planar Graphs- Degree of a Rregion, Homeomorphic Graphs.		
	13	8.7 Graph Coloring- Graph Coloring, Chromatic Number, The Four-Color Problem (Example 8.27 is optional).		
	14	9.1 Trees- Trees (Proof of theorem 9.1 and 9.2 are optional).		
	15	9.2 Spanning Trees - Spanning Trees, Kruskal's Algorithm for a Spanning Tree.		
IV	**Automata**		**13**	**Min. 15**
	16	2.1 The Concept of Sets – Alphabet, Length of a Word, Language, Concatenation.		
	17	11.1 Formal Languages - Equality of Words, Concatenation of Languages (Examples 11.2, 11.3, 11.5 and Proof of Theorem 11.1 are optional).		
	18	11.1 Formal Languages – Kleene Closure.		
	19	11.2 Grammars – Grammars, Phase Structure Grammar.		
	20	11.2 Grammars – Derivation and Language.		
	21	11.3 Finite State Automata – up to and including Example 11.30 (Example 11.27 is optional).		
	22	11.3 Finite State Automata – Equivalent Finite State Automata up to and including example 11.35.		
V	**Open Ended Module**		**12**	
	Computer representation of graphs, minimal spanning trees, rooted trees, Digraphs and Finite state machines			

References:

1. Discrete Mathematics and Its Applications (7/e), Kenneth H. Rosen, McGraw-Hill, NY (2007).

2. Discrete Mathematics with Applications (4/e), Susanna S Epp, Brooks/ Cole Cengage Learning (2011).

3. A First Look at Graph Theory, John Clark and Allan Holton, Allied Publishers (1991).

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	2	1	1	0	3	0	0
CO 2	2	1	2	0	1	1	2	0	0
CO 3	2	1	2	0	1	1	3	0	0

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT3MN204
Course Title	**BOOLEAN ALGEBRA AND SYSTEM OF EQUATIONS**
Type of Course	**Minor**
Semester	III
Academic Level	200-299

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	MAT1MN203 and MAT2MN203
Course Summary	This course comprises four main modules: Lattice, Boolean Algebra, System of Equations, and Eigenvalue and Eigenvectors. Module I introduce concepts like ordered sets and lattices, while Module II explores Boolean Algebra and its applications. Module III covers linear systems of equations, including Gauss elimination and determinants. Finally, Module IV delves into Eigenvalue and Eigenvectors, offering insights into matrix properties and applications.

Course Outcome

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse Lattices and Boolean Algebra	E	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply Matrix Operations and Linear Systems	Ap	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO3	Investigate Eigenvalue and Eigenvector Problems	An	P	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	1. Theory and Problems of Discrete mathematics (3/e), Seymour Lipschutz, Marc Lipson, Schaum's Outline Series. 2. Advanced Engineering Mathematics (10/e), Erwin Kreyzsig, Wiley India.			
Module	**Unit**	**Content**	Hrs (48 +12)	**Ext. Marks (70)**
I		**Lattice (Text 1)**	12	Min 15
	1	14.2 Ordered set		
	2	14.3 Hasse diagrams of partially ordered sets		
	3	14.5 Supremum and Infimum		
	4	14.8 Lattices		
	5	14.9 Bounded lattices, 14.10 Distributive lattices		
	6	14.11 Complements, Complemented lattices		
II		**Boolean Algebra (Text 1)**	10	Min 15
	7	15.2 Basic definitions		
	8	15.3 Duality		
	9	15.4 Basic theorems		
	10	15.5 Boolean algebra as lattices		
	11	15.8 Sum and Product form for Boolean algebras		
	12	15.8 Sum and Product form for Boolean algebras - Complete Sum and Product forms		
III		**System of Equations (Text 2)**	14	Min 15
	13	7.1 Matrices, Vectors: Addition and Scalar Multiplication		
	14	7.2 Matrix Multiplication (Example 13 is optional)		
	15	7.3 Linear System of Equations- Gauss Elimination		
	16	7.4 Linear Independence- Rank of a matrix- Vector Space (Proof Theorem 3 is optional)		

	17	7.5 Solutions of Linear Systems- Existence, Uniqueness (Proof of Theorem 1, Theorem 2 and Theorem 4 are optional)		
IV	**Eigen Value and Eigen Vectors (Text 2)**		12	Min 15
	18	7.6 Second and Third Order Determinants- up to and including Example 1		
	19	7.6 Second and Third Order Determinants- Third order determinants		
	20	7.7 Determinants- Cramer's Rule (Proof of Theorem 1, Theorem 2, Theorem 3 and Theorem 4 are optional)		
	21	7.8 Inverse of a Matrix- Gauss- Jordan Elimination (Proof Theorem 1, Theorem 2, Theorem 3 and Theorem 4 are optional)		
	22	8.1 The Matrix Eigenvalue Problem- Determining Eigenvalues and Eigenvectors (Proof of Theorem 1 and Theorem 2 are optional)		
V	Open Ended Module		12	
	Relation on a set, Equivalence relation and partition, Isomorphic ordered sets, Well-ordered sets, Representation theorem of Boolean algebra, Logic gates, Symmetric, Skew-symmetric and Orthogonal matrices, Linear Transformation.			

References:

1. Howard Anton & Chris Rorres, Elementary Linear Algebra: Application (11/e) : Wiley

2. Ron Larson, Edwards, David C Falvo : Elementary Linear Algebra (6/e), Houghton Mi_in

Harcourt Publishing Company (2009)

3. Thomas Koshy - Discrete Mathematics with Applications-Academic Press (2003)

4. George Gratzer, Lattice theory: First concepts and distributive lattices. Courier Corporation (2009)

Note: 1) Optional topics are exempted for end semester examination. 2) Proofs of all the results are also exempted for the end semester exam.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	1	3	1	2
CO 2	3	2	3	2	3	2	3	1	2
CO 3	3	2	3	2	3	2	3	1	2

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Title	**MATRIX THEORY**			
Course Code	MAT1MN105			
Type of Course	**Minor**			
Semester	I			
Academic Level	100 – 199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Higher Secondary Algebra			
Course Summary	This course provides a comprehensive introduction to linear algebra, focusing on systems of linear equations, matrix algebra, determinants, and Euclidean vector spaces. Through a blend of theoretical concepts and practical applications, students will develop a strong foundation in linear algebra techniques and their uses in various fields.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the fundamental operations and concepts of systems of linear equations, including Gaussian elimination and elementary row operations, leading to an understanding of matrix algebra	U	C	Internal Exam/Assignment/ Seminar/ Viva / End Sem Exam
CO2	Apply the properties of determinants to evaluate them using cofactor expansions and row reduction techniques, and comprehend the relationships between matrices and determinants.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Explore the geometry and properties of Euclidean vector spaces, including norms, dot products, distances, orthogonality, and the cross product.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (48 +12)	Ext. Marks (70)
Text : Howard Anton and Chriss Rorres, Elementary Linear Algebra (11/e), Applications version, Wiley				
I		**System Of Linear Equations**	**12**	
	1	Section 1.1: -Introduction to systems of linear equations – up to and including Example 5		
	2	Section 1.1: - Rest of the section.		
	3	1.2 :- Gaussian Elimination – up to Example 5		
	4	Section 1.2; - From Example 5 onwards.		
	5	Section 1.3: - Matrices and Matrix Operations – up to and including Example 7.		
	6	Section 1.3; - Rest of the section.		
II		**Matrix Algebra**	**12**	
	7	Section 1.4: - Inverses; Algebraic Properties of Matrices - up to and including Example 6.		
	8	Section 1.4; - Properties of inverses onwards – up to and including Example 12.		
	9	Section 1.4: - Rest of the section.		
	10	Section 1.5; - Elementary matrices and a method for finding inverse (Proof of Theorem 1.5.3 is optional)		
	11	Section 1.6: - More on Linear systems and Invertible Matrices (Proofs of all the theorems are optional)		
	12	Section 1.7; - Diagonal, Triangular and Symmetric Matrices (Proof of theorem 1.7.1 is optional)		
III		**Determinants**	**12**	
	13	Section 2.1 :- Determinants by Cofactor expansions		
	14	Section 2.2; - Evaluating determinants by row reduction		
	15	Section 2.3: - Properties of determinants; Cramer's Rule – up to and including Theorem 3.2.5 (proofs of all the results are optional).		
	16	Section 2.3;- up to and including Example 7.		
	17	Section 2.3;- rest of the section.(proofs of all the results are optional)		
IV		**Euclidean Vector Spaces**	**12**	
	18	Section 3.1:- Vectors in 2-space, 3-space and n-space		
	19	Section 3.2:- Norm , dot product and distance in R^n (proofs of all the results are optional).		
	20	Section 3.3: - Orthogonality (proofs of all the results are optional).		
	21	Section 3.4:-The geometry of linear systems.		
	22	Section 3.5:-Cross product (Proof of Theorem 3.5.4 is optional)		
V		**Open Ended Module**	**12**	
	Matrix Transformations, Combinatorial approach to determinants, Rank of Matrix (From reference 1) Orthogonal Matrices (from reference 1)			

References:

1. Advanced Engineering Mathematics, 6th Edition, Dennis G. Zill, Jones & Bartlett Learning LLC (2018) ISBN: 978-1-284-10590-2.
2. Advanced Engineering Mathematics, Erwin Kreyzsig, 10th Edition, Wiley India.
3. Linear Algebra and its Applications: 3rd Edition, David C. Lay, Pearson Publications

Note: 1) Optional topics are exempted for end semester examination. (2) Proofs of all the results are exempted for external exam. (3) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	1	2	2	3	1	2
CO 2	3	2	3	1	2	2	3	1	2
CO 3	2	1	3	1	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours
Course Code	MAT2MN105
Course Title	**VECTOR SPACES AND LINEAR TRANSFORMATIONS**
Type of Course	**Minor**
Semester	II
Academic Level	100 – 199

Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60

Pre-requisites	Linear Algebra Course in Semester 1 - Vectors and Matrices
Course Summary	This course delves into advanced concepts in linear algebra, focusing on general vector spaces, basis and dimension, matrix transformations, and eigenvalues and diagonalization. The course builds on foundational linear algebra principles and explores their applications in higher-dimensional spaces and complex transformations.

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Define and apply concepts related to vector spaces, including understanding vector space axioms, subspaces, and the solution space of homogeneous systems.	U	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Explore the concepts of linear independence, coordinates, basis, and dimension within vector spaces, including computing basis vectors and understanding coordinate systems relative to a basis.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Analyse and apply matrix transformations, including basic transformations in R2R2 and R3R3, understanding properties of these transformations, and exploring concepts related to eigenvalues, eigenvectors, and diagonalization of Amatrices.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text: Howard Anton and Chriss Rorres, Elementary Linear Algebra (11/e), Applications version, Wiley

Module	Unit	Content	Hrs (60)	Ext. Marks (70)
I		**General Vector Spaces**	**12**	
	1	Section 4.1: -Real vector spaces – up to and including Example 8.		
	2	Section 4.1:- Rest of the section.		
	3	Section 4.2: - Subspaces (examples 7, 8 are optional) – up to and Example 10.		
	4	Section 4.2: - From Example 10 to Example 15 (proof of theorem .4.2.3 is optional)		
	5	Section 4.2: - Rest of the section (Linear transformation view point is optional)		
II		**Basis And Dimension**	**12**	
	6	Section 4.3: - Linear independence – up to and including Theorem 4.3.3		
	7	Section 4.3: - Rest of the section (proofs of all the results are optional).		
	8	Section 4.4:- Coordinates and Basis -up to and including Example 5		
	9	Section 4.4: - rest of the section from Theorem 4.4.1.		
	10	Section 4.5:-Dimension – up to and including Example 3.		
	11	Section 4.5: - Rest of the section from Example 3 (proofs of all the theorems are optional).		
III		**Matrix Transformations**	**12**	
	12	Section 4.9: - Basic matrix transformations in R^2 and R^{3-} Reflection operators, Projection operators		
	13	Section 4.9:- Rotation Operators – Rotation in R^3		
	14	Section 4.9:- Rest of the section.		
	15	Section 4.10: - Properties of Matrix Transformations – up to and including Example 4.		
	16	Section 4.10:- rest of the section (proofs of theorems are optional)		
	17	Section 4.11: - Geometry of Matrix Operators on $R^{2\,(}$proof of Theorem 4.11.2 is optional)		
IV		**Eigen Values and Diagonalization**	**12**	
	18	Section 5.1:- Eigen values and eigen vectors – up to Theorem 5.1.3		
	19	Section 5.1; -From Theorem 5.1.3 to Example 7 (including)		
	20	Section 5.1: - Rest of the section (Eigen values of general linear transformation is optional)		
	21	Section 5.2: - Diagonalization – up to and including Example 4 (proofs of theorems are optional)		
	22	Section 5.2; - Rest of the section (Geometric and algebraic multiplicity are optional)		
V		**OPEN ENDED**	**12**	
		Rank space, Null space and Rank- Nullity theorem, General Linear transformations and Matrix representation, Eigen values of general linear transformation, Geometric and algebraic multiplicity.		

References:

1 Advanced Engineering Mathematics, 6th Edition, Dennis G. Zill, Jones & Bartlett Learning LLC (2018) ISBN: 978-1-284-10590-2.
2. Advanced Engineering Mathematics, Erwin Kreyzsig, 10th Edition, Wiley India.
3. Linear Algebra and its Applications: 3rd Edition, David C. Lay, Pearson Publications

Note: 1) Optional topics are exempted for end semester examination. (2) Proofs of all the results are exempted for external exam. (3) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	1	3	1	1	1	3	0	0
CO 2	2	1	2	1	1	1	2	0	0
CO 3	2	1	3	1	1	1	3	0	0

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT3MN205			
Course Title	**OPTIMIZATION TECHNIQUES**			
Type of Course	**Minor**			
Semester	III			
Academic Level	200 - 299			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Basic understanding of linear algebra and introductory optimization concepts.			
Course Summary	This course provides a comprehensive exploration of linear programming and optimization techniques, focusing on graphical methods, the simplex method, and specialized problems like transportation and assignment. Students will gain practical skills in formulating, solving, and analyzing linear programming models, with applications in various optimization scenarios.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Describe the fundamental properties and types of linear programming models, distinguishing between maximization and minimization models, and explain various methods used for solving linear programming problems including graphical methods.	U	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Apply the simplex method to solve both maximization and minimization linear programming problems, compare the graphical method with the simplex method in terms of efficiency and applicability, and demonstrate problem-solving skills through worked-out examples.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Evaluate and solve transportation and assignment problems using specific techniques such as the North-West corner method, Least Cost cell method, Vogel's approximation method, and the Hungarian method, while also comparing the transportation model with general linear programming models.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam

Detailed Syllabus:

Text book	Operations Research (2/e), P Rama Murthy ,New Age International Publishers			
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Linear Programming Models: (Graphical Method)**	**10**	**Min 15**
	1	Section 2.1- Introduction, 2.2- Properties of Linear Programming Model		
	2	Section 2.3-Maximization Models		
	3	Section 2.4- Minimization Models		
	4	Section 2.5- Methods for the Solution of a Linear Programming Problem (up to Problem 2.9)		
	5	Section 2.5- Methods for the Solution of a Linear Programming Problem (From Problem 2.9)		
II		**Linear Programming Models: (Simplex Method)**	**13**	**Min 15**
	6	Section 3.1- Introduction, 3.2- Comparison Between Graphical and Simplex Methods		
	7	Section 3.3- Maximisation Case		
	8	Section 3.4- Minimisation Case		
	9	Section 3.5- Worked Out Problems- Maximization		
	10	Section 3.7- Minimisation Problems		
III		**Linear Programming Models: (Two Phase Simplex Method and Transportation Problem)**	**11**	**Min 15**
	11	Section 3.8- Mixed Problems		
	12	Section 3.10- Artificial Variable Method or Two Phase Method		
	13	Section 3.11- Degeneracy in Linear Programming Problems		
	14	Section 4.1 , 4.2 Transportation model		
	15	Section 4.3 – Comparison between Transportation model and general linear programming model, 4.4- Approach to solution to a transportation problem by Transportation Algorithm.		
IV		**Linear Programming Models: (Transportation Problem and Assignment Problem)**	**14**	
	16	Section 4.4.3- Basic feasible solution by North -West corner method		**Min 15**
	18	Section 4.4.4- Solution by Least Cost cell method		
	19	Section 4.4.5- Solution by Vogel's approximation method		
	20	Section 4.4.6- Optimality test- Stepping stone method (Modified distribution method is in open ended module)		
	21	Section 5.1, 5.2 – Assignment model,		
	22	Section 5.4- Approach to solution-Hungarian method(Other methods of solution are optional)		
V		**Open Ended Module**	**12**	
	Simplex method special Cases- Alternate solution. Unbound Solutions ,Problem with Unrestricted Variables Transportation model- Modified distribution method Game theory			

References :

1. KV Mittal and C Mohan, Optimization methods in Operations research and system analysis(3/e)

2. Kanti Swarup, PK Gupta and Manmohan, Operations Research(20/e)

Note: 1) Optional topics are exempted for end semester examination. (2) Proofs of all the results are exempted for external exam. (3) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	2	3	2	3	2	3	1	2
CO 3	3	2	3	2	3	2	3	1	2

Correlation Levels:

Level	**Correlation**
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT1MN106			
Course Title	**PRINCIPLES OF MICRO ECONOMICS**			
Type of Course	**Minor**			
Semester	I			
Academic Level	100 - 199			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Higher Secondary Mathematics			
Course Summary	Explore market behaviour in Demand and Supply Analysis, focusing on utility, the law of demand, supply, and elasticity, and delve into Cost and Revenue Functions to understand cost structures, revenue functions, and their relation to demand elasticity. Explore the Theory of Consumer Behaviour to comprehend utility maximization and rational consumer choices, then apply economic optimization techniques using derivatives in Economic Applications to optimize functions and solve constrained optimization problems efficiently.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse the factors affecting demand and supply and determine market equilibrium.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Apply the concepts of cost and revenue functions to analyze short-run and long-run production decisions.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Evaluate economic functions and optimize using derivatives and Lagrange multipliers.	E	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text Book		1. Principles Of Microeconomics, 15th revised edition H.L.Ahuja, S.Chand 2. Introduction to Mathematical Economics, 3rd edition, Edward.T.Dowling, Schaum's Outline series, TMH		
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Demand and Supply Analysis Text(1)** **(Relevant sections of chapter 5 and 7)**	**13**	
	1	Utility and demand, the meaning of demand and quantity demanded		
	2	The law of demand- demand curve- market demand curve		
	3	Reasons for the law of demand- slope of a demand curve		
	4	Shift in demand- demand function and demand curve		
	5	The meaning of supply- supply function- law of supply		
	6	Slope of a supply curve- shift in supply- market equilibrium		
	7	Price elasticity if demand- measurement of price elasticity- arc elasticity of demand- cross elasticity of demand		
II		**Cost and Revenue Functions Text (2)** **(Relevant sections of chapter 19and 2)**	**12**	
	8	Cost function- Average Cost(AC) and Marginal Cost(MC)		
	9	Short run costs: Total Fixed and Variable Cost- Short Run average cost curve- Average Variable Cost(AVC)- Relationship between AVC and Average product- Average Total Cost- Marginal Cost		
	10	Long run costs: Long Run Average Cost Curve- relationship of Long run Average Cost Curve(LAC) and Long run Marginal Cost Curve(LMC) with SAC and SMC		
	11	Revenue function, Marginal Revenue(MR) and Average Revenue(AR)		
	12	Relation between MR, AR and elasticity of demand		
III		**Theory Of Consumer Behaviour Text(1)** **(Relevant sections of chapter 9 and 11)**	**10**	
	13	Cardinal utility analysis- the law of diminishing marginal utility- illustration of law of diminishing marginal utility		
	14	The law of equi-marginal Utility		
	15	Indifference curves- ordinal utility		
	16	Marginal rate of substitution- properties of indifference curves		
IV		**Economic Applications of Derivatives Text (2)** **(Chap-4:sec.4.7&4.8 ,Chap 5,Chap6:sec.6.1-6.6)**	**13**	
	17	Economic application of derivatives- marginal, average, total concepts		

	18	Optimizing economic function		
	19	Functions of several variables and partial derivatives		
	20	Second order partial derivatives, optimization of multivariable function		
	21	Constrained optimization with Lagrange multipliers		
	22	Significance of Lagrange multipliers, total differential		
V	**Open Ended**		**1**	
	Derivative of a function, first order derivative, second order derivative, local maxima, local minima, optimization			

References:
1. RGD Allen, Mathematical analysis for economists Macmillan
2. Geoff Renshaw: Maths for Economics(3/e) Oxford University Press, N.Y. (2012) ISBN 978-0-19-96212-4

Note: 1) Proofs of all the results are exempted for external exam. (2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	2	3	2	3	1	2
CO 2	2	1	3	2	3	2	3	1	2
CO 3	3	2	3	1	3	2	3	1	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours				
Course Code	MAT2MN106				
Course Title	**OPTIMIZATION TECHNIQUES IN ECONOMICS**				
Type of Course	**Minor**				
Semester	II				
Academic Level	100 - 199				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	4	-	60	
Pre-requisites	Higher Secondary Mathematics				
Course Summary	This course examines the causes, effects, and measures of income inequality, including its measurement using tools like the Lorenz curve and Gini ratio. It explores calculus of several variables, focusing on directional derivatives, gradients, and optimization techniques, both constrained and unconstrained, with applications in economic contexts such as profit maximization and monopolistic practices. Additionally, the course covers input-output analysis, introducing technological coefficient matrices and models to analyse economic equilibrium and production functions.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse the causes and effects of income inequality and evaluate the measures used to reduce it.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Apply the principles of calculus to optimize economic functions without constraints.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Evaluate constrained optimization problems using appropriate mathematical techniques.	E	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text book:	1. M.L.Jhingan: Micro Economic Theory(6/e), Vrinda publications 2. Carl.P.Simon, Lawrence Blume: Mathematics for Economists W.W. Nortan& Company, Inc(1994) ISBN 0-393-95733-O 3.Mehta- Madnani: Mathematics for Economics Revised Edn S. Chand.			
Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Inequalities in Income Text (1)(Chapter 47)**	**10**	
	1	Inequalities in Income- Causes of inequality		
	2	Effects of inequality – measures to reduce inequality		
	3	Measurement of inequality of income- Lorenz curve Gini ratio		
II		**Calculus of Several Variables and Unconstrained Optimization Text(2)(Chap:14:sec.14.6,14.7,14.8,Chap 17: sec.17.1-17.5)**	**14**	
	4	Directional derivatives and gradients, the gradient vector		
	5	Approximation by differential Jacobian derivative		
	6	The chain rule, higher order derivative		
	7	Second order derivatives and Hessians		
	8	Young’s theorem, economical applications		
	9	Unconstrained optimization: definitions, first order conditions, second order conditions		
	10	Global maxima and minima, global maxima of concave functions		
	11	Economic applications- profit maximising firm- discriminating Monopolist		
	12	Least square analysis		
III		**Constrained Optimization Text (2) (Chap 18: sec.18.1-18.7)**	**12**	
	13	First order conditions: objective function, constraint functions, examples		
	14	Equality constraints, two variables and one equality constraints, several equality constraints		
	15	Ineuality constraints, one inequality constraints, several inequality constraints		

	16	Mixed constraints, constrained minimization problems		
	17	Kuhn-Tucker formulation, examples and applications		
IV		**Input output analysis Text(3) (Chap 19 :sec.19.1-19.7,19.9,19.11,19.13)**	**12**	
	18	Introduction- assumption- technological coefficient matrix		
	19	Closed and open input output model- coefficient matrix and open model		
	20	The Hawkins- Simon conditions- solution for two industries		
	21	Determination of equilibrium of prices- coefficient matrix and closed model		
	22	The Leontief production function- limitation of input output analysis		
V		**Open Ended Module**	**12**	
		The total derivative,The chain rule,Level curves and their tangents,Concave and Convex Functions		

References:
1. R G D Allen: Mathematical analysis for economists Macmillain
2. A C Chiang& K Wainwright: Fundamentals of Mathematical Economics(4/e) McGraw Hill
3. Michael D Intriligator: Mathematical Optimization and Economic Theory Classics in Applied Mathematics, SIAM(2002)

Note: 1) Proofs of all the results are exempted for external exam. (2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	3	2	2	1	3	2	1
CO 2	3	2	3	1	2	1	3	1	1
CO 3	2	2	3	1	2	1	3	1	1

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Code	MAT3MN206			
Course Title	**APPLIED MATHEMATICS FOR ECONOMIC ANALYSIS**			
Type of Course	**Minor**			
Semester	III			
Academic Level	200 - 299			
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours
	4	4	-	60
Pre-requisites	Higher Secondary Mathematics			
Course Summary	This course covers differential and difference equations and their economic applications. It explores production functions, including the law of variable proportions, isoquants, and optimization of Cobb-Douglas and CES functions. Additionally, it introduces econometrics, focusing on regression analysis and econometric methodology.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply differential and difference equations to model and solve economic problems.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Analyse production functions to understand the relationship between inputs and outputs, including optimization techniques.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Evaluate econometric models to interpret statistical relationships and economic variables.	E	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)
# - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Detailed Syllabus:

Text Books	1. Edward.T.Dowling: Introduction to mathematical Economics, Schaum's Outline series, 3rd edition TMH 2. SP singh, AP Parashar, HP singh: Econometrics and Mathematical Economics, S.Chand 3. Damodar N Gujarati and Sangeeta: Basic Economics(4/e) TMH Indian Reprint, 2008

Module	**Unit**	**Content**	**Hrs (48 +12)**	**Ext. Marks (70)**
I		**Differential and Difference Equations Text(1) (Chapter 16, 17)**	**12**	
	1	Differential Equation: definition and concepts		
	2	First order linear differential equation, exact differential equations, integrating factors		
	3	Separation of variables, Economic applications		
	4	Difference equations: definitions and concepts		
	5	First order linear difference equations, Economic applications		
	6	The Cobweb Model, the Harrod model		
II		**The Production Function Text (2) (Chapter 14: sec 14.1-14.9)**	**10**	
	7	Meaning and nature of production function, the Law of Variable Proportions		
	8	Isoquants, Marginal Rate of Technical Substitution(MRTS)		
	9	Producers' equilibrium, expansion of path.		
	10	The elasticity of substitution, ridge lines and Economic region of production		
III		**The Production Function(contd.) and Euler's theorem Text(1&2) (Chapter 14: sec 14.10-14.3 of text 2, Chap 6: sec 6.9 &6.10 of text 1)**	**14**	
	11	Euler's theorem(Statement only), Euler's theorem and homogenous production function		
	12	Cobb Douglas production function, properties, limitations		
	13	CES production function, properties, advantages, limitations		
	14	Returns to scale, Cobb Web theorem		
	15	Optimization of Cobb Douglas, Optimization of CES production Function		
IV		**Econometrics Text(3) (Pages 1 to 59)**	**12**	
	16	Introduction to econometrics		
	17	Statistical v/s deterministic relationships, regression v/s correlation		
	18	Types of data, Measurements of Economic variables		
	19	Methodology of Econometrices		
	20	Two variable regression analysis		
	21	Population regression function (PRF), Stochastic specification of PRF		
	22	Sample regression function (SRF)		

V	Open Ended Module	12	
	Matrix solution of Simultaneous Differential and Difference equations,Differentiation of Exponential and Logarithamic functions		

References:

1.RGD Allen Mathematical Analysis for Economists MacMillan
2.AC Chiang & K Wainwright: Fundamentals of Mathematical Economics (4/e,) McGraw Hill
3.Jeffrey.M. Wooldridge: Introductory Econometrics: A modern Approach (6/e), Cengage learning 2016

Note: 1) Proofs of all the results are exempted for external exam. (2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	1	3	2	3	2	3	1	2
CO 2	3	1	3	2	3	2	3	1	2
CO 3	2	3	3	2	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

DOUBLE MAJOR COURSES

(Courses other than listed in the pathways 1 – 4)

Programme	B. Sc. Mathematics Honours			
Course Title	**ELEMENTARY LINEAR ALGEBRA**			
Type of Course	**Double Major**			
Semester	IV			
Academic Level	200 – 299			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus			
Course Summary	After introducing the basic notions in set theory, the course develops into the construction of the Real number system. Thereafter Real functions are introduced and the notion of limit is developed in a rigorous way..			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse the properties and relationships within vector spaces, eigenvalues, eigenvectors, and orthogonality, demonstrating proficiency in identifying subspaces, bases, eigen decomposition, and orthogonal sets.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	Apply techniques such as finding null spaces, column spaces, solving characteristic equations, diagonalizing matrices, and performing QR factorization.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	Evaluate the significance and utility of results such as Spectral theorem and singular value decomposition in various applications	E	M	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45+30)	External Marks (70)
Text	Linear Algebra and its Applications, Third Edition, David .C. Lay, Pearson Publications.			
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**
I		**Vector Spaces**	**14**	**20**
	1	Section 4.1 – Vector Spaces and Subspaces		
	2	Section 4.2 – Null Spaces, Column Spaces and Linear Transformations.		
	3	Section 4.2 – The Column Space of a Matrix.		
	4	Section 4.2 – Kernel and Range of a Linear Transformation.		
	5	Section 4.3 – Linearly Independent; Bases.		
	6	Section 4.3 – Bases for Nul A and Col A.		
		Continue the study of sections 4.5 to 4.6 in the practicum mode as instructed.		
II		**Eigen Values and Eigen Vectors**	**11**	**20**
	7	Section 5.1 – Eigen Vectors and Eigen Values.		
	8	Section 5.2 – The Characteristic Equation.		
	9	Section 5.2 – Similarity of Matrices.		
	10	Section 5.3 - Diagonalization		
	11	Section 5.3 – Diagonalizing Matrices		
III		**Orthogonality**	**10**	**15**
	12	Section 6.1 – Inner Product, Length and orthogonality.		
	13	Section 6.1 – Orthogonal Vectors (Orthogonality)		
	14	Section 6.2 – Orthogonal Sets.		
	15	Section 6.2 – Orthonormal sets.		
	16	Section 6.4 – The Gram – Schmidt Process – Orthonormal Bases		
	17	Section 6.4 – QR Factorization of Matrices		
IV		**Singular Value Decomposition**	**10**	**15**
	18	Section 7.1 – Diagonalization of Symmetric Matrices.		
	19	Section 7.1 – The Spectral Theorem.		
	20	Section 7.2 - Quadratic Forms - Change of Variable and Geometric View of Principal Axes omitted.		
	21	Section 7.2 – Quadratic Forms – Classifying Quadratic Forms.		
	22	Section 7.4 - The Singular Value Decomposition – (applications are omitted for exam)		
V		Practicum: The goal is for the students to learn the following selected topics via self-study and group activities. The lecturer may assist by running and overseeing group discussions and class seminars and referring library books for self-study and note preparations.	**30**	**-**

		Chapters 1 to 3 of the text for giving an introduction and motivation to the concepts of vector spaces, subspaces, Linear dependence and independence, Linear Transformations and their relations with matrices.		
		Section 4.4 – Coordinate Systems.		
		Section 4.4 – The Coordinate Mapping.		
		Section 4.5 – The Dimension of a Vector Space.		
		Section 4.5 – Subspaces of a Finite Dimensional Space.		
		Section 4.6 – Rank.		
		Section 4.6 – The Rank Theorem.		

References

1. Elementary Linear Algebra: Application Version,11/e, Howard Anton & Chris Rorres Wiley
2. Algebra Done Right, 3/e, Sheldon Axler, Springer Nature,2015.
3. Introduction to Linear Algebra, 6/e, Gilbert Strang, Wellesley-Cambridge Press.
4. Basic Linear Algebra, 2/e, T. S. Blyth and E.F. Robertson, Springer, 2002.
5. Linear Algebra, 2/e, Hoffman K and Kunze R, Prentice Hall of India,1991.
6. Bretscher, Otto. *Linear algebra with applications*. Vol. 52. Eaglewood Cliffs, NJ: Prentice Hall, 1997.
7. Blyth, Thomas Scott, and Edmund F. Robertson. *Basic linear algebra*. Springer Science & Business Media, 2013.

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Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	2	3	1	3	2	3	1	2
CO 2	3	3	3	2	3	1	3	2	3	1	2
CO 3	3	3	2	3	3	1	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Title	**REAL ANALYSIS**			
Type of Course	**Double Major**			
Semester	IV			
Academic Level	200 – 299			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	1. Mathematical Logic and necessary exposure to set theory. 2. Basic Calculus			
Course Summary	After introducing the basic notions in set theory, the course develops into the construction of the Real number system. Thereafter Real functions are introduced and the notions of limit and continuity are developed.			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Analyse sequences and their limits, apply limit theorems, and demonstrate understanding of monotone sequences and apply the Bolzano Wierstrass theorem and its implications on sub sequences.	An	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	To apply the concepts of continuous functions, including combinations of continuous functions and their behaviour on intervals. Also demonstrate proficiency in determining uniform continuity and its applications.	Ap	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	To evaluate Riemann integrals, identify Riemann integrable functions, and apply the Fundamental Theorem of Calculus. Demonstrate proficiency in solving problems related to L'Hospital's Rule, Taylor's Theorem, Pointwise and Uniform Convergence, and Interchange of Limits.	E	P	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text	Introduction to Real Analysis, 4/e, Robert G Bartle, Donald R Sherbert John Wiley & Sons (2011)				
Module	**Unit**	**Content**	**Hrs (45+30)**	**External Marks (70)**	**Internal Marks**
I		**Sequences and Limits**	**12**	**20**	**10**
	1	Section 3.1 – Sequences and their limits.	3		
	2	Section 3.2 – Limit theorems.	3		
	3	Section 3.3 – Monotone sequences – Euler's number introduction only.	2		
	4	Section 3.4 – Sub sequences and the Bolzano Wierstrass theorem – 3.4.1 to 3.4.9 (second proof of Theorem 3.4.8 is optional)	2		
	5	Section 4.1- Limit of functions (Proofs included in Practicum).	1		
	6	Section 4.2: Limit theorems (Proofs included in Practicum).	1		
II		**Continuous Functions**	**10**	**20**	
	7	Section 5.1 – Continuous functions.	2		
	8	Section 5.2 – Combinations of continuous functions.	2		
	9	Section 5.3 – Continuous functions on Intervals - 5.3.1 to 5.3.5	2		
	10	Section 5.3 – from 5.3.7 to 5.3.10	2		
	11	Section 5.4 – Uniform Continuity - 5.1.1 to 5.4.8	2		
III		**Differentiation**	**10**	**20**	
	12	Section 6.1 – The Derivative – 6.1.1 to 6.1.4	2		
	13	Section 6.1 – from 6.1.5 to 6.1.7	2		
	14	Section 6.2- The Mean Value Theorem - 6.2.1 to 6.2.4	2		
	15	Section 6.2- from 6.2.5 to 6.2.9	2		
	16	Section 6.2- from 6.2.10 to 6.2.13	2		
IV		**The Riemann Integral**	**13**	**15**	
	17	Section 7.1 –Riemann Integral –7.1.1 to 7.1.4 (a)	2		
	18	Section 7.1 – from 7.1.5 to 7.1.7	2		
	19	Section 7.2 – Riemann Integrable functions – 7.2.1 to 7.2.5 (example 7.2.6 is optional)	2		
	20	Section 7.2 – from 7.2.7 to 7.2.13	2		
	21	Section 7.3 – The Fundamental Theorem – 7.3.1 to 7.3.9	3		
	22	Section 7.3 – The Fundamental Theorem – 7.3.10 to 7.3.18	2		

V	**Practicum:** The goal is for the students to learn the following selected topics in 15 practicum sessions of two hours each via self-study and group activities. The lecturer may assist by running group discussions and supervising class seminars and referring library books for self-study and note preparations.	**30**	**-**	**20**
	Session 1: Sets and Functions – Section 1.1			
	Session 2: Mathematical Induction – Section 1.2			
	Session 3: Finite and Infinite Sets – Section 1.3			
	Session 4: The Algebraic and Order Properties of R-Section 2.1			
	Session 5: Absolute Value and the Real Line - Section 2.2			
	Session 6: The Completeness property of R- Section 2.3			
	Session 7: Intervals - Section 2.5			
	Session 8: The Cauchy Criterion – Section 3.5			
	Session 9: Introduction to Infinite Series - Section 3.7			
	Session 10: Section 4.1 – proofs as in Module I			
	Session 11: Section 4.2 - proofs as in Module I			
	Session 12: L'Hospital's Rules - Section 6.1			
	Session 13: Taylor's Theorem - Section 6.4			
	Session 14: Pointwise and Uniform Convergence -Section 8.1			
	Session 15: Interchange of Limits - Section 8.2			
References	1. Tom.M.Apostol, Calculus I, Wiley & Sons. 2. Tom.M.Apostol, Mathematical Analysis, 2/e, Addison-Wesley. 3. Richard R Goldberg, Methods of Real Analysis, 2/e, Wiley 4. Raymond L Wilder, Introduction to the Foundations of Mathematics,2/e, John Wiley & Sons			

Note: 1) Optional topics are exempted for end semester examination (2) 70 external marks are distributed over the first four modules subjected to a minimum of 15 marks from each module.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	2	3	1	3	2	3	1	2
CO 2	3	3	2	3	3	1	3	2	3	1	2
CO 3	3	3	3	3	3	1	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	B. Sc. Mathematics Honours			
Course Title	**COMPLEX ANALYSIS**			
Type of Course	**Double Major**			
Semesters	5/6			
Academic Level	300 - 399			
Course Details	Credit	Lecture/Tutorial per week	Practicum per week	Total Hours
	4	3	2	75
Pre-requisites	Basic algebra of numbers, basic Calculus and basic proof techniques.			
Course Summary	This course discusses the concepts of complex numbers. Module-I discusses complex numbers and their properties, complex plane, polar form of complex numbers, powers and roots and sets points in the complex plane. Module-II discusses the complex functions, special power functions such as z^n and $z^{1/n}$. The third module includes the concepts of limits and continuity, Differentiability and analyticity, Cauchy Riemann equations and Harmonic conjugates. Module-IV discusses elementary functions such as Exponential functions, Logarithmic functions, Trigonometric and hyperbolic functions. Final module is an open ended part that includes linear mappings, reciprocal functions, Branch cuts and points, etc...			

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understanding the concepts of Complex numbers and their properties.	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO2	To gain a thorough understanding of the algebraic, geometric, and topological aspects of the complex number system, as well as complex variable functions, their limits and continuity.	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
CO3	To understand harmonic functions and their relationship with analytic functions. Also to understand a few simple analytic functions of complex analysis and their properties.	Ap	C	Internal Exam/ Assignment/ Seminar/ Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Text	Complex Analysis (Third Edition): Dennis G. Zill & Patric D. Shanahan			
Module	**Unit**	**Content**	**Hrs (75)**	**External Marks (70)**
I		**Module I**	**11**	**15**
	1	Section 1.1 Complex Numbers and Their Properties		
	2	Section 1.2 Complex Plane		
	3	Section 1.3 Polar Form of Complex Numbers-up to and including Example 2.		
	4	Section 1.3 Polar Form of Complex Numbers- All the topics after Example 2.		
	5	Section 1.5 Sets of Points in Complex Plane- up to and including Example 2.		
	6	Section 1.5 Sets of Points in Complex Plane -All the topics after Example 2.		
II		**Module II**	**12**	**15**
	7	Section 2.1 Complex Functions		
	8	Section 2.2 Complex Functions as Mappings- up to and including Example 4.		
	9	Section 3.1 Limits and Continuity-Limits (All the topics in 3.1.1)		
	10	Section 3.1 Limits and Continuity-Continuity (Topics in 3.1.2, up to Example 7.)		
	11	Section 3.1 Limits and Continuity-Continuity (Theorem 3.1.4 to up to and including a bounding property.		
III		**Module III**	**10**	**20**
	12	Section 3.2 Differentiability and Analyticity- up to and including Example 2.		
	13	Section 3.2 Differentiability and Analyticity- All the topics after Example 2.		
	14	Section 3.3 Cauchy-Riemann Equations-up to and including Theorem 3.3.2		
	15	Section 3.3 Cauchy Riemann Equations:-All the topics after Theorem 3.3.2.		
	16	Section 3.4 Harmonic Functions		
IV		**Module IV**	**12**	**20**
	17	Section 5.2 Complex Integrals-up to and including Example 2		
	18	Section 5.2 Complex Integrals- All the topics after Example 2		
	19	Section 5.3 Cauchy- Goursat Theorem-up to and including Example 4.		
	20	Section 5.3 Cauchy- Goursat Theorem-All the topics after Example 4.		
	21	Section 5.4 Independence of Path- up to and including Example 1.		
	22	Section 5.4 Independence of Path- All the topics after Example 1.		
V		**Practicum**	**30**	
	Section 5.5 Cauchy's Integral Formulas and Their Consequences- Cauchy's Two Integral Formulas (All the topics in 5.5.1)			
	Section 5.5 Cauchy's Integral Formulas and Their Consequences- Some Consequences of the Integral Formulas (All the topics in 5.5.2)			

	Section 6.1 Sequences and Series- up to and including Example 4.		
	Section 6.1 Sequences and Series- All the topics after Example 4.		
	Section 6.2 Taylor Series-up to and Excluding Theorem 6.2.4.		
	Section 6.2 Taylor Series-From Theorem 6.2.4 to Example 3.		
	Section 6.3 Laurent Series-up to and including Example 1.		
	Section 6.3 Laurent Series- All the topics after Example 1.		
	Section 6.4 Zeros and Poles- Proofs of Theorem 6.4.1, Theorem 6.4.2, Theorem 6.4.3 are omitted.		
	Section 6.5 Residues and Residue Theorem-up to and including Example 3.		
	Section 6.5 Residues and Residue Theorem-All the topics after Example 3.		
	Section 6.6 Some Consequences of the Residue Theorem- Evaluation of Real Trigonometric Functions (up to and including example1 of 6.6.1)		
	Section 6.6 Some Consequences of the Residue Theorem- Evaluation of Real Improper Integrals(up to and including Example 2)		
	Section 6.6 Some Consequences of the Residue Theorem- Theorem 6.6.1 and Example 3.		
	Section 6.6 Some Consequences of the Residue Theorem- Theorem 6.6.2 and Example 4.		

References

	1	Brown, James Ward, and Ruel V. Churchill. Complex variables and applications. McGraw-Hill,, 2009.
	2	Stein, Elias M., and Rami Shakarchi. Complex analysis. Vol. 2. Princeton University Press, 2010.
	3	Burckel, Robert B. An Introduction to Classical Complex Analysis: Vol. 1. Vol. 64. Birkhäuser, 2012.
	4	Hormander, Lars. An introduction to complex analysis in several variables. Elsevier, 1973.
	5	Priestley, Hilary A. Introduction to complex analysis. OUP Oxford, 2003.
	6	Silverman, Richard A. Introductory complex analysis. Courier Corporation, 2013.

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1	2	3	1	3	2	3	1	2
CO 2	3	3	2	3	3	1	3	2	3	1	2
CO 3	3	3	2	3	3	1	3	2	3	1	2

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

Programme	BSc Mathematics Honours				
Course Title	**INTRODUCTION TO PYTHON AND SCIENTIFIC COMPUTING**				
Type of Course	**SEC – Double Major**				
Semester	IV				
Academic Level	200-299				
Course Details	Credit	Lecture/Tutorial per week	Practical per week	Total Hours	
	4	3	2	75	
Pre-requisites	(1) Basic knowledge to start a desktop/laptop computer. (2) A basic course in calculus with an understanding of differential and integral calculus. (3) A basic course in matrix algebra (higher secondary level)				
Course Summary	This course introduces the fundamentals of Python with a focus towards mathematical programming. Getting started with Python, Various Interfaces, Variables, Modules, Loops, Lists, Tuples, Functions, Branching, Input and Output, Arrays and Plotting, Dictionaries and Strings and finally Classes and Object-Oriented Programming are introduced. Using the Python programming structure, an introduction to the advanced mathematics software SageMath is given in the last part of the course. Various practical problems making use of concepts from calculus and linear algebra are to be solved using the SageMath software in the open-ended practical part so that the students will come to know how to apply software to answer and compute typical problems from these subjects.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand Basics of Python Programming.	U	C	Internal Exam/ Assignment/ Practical Assessment / Viva/ End Sem Exam
CO2	Intermediate Level Concepts such as Object-Oriented Programming.	An	P	Internal Exam/ Assignment/ Practical Assessment / Viva/ End Sem Exam
CO3	Scientific Computation using SageMath.	E	P	Internal Exam/ Assignment/ Practical Assessment / Viva/ End Sem Exam
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Textbook	1. Introduction to Scientific Programming with Python, Joakim Sundnes, Simula SpringerBriefs on Computing, 2020, ISBN: 978-3-030-50356-7. Open Access: https://link.springer.com/book/10.1007/978-3-030-50356-7 2. Sage for Undergraduates, 2nd Ed., Gregory V. Bard, 2022, American Mathematical Society, 2022. ISBN: 978-1470411114. 2014 Online Ed: http://www.people.vcu.edu/~clarson/bard-sage-for-undergraduates-2014.pdf			
Module	**Unit**	**Content**	**Hrs (36+9)**	**Marks** **Ext: 50**
I		**Python Basics** (Text 1, Ch. 1, 2, 3, 4.)	**8**	**Min.10**
	1	Getting Started (Ch 1). Programming Simple Mathematics (Sec 2.1). Variables and Variable Types (Sec 2.2).		
	2	Formatting Text Output. Importing Modules. (Sec 2.3, 2.4).		
	3	Loops and Lists. Loops for Automating Repeated Tasks. Using Lists to Store Sequences of Data. (Sec 3.1, 3.2, 3.3).		
	4	Iterating over a List with a for Loop.. Nested Lists and List Slicing. (Sec 3.4, 3.5).		
	5	Tuples. (Sec 3.6)		
II		**Functions, Branching, I/O, Modules.**	**8**	Min 10
	6	Programming with Functions.. Function Arguments and Local Variables. Default Arguments and Doc Strings. (Sec 4.1, 4.2, 4.3)		
	7	If Tests for Branching the Program Flow. Functions as arguments to Functions. (Sec 4.4, 4.5)		
	8	Solving Equations with Python Functions. (Sec 4.6)		
	9	Writing Test Functions to Verify Programs (Sec 4.7).		
	10	User Input and Error Handling. Reading Input User Data. Reading Data from Files. Writing Data to Files. (Sections 5.1, 5.3, 5.4. Section 5.2 omitted).		
	11	Handling Errors in Programs. (Sec 5.5)		
	12	Making Modules. (Sec 5.6)		
III		**More Data Structures, Plotting**		

		(Text 1, Ch. 6, 7).	7	**Min 10**
	13	Arrays and Plotting. Numpy and Array Computing. Plotting Curves with Matplotlib. (Sec 6.1, 6.2)		
	14	Plotting Discontinuous and Piecewise Defined Functions. (Sec 6.3).		
	15	Dictionaries and Strings. Examples: A Dictionary for Polynomials, Reading File Data to a Dictionary. (Sec 7.1 7.2, 7.3),		
	16	String Manipulation (Sec 7.4).		
IV		**Classes and Object-Oriented Programming.** (Text 1, Ch. 9, 10.)	7	**Min 10**
	17	Basics of Classes. (Sec 8.1)		
	18	Protected Class Attributes, Special Methods. Example: Automatic Differentiation of Functions. (Sec 8.2, 8.3, 8.4).		
	19	Test Functions for Classes. Example: A Polynomial Class. (Sec 8.5, 8.6).		
	20	Class Hierarchies and Inheritance. Example: Classes for Numerical Differentiation, Integration. (Sec 9.1, 9.2, 9.3).		

V	**Practical (Open-Ended)** Lecturer's selections of 15 sessions of 2 hours each from below. **Miscellaneous Python Exercises** 1. Pitfalls of Programming, Text 1, Section 2.5. 2. Familiarize various Python runtime environments and IDEs like IDLE, Spyder, VS Code, Virtual Environments, Jupyter Notebook, Google Colab, Anaconda/Miniconda/Mamba, Replit. 3. Familiarize various documentation websites and how to refer to the syntax and implementation of a Python concept or Package. 4. Case studies from Reference 2:, Income Tax Calculator (page 38), Investment Report (p. 73), Approximating Square Roots. (p. 92), Text Analysis (p. 126), Generating Sentences (p. 150). **Sagemath** 1. Getting and installing sagemath in Windows, Ubuntu OS Using sagemath using cocalc (online). 2. Using Sage as a Calculator, Using Sage with Common Functions, Using Sage for Trigonometry (Text 2, sections 1.1, 1.2, 1.3). 3. Using Sage to Manipulate Polynomials (Text 2, section 1.7) 4. Matrices and Sage-A First Taste of Matrices, Doing the RREF in Sage (Text 2, section 1.5) 5. Using Sage for 2-D graphs (Text 2, section 1.4) 6. The Derivative, Slope of Tangent, Higher-Order Derivatives (Text 2, section 1.11)) 7. Antiderivatives (Indefinite Integral), Definite Integrals, Improper Integrals (Text 2, sec 1.12, upto sec 1.12.6)) **Sympy (Reference 3).** 1. Sympy Introductory Tutorial. 2. Solve an equation algebraically. 3. Solve a system of equations algebraically. 4. Solve one or a system of equations numerically. 5. Find the roots of a polynomial symbolically or numerically. 6. Solve a matrix equation algebraically. 7. Solve a Diophantine equation algebraically. 8. Solve an ODE algebraically. **More Numpy and Data Visualization** (Reference 1: Chapter 3, 4) 1. Numpy Functions: arange, linspace, zeros, ones, random.random, reshaping. (Sec 3.1.1 to 3.1.6). Copying, Saving and Restoring, Slicing, Arithmetic Operations. (Sec 3.1.7 to 3.1.10). 2. Matplotlib Module: 2D Plots, Polar Plots, Pie Charts, Multiple Plots. (Sec 4.1) 3. Sine function and friends, Circle, Parametric Plots, Error Bars. (Sec 4.2)

4. Simple 2D Animation (Reference 1, Section 4.4), Making a movie of a Plot (Text 1, Section 4.4)
5. Famous Curves: Astroids, Ellipse, Spirals of Archimedes and Fermat (Reference 1, Sec 4.5)
6. 2D Plots and Fractals (Reference 1, Section 4.6)
7. 3D Plots (Reference 1, Section 4.7)

Numerical methods using SageMath (Reference 5: Chapter 7)(7.1 - 7.10, 7.12)

1) Evaluate a Taylor series numerically.
2) Interpolate a function using
   a) Newton's forward interpolation.
   b) Newton's backward interpolation.
   c) Lagrange's Interpolation.
   d) Newton's General Interpolation.
3) Find integral of function using
   a. Trapezoidal Rule
   b. Simpson's 1/3-rule
4) Find derivative of function numerically.
5) Solve first order differential equations numerically.
   a) Euler method
   b) Fourth order Runge-Kutta method
6) Solve algebraic equations numerically.
   a) The Bisection method
   b) Regula Falsi Method

References

1. Python for Education, Ajith Kumar B. P., 2023 https://scischool.in/python/pythonForEducation.pdf
2. Fundamentals of Python First Programs, Kenneth A Lambert, 2 Ed., Cengage, 2018.
3. Sympy Tutorial: https://docs.sympy.org/latest/tutorials/intro-tutorial/index.html
   Solving Equations: https://docs.sympy.org/latest/guides/solving/index.html
4. Computational Mathematics with SageMath, Paul Zimmermann, Alexandre Casamayou, https://www.sagemath.org/sagebook/english.html
5. SageMath Advice For Calculus, Tuan A. Le and Hieu D. Nguyen, https://users.rowan.edu/~nguyen/sage/SageMathAdviceforCalculus.pdf
6. Sagemath Reference: https://doc.sagemath.org/

Programming Resources

1. Python official website: https://www.python.org
   Documentation: https://docs.python.org/
2. Spyder official website and documentation, https://www.spyder-ide.org/
3. MIT Courseware, Getting Started: Python and IDLE, https://web.mit.edu/6.s189/www/handouts/GettingStarted.html
4. Jupyter Notebook, https://jupyter.org/
5. Google Colaboratory (colab), https://colab.google/
6. Visual Studio Code: https://code.visualstudio.com,
   Documentation: https://code.visualstudio.com/docs
   VS Code for Web: https://vscode.dev/
7. Replit, https://replit.com/
8. Python Virtual Environments: https://docs.python.org/3/tutorial/venv.html
9. Anaconda, Miniconda and Mamba.
   Anaconda: https://docs.anaconda.com/free/anaconda/
   Miniconda: https://docs.anaconda.com/free/minicoda
   Mamba: https://mamba.readthedocs.io/en/latest/
10. SageMathCloud at Cocalc: https://cocalc.com
    Documentation: https://doc.cocalc.com/

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	3	2	1	3	2	3	3	2	1	2
CO 2	3	3	2	2	3	2	3	3	2	1	2
CO 3	3	3	3	3	3	1	3	3	3	1	3

Correlation Levels:

Level	Correlation
-	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Assignment/ Seminar
- Internal Exam
- Viva
- Final Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Exam	Assignment	Seminar	Viva	End Semester Examinations
CO 1	✓	✓	✓	✓	✓
CO 2	✓	✓	✓	✓	✓
CO 3	✓	✓	✓	✓	✓

ONLINE EQUIVALENT COURSES

(These courses are currently available on the government portal SWAYAM. If they are removed in the future, the board will update the course listings accordingly)

The course in brackets, including its course code, is equivalent to the online course specified against it.

1. (MAT8EJ401 Advanced Topology)

   https://onlinecourses.nptel.ac.in/noc24_ma74/preview

   An Introduction to Point-Set-Topology Part-II
   By Prof. Anant R. Shastri | IIT Bombay

2. (MAT8EJ402 PARTIAL DIFFERENTIAL EQUATIONS)

   https://onlinecourses.nptel.ac.in/noc24_ma73/preview

   Partial Differential Equations
   By Prof. Sivaji Ganesh | IIT Bombay

3. (MAT8EJ403 RINGS AND MODULES)

   https://onlinecourses.nptel.ac.in/noc24_cs72/preview

   Modern Algebra
   By Prof. Manindra Agrawal | IIT Kanpur

4. (MAT8EJ405 FOUNDATIONS OF MATHEMATICS)

   https://onlinecourses.nptel.ac.in/noc24_ma42/preview

   Set Theory and Mathematical Logic
   By Prof. Amit Kuber | IIT Kanpur

5. (MAT8EJ406 OPERATIONS RESEARCH)

   https://onlinecourses.swayam2.ac.in/cec24_ma05/preview

   Operations Research
   By Professor Bibhas C. Giri | Jadavpur University

6. (MAT1CJ101 Differential Calculus + MAT2CJ101 Integral Calculus)

   https://onlinecourses.nptel.ac.in/noc24_ma47/preview

   Calculus of One Real Variable
   By Prof. Joydeep Dutta | IIT Kanpur

7. (MAT3CJ201 MULTIVARIABLE CALCULUS)

   https://onlinecourses.nptel.ac.in/noc24_ma52/preview

   Calculus of Several Real Variables
   By Prof. Joydeep Dutta | IIT Kanpur

8. (MAT4CJ203 REAL ANALYSIS I)

   https://onlinecourses.swayam2.ac.in/cec24_ma01/preview

   Real Analysis
   By Prof. Surajit Borkotokey | Dibrugarh University

9. (MAT5CJ302 ABSTRACT ALGEBRA I)

   https://onlinecourses.nptel.ac.in/noc24_ma50/preview

   Introduction to Abstract Group Theory
   By Prof. Krishna Hanumanthu | Chennai Mathematical Institute

10. (MAT5CJ303 COMPLEX ANALYSIS I + MAT6CJ304 COMPLEX ANALYSIS II)

   https://onlinecourses.nptel.ac.in/noc24_ma60/preview

   Complex Analysis
   By Prof. Pranav Haridas | Kerala School of Mathematics