Curriculum
of
BS Mathematics with Computer Science

Institute of Mathematics
University of the Punjab
Lahore

January 27, 2025

SYLLABI FOR 4 YEAR BS MATHEMATICS WITH COMPUTER SCIENCE (SEMESTER SYSTEM PROGRAMME)

To be offered in Institute of Mathematics, University of the Punjab, Lahore and Affiliated Colleges with effect from Admissions 2025 to onwards.

Programme	BS Mathematics with Computer Science
Duration	4 Years
Semesters	8
Credit Hours	144
Institute	Mathematics
Faculty	Science

Introduction

The Department of Mathematics at the University of the Punjab is one of the university's oldest academic units, founded in 1921. Over the years, it has produced numerous distinguished graduates, many of whom have gained prominence in Mathematics. For a considerable period, the department operated on an inter-collegiate basis, with faculty members from local institutions such as Government College Lahore, Forman Christian College, Dyal Singh College, Islamia College Civil Lines, and M.A.O. College, Lahore, conducting M.Sc. classes at the university. In 1956, the department became an independent institution with the appointment of two full-time faculty members: one reader and one senior lecturer. Since then, the department has steadily grown and now offers a range of programs, including BS (4 years), BS (5 semesters), M.Phil., and Ph.D.

In 1982, the department established a computer center to enhance the computational capabilities of university students, faculty, and staff. Furthermore, the Department of Mathematics publishes the Punjab University Journal of Mathematics, with its inaugural issue released in 1967 under the editorship of Prof. Dr. Syed Manzur Hussain.

In December 2024, the Department of Mathematics was elevated into the Institute of Mathematics. The Institute is home to four robust research groups: Computational Mathematics, Fuzzy Mathematics, Gravitation & Cosmology, and Pure Mathematics. These groups contribute to the academic strength of the institute, fostering innovation and advancing knowledge in their respective fields.

Vision

The Institute of Mathematics aims to be recognized as an internationally top-ranking center of excellence in both teaching and research.

Mission

In pursuit of our vision, the Institute of Mathematics strives to provide quality education at both undergraduate and postgraduate levels, aiming to produce high-calibre graduates who will excel in their chosen careers in industry, the professions, and academia. Our students are selected based on intellectual merit, without discrimination based on gender, race, or physical disabilities. We are committed to fostering a diverse and well-balanced portfolio of research of the highest quality, encompassing a wide range of interests.

Objectives

The following objectives are designed to guide the Institute of Mathematics toward achieving its vision of becoming an internationally recognized center of excellence in teaching and research.

- Expand and diversify the faculty to encompass all disciplines of Mathematics.
- Strengthen all existing academic programs, with particular emphasis on the MPhil/PhD programs to facilitate world-class research.
- Develop an industry-based Mathematics curriculum, fostering close collaboration between mathematics and industry.
- Encourage faculty engagement in research projects, paper presentations at international conferences, organizing conferences, international research collaborations, and postdoctoral training.
- Promote the "Punjab University Journal of Mathematics" as a premier research journal of international repute.
- Provide strong support for both individual researchers and research groups.
- Enhance the abilities and character of students, nurturing them into well-rounded individuals.
- Recognize and reward the institute's staff, acknowledging them as its greatest asset.

Program Introduction

The Institute of Mathematics at University of the Punjab, Lahore, is proud to announce the launch of a new undergraduate program, "Mathematics with Computer Science." This interdisciplinary program bridges the foundational rigor of mathematics with the transformative power of computer science, offering students a unique blend of theoretical knowledge and practical skills. As the digital age reshapes industries and accelerates technological advancements, the demand for professionals who can solve complex problems at the intersection of mathematics and computer science is greater than ever. Our program is designed to equip students with the tools to excel in this rapidly evolving landscape, combining the elegance of mathematical reasoning with cutting-edge computational techniques.

Program Objectives

- Develop Strong Mathematical Foundations: Cultivate a deep understanding of core mathematical concepts, enabling students to analyze and model complex systems effectively.
- Enhance Computational Expertise: Equip students with advanced programming skills, algorithms, and computational techniques to address real-world challenges.
- Cross-Disciplinary Problem-Solving: Bridge the gap between theory and practice by integrating mathematical insights with computational applications in diverse fields such as data science, artificial intelligence, cryptography, and optimization.

Market Need / Rationale of the Program

The " Mathematics with Computer Science" program is being introduced to address the increasing demand for interdisciplinary expertise in Mathematics and Computer Science. The following points highlight the rationale for launching this program:

a. Potential Students: There is a growing interest among students to pursue careers at the intersection of mathematics and computer science, driven by the need for versatile skills in fields such as artificial intelligence and computational research.

b. Potential Employers: Industry trends indicate a rising demand for professionals skilled in mathematical modeling, algorithm development, data analysis, and software engineering. Employers in technology, finance, and research sectors are seeking candidates who can bridge the gap between theoretical and practical problem-solving.

c. Academic Projections: Several reputable national and international universities have successfully launched similar programs, demonstrating the value and relevance of such an interdisciplinary approach.

d. Faculty: The Institute has a strong pool of faculty members with expertise in both mathematics and computer science, capable of delivering a comprehensive curriculum that meets global academic standards.

e. Physical Facilities: The program will utilize existing facilities, including modern computer labs and a well-equipped library. Additional resources will be allocated to ensure the program's success as it grows.

Admission Eligibility Criteria

- Intermediate or equivalent qualification with Mathematics having at least 45% overall marks.
- The students who studied Mathematics in Intermediate (F.A./F.Sc./ICS or equivalent) will be eligible in this program.

Coding Scheme of Courses

The course code consists of two parts:
1. Letter code consists of 3 to 4 characters.

- For general education courses, the first character begins with G, followed by 2 to 3 characters that represent the course category within the general education course. For example, GISL represents a general education course of Islamic Studies, GQR represents a general education course of Quantitative Reasoning.
- Major courses: The letter code MATH is used for all major Mathematics courses.
- Interdisciplinary/allied courses: The letter code MAAL is used for Interdisciplinary/allied courses.
- Computer Science courses: The letter code MACS is used for Computer Science courses.

2. Numeric code consists of 3 digits. The first number from the left represents the year, with values starting from 1, the second number represents the subject, and the third number represents the sequence of courses within the same subject category.

BS Mathematics with Computer Science

Categorization of Courses as per HEC Guidelines

Semester	Courses		Category (Credit Hours)					
		General Education	Major Math	Interdisciplinary /Allied	Minor	Holy Qura	Internship/(Project	Semester Load
1	7	10	6	------------		0	------------	16
2	7	8	6	-------------	- ------------	1	------------	15
3	7	8	9	----------	------------	0	------------	17
4	6	6	9	-----------	------------	1	------------	16
5	7	--------	15	3	------------	0	------------	18
6	8	--------	12	6	3	1	------------	22
7	8	---------	9	3	6	0	3	21
8	7	----------	6	----------	9	1	3	19
PU		30	72	12	18	4	6	144
HEC Guidelines		30	Min 72	Min 12	Min 12	4	6	120----144

Institute of Mathematics, University of the Punjab, Lahore

Scheme of Studies for BS in Mathematics with Computer Science - With Effect From Fall 2025

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
MATH-101 (3) Single Variable Calculus	**MATH-103 (3)** Plane Curves & Analytic Geometry	**MATH-201 (3)** Multivariable Calculus	**MATH-204 (3)** Real Analysis	**MATH-301 (3)** Complex Analysis	**MATH-306 (3)** Advanced Analysis	**MATH-401 (3)** Functional Analysis	**MATH-404 (3)** Operations Research
MATH-102 (3) Discrete Mathematics	**MATH-104 (3)** Introduction to Graph Theory	**MATH-202 (3)** Ordinary Differential Equations	**MATH-205 (3)** Fundamentals of Mechanics	**MATH-302 (3)** Linear Algebra	**MATH-307(3)** Tensor Analysis	**MATH-402 (3)** Differential Geometry	**MATH-405 (3)** Numerical Methods with Computer Prog.
GENG-101(3) Functional English	**GSS-101(2)** Introduction to Economics	**MATH-203 (3)** Number Theory	**MATH-206 (3)** Group Theory	**MATH-303(3)** Partial Differential Equations	**MATH-308 (3)** Rings and Modules	**MATH-403 (3)** Numerical Analysis	**MACS-403 3(2+1)** Artificial Intelligence
GQR- 101(3) Quantitative Reasoning I	**GCCE-101(2)** Civics and Community Engagement	**GNS-201 (3)** Introduction to Physics	**GQR- 202(3)** Quantitative Reasoning II	**MATH-304(3)** Computational Tools	**MATH-309 (3)** Methods of Mathematical Physics	**MACS-401 3(2+1)** Object Oriented Programming	**MACS-404 3(2+1)** Data Structures and Algorithms
GICP-101(2) Ideology and Constitution of Pak.	**GISL-101(2)** Islamic Studies / Ethics	**GENG-201(3)** Expository Writing	**GICT-201 3(2+1)** Applications of ICT	**MATH-305 (3)** Topology	**MACS-301 3(2+1)** Programming Fundamentals	**MACS-402 3(2+1)** Database Management System	**MACS-405 3(2+1)** Web Programming
GAH-101(2) Fundamentals of Philosophy	**GENT-101(2)** Entrepreneurship	**GPAK-201(2)** Pakistan Studies	**HQ-004 (1)** Translation of Holy Quran	**MAAL-301 (3)** Digital Logic Design	**MAAL-302 (3)** Decision Making Methods	**INTE-401 (3)** Field Experience/ Internship	**CAPP-401 (3)** Capstone Project
HQ-001 (0) Translation of Holy Quran	**HQ-002 (1)** Translation of Holy Quran	**HQ-003 (0)** Translation of Holy Quran		**HQ-005(0)** Translation of Holy Quran	**MAAL-303 (3)** Probability and Statistics	**MAAL-401 (3)** Data Science	**HQ-008(1)** Translation of Holy Quran
					HQ-008(1) Translation of Holy Quran	**HQ-008(0)** Translation of Holy Quran	

Knowledge Domains	Cr. Hours
Major Mathematics	72
General Education Courses	32
Minor Courses	18
Interdisciplinary/Allied Courses	12
Field Experience/Internship	3
Capstone Project	3
Holy Quran (HQ)	4
Total	**144**

STRUCTURE OF BACHELOR DEGREE PROGRAM IN MATHEMATICS WITH COMPUTER SCIENCE

A bachelor degree with a single major Mathematics and one minor consists of 144 credit hours. The breakup of credit hours is as under:

Degree Awarded:	BS Mathematics with Computer Science
Duration:	4 Years (8 Semesters)
Total Credit Hours:	144
Major Mathematics:	24(72 credit hours)
General Education Courses:	13 (32 credit hours)
Computer Science Courses:	6 (18 credit hours)
Interdisciplinary/Allied Courses:	4 (12 credit hours)
Field Experience/Internship:	The field experience of six to eight weeks (preferably undertaken during semester or summer break) must be graded by a faculty member in collaboration with the supervisor in the field. Internship carries **3 credit hours** and is a mandatory requirement for the award of BS degree.
Capstone Project:	The capstone project must be supervised and graded by a faculty member as per the protocols prescribed by the concerned Department/Institute. Capstone Project carries **3 credit hours** and is a mandatory requirement for the award of BS degree.
Holy Quran Courses:	8 (04 credit hours)

General Education Courses

Details of the general education requirements (i.e., courses) are given in the Table 1 .

Table 1: List of General Education Courses

Sr.No.	Course Code	General Education Cluster	Credit Hours
1	GAH- 101	Fundamentals of Philosophy	2
2	GSS- 101	Introduction to Economics	2
3	GENG-101	Functional English	3
4	GENT-101	Entrepreneurship	2
5	GQR- 101	Quantitative Reasoning I	3
6	GCCE-101	Civics and Community Engagement	2
7	GICP-101	Ideology and Constitution of Pakistan	2
8	GISL-101	Islamic Studies	2
9	GPAK-201	Pakistan Studies	2
10	GNS- 201	Introduction to Physics	3
11	GQR- 202	Quantitative Reasoning II	3
12	GENG-201	Expository Writing	3
13	GICT- 201	Applications of ICT	3(2+1)
	Total	**13**	**32**

List of Major Mathematics Courses

Details of the major Mathematics courses are given in the Table 2.

Table 2: List of Major Mathematics Courses

Sr No.	Course Code	Course Title	Credit Hours
1	MATH-101	Single Variable Calculus	3
2	MATH-102	Discrete Mathematics	3
3	MATH-103	Plane curves & Analytical Geometry	3
4	MATH-104	Introduction to Graph Theory	3
5	MATH-201	Multivariable Calculus	3
6	MATH-202	Ordinary Differential Equations	3
7	MATH-203	Number Theory	3
8	MATH-204	Real Analysis	3
9	MATH-205	Fundamentals of Mechanics	3
10	MATH-206	Group Theory	3
11	MATH-301	Complex Analysis	3
12	MATH-302	Linear Algebra	3
13	MATH-303	Partial Differential Equations	3
14	MATH-3044	Computational Tools	3
15	MATH-305	Topology	3
16	MATH-306	Advanced Analysis	3
17	MATH-307	Tensor Analysis	3
18	MATH-308	Rings and Modules	3
19	MATH-309	Methods of Mathematical Physics	3
20	MATH-401	Functional Analysis	3
21	MATH-402	Differential Geometry	3
22	MATH-403	Numerical Analysis	3
23	MATH-404	Operations Research	3
24	MATH-405	Numerical Methods with Computer Programming	3
	Total	**24**	**72**

List of Interdisciplinary/Allied Courses

Table 3: List of Interdisciplinary/Allied Courses

Sr. No.	Course Code	Course Title	Credit Hours
1	MAAL-301	Digital Logic Design	3
2	MAAL-302	Decision Making Methods	3
3	MAAL-303	Probability and Statistics	3
4	MAAL-401	Data Science	3

List of Computer Science Courses

Table 4: List of Computer Science Courses

Sr. No.	Course Code	Course Title	Credit Hours
1	MACS-301	Programming Fundamentals	3(2+1)
2	MACS-401	Object Oriented Programming	3(2+1)
3	MACS-402	Database Management System	3(2+1)
4	MACS-403	Artificial Intelligence	3(2+1)
5	MACS-404	Data Structures and Algorithms	3(2+1)
6	MACS-405	Web Programming	3(2+1)

SEMESTER-WISE WORKLOAD

The structure of the Bachelor's degree in Mathematics with Computer Science consists of eight regular semesters over four years. The semester workload is as follows:

Semester I

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-101	Single Variable Calculus	Major Math	N/A	3
MATH-102	Discrete Mathematics	Major Math	N/A	3
GQR- 101	Quantitative Reasoning I	General Education	N/A	3
GENG-101	Functional English	General Education	N/A	3
GAH-101	Fundamentals of Philosophy	General Education	N/A	2
GICP-101	Ideology and Constitution of Pakistan	General Education	N/A	2
HQ-001	Translation of Holy Quran	Compulsory	N/A	0
Total Semester Credits				**16**

Semester II

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-103	Plane Curves & Analytic Geometry	Major Math	MATH-101	3
MATH-104	Introduction to Graph Theory	Major Math	N/A	3
GSS-101	Introduction to Economics	General Education	N/A	2
GCCE-101	Civics and Community Engagement	General Education	N/A	2
GENT-101	Entrepreneurship	General Education	N/A	2
GISL-101	Islamic Studies / Ethics	General Education	N/A	2
HQ-002	Translation of Holy Quran	Compulsory	HQ-001	1
Total Semester Credits				**15**

Semester III

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-201	Multivariable Calculus	Major Math	MATH-101, MATH-102	3
MATH-202	Ordinary Differential Equations	Major Math	MATH-101	3
MATH-203	Number Theory	Major Math	N/A	3
GNS-201	Introduction to Physics	General Education	N/A	3
GENG-201	Expository Writing	General Education	GENG-101	3
GPAK-201	Pakistan Studies	General Education	N/A	2
HQ-003	Translation of Holy Quran	Compulsory	HQ-002	0
Total Semester Credits				**17**

Semester IV

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-204	Real Analysis	Major Math	MATH-101	3
MATH-205	Fundamentals of Mechanics	Major Math	GNS-201	3
MATH-206	Group Theory	Major Math	N/A	3
GQR- 202	Quantitative Reasoning II	General Education	GQR-101	3
GICT-201	Applications of ICT	General Education	N/A	3(2+1)
HQ-004	Translation of Holy Quran	Compulsory	HQ-003	1
Total Semester Credits				**16**

Semester V

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-301	Complex Analysis	Major Math	MATH-201, MATH-204	3
MATH-302	Linear Algebra	Major Math	MATH-206	3
MATH-303	Partial Differential Equations	Major Math	MATH-202	3
MATH-304	Computational Tools	Major Math	GICT-201	3
MATH-305	Topology	Major Math	N/A	3
MAAL-301	Digital Logic Design	Interdisciplinary/Allied	GICT-201	3
HQ-005	Translation of Holy Quran	Compulsory	HQ-004	0
Total Semester Credits				**18**

Semester VI

Course Code	Course Title	Course Type	Prerequisite	Credit Hour
MATH-306	Advanced Analysis	Major Math	MATH-204, MATH-306	3
MATH-307	Tensor Analysis	Major Math	MATH-201	3
MATH-308	Rings and Modules	Major Math	MATH-206, MATH-303	3
MATH-309	Methods of Mathematical Physics	Major Math	MATH-304	3
MACS-301	Programming Fundamentals	Computer Science	GICT-201	3(2+1)
MAAL-302	Decision Making Methods	Interdisciplinary/Allied	N/A	3
MAAL-303	Probability and Statistics	Interdisciplinary/Allied	GQR-101, GQR-202	3
HQ-006	Translation of Holy Quran	Compulsory	HQ-005	1
Total Semester Credits				**22**

Semester VII

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-401	Functional Analysis	Major Math	MATH-302	3
MATH-402	Differential Geometry	Major Math	MATH-307	3
MATH-403	Numerical Analysis	Major Math	MATH-101	3
MACS-401	Object Oriented Programming	Computer Science	MACS-301	3(2+1)
MACS-402	Database Management System	Computer Science	MACS-301	3(2+1)
MAAL-401	Data Science	Interdisciplinary/Allied	MAAL-303	3
INTE-401	Field Experience/ Internship	Mandatory	Semesters I-VI	3
HQ-007	Translation of Holy Quran	Compulsory	HQ-006	0
Total Semester Credits				**21**

Semester VIII

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-404	Operations Research	Major Math	MATH-302	3
MATH-405	Numerical Methods with Comp. Prog.	Major Math	MATH-403	3
MACS-403	Artificial Intelligence	Computer Science	MAAL-401, MACS-301	3(2+1)
MACS-404	Data Structures and Algorithms	Computer Science	MATH-104, MACS-401	3(2+1)
MACS-405	Web Programming	Computer Science	MACS-301	3(2+1)
CAPP-401	Capstone Project	Mandatory	Semesters I-VII	3
HQ-008	Translation of Holy Quran	Compulsory	HQ-007	1
Total Semester Credits				**19**

COURSE OUTLINES OF MAJOR MATHEMATICS COURSES

To be offered in Institute of Mathematics, University of the Punjab, Lahore and Affiliated Colleges with effect from Admissions 2024 to onwards.

Course Title: Single Variable Calculus

Course Code: MATH-101

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

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

- Master the concepts of limits, continuity, and differentiation of functions.
- Apply derivatives to solve problems involving rates of change, extremum, and curve sketching.
- Evaluate indefinite and definite integrals, utilizing techniques such as substitution and integration by parts.
- Use calculus to solve geometric problems involving area, volume, and arc length.

Course Contents:

Preliminaries: Real numbers and the real line, Inequalities, Function, Families of functions (Bijective, Floor, Ceiling, Characteristic, Extension and restriction) , Inverse functions, Graph of functions.

Limits and Continuity: Limit of a function, Left hand and right hand limits, Continuity.

Differentiable functions: Differentiation of a polynomial, Rational and transcendental functions, Higher derivatives, Leibnizs theorem, Taylors and Maclaurin's theorem with their remainders.

Applications of Derivatives: Rate of change, The chain rule, Extremum problems, L'Hôspital's rule, Mean value theorem, Asymptotes, Curve sketching.

Indefinite Integration: Techniques of evaluating indefinite integrals, Integration by substitutions, Integration by parts.

Definite Integrals: Riemann sum, Definite integral, Fundamental theorem of calculus.

Applications to Geometry: Area, Volume, Arc length, Improper integrals.

Recommended Books:

1. Anton, H., Bevens, I. and Davis S., *Calculus*, John Wiley & Sons, Inc., 12th edition, 2022.
2. Edward, C.H., *Calculus and Analytic Geometry*, Prentice Hall College Div., 3rd edition, 1990.
3. Hallett, D. H. and Gleason A. M., *Calculus: Single and Multivariable*, Wiley, 8th edition, 2020.

4. Mendelson, E. and Ayres, F., *Calculus, Schaums outlines series*, McGraw-Hill, 4th edition, 1999.
5. Thomas, G. B. and Finney, R. L., *Calculus*, Addison Wesley Publishing Company, 11th Edition, 2005.

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Course Title: Discrete Mathematics

Course Code: MATH-102

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

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

- Master principles of computational logic and methods of proof.
- Develop proficiency in counting techniques and solving recurrence relations.
- Gain foundational knowledge in probability for data analysis.

Course Contents:

Computational Logic: Propositional logic, applications of propositional logic, propositional equivalences, first-order logic or predicate logic, quantifiers in first-order logic, free and bound variables, Proof methods: Direct proof, Proof by contradiction, Proof by contrapositive.

Relations: Sets, Functions, Sequences, Relations and their properties, n-ary relations, Representing relations, Equivalence relations, Partial orderings, Hasse diagram, Lattice.

Counting Techniques: Basics of counting, Pigeonhole principle, Permutations, Combinations, Recursive definitions, Recurrence relations, Solving linear recurrence relations, Generating functions, Inclusion–exclusion principle.

Probability: Axioms of probability, Addition and multiplication rules of probability, Conditional Probability, Bayes' Theorem.

Recommended Books:

1. Grimaldi, R.P., *Discrete and Combinatorial Mathematics*, Pearson, 5th edition, 2003.
2. Richard, J., *Discrete Mathematics*, Pearson, 7th edition, 2007.
3. Rosen, K. *Discrete Mathematics and Its Applications*, McGraw-Hill Education; 7th edition, 2011.

4. Susanna S. Epp, Discrete Mathematics with Applications, Cengage Learning, 4th edition, 2010.

5. Walpole, R. E., *Introduction to Statistics*, Macmillan Publishing Company, 3rd edition, 1982.

Course Title: Plane Curves & Analytic Geometry

Course Code: MATH-103

Course Type: Major Math

Prerequisites: Single Variable Calculus

Credit Hours: 3 (3 + 0)

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

- Understand the convergence of sequences and series using various tests.
- Analyze and classify conic sections, and represent curves using polar coordinates and parametric equations.
- Master the concepts and properties of conic sections, including circles, parabolas, ellipses, and hyperbolas.
- Apply analytic geometry to three-dimensional space, utilizing various coordinate systems and equations of lines and planes.

Course Contents:

Plane Curves: Conic section and quadratic equations, Classifying conic section by eccentricity, Translation and rotation of axis, Properties of circles, parabolas, ellipses, hyperbolas. Polar coordinates, Conic sections in polar coordinates, Polar curves and their sketching, Tangents and normal, Pedal equations, Parametric representations of curves.

Vectors and Three-dimensional Space: Three-dimensional coordinate systems, Vectors in plane and space, Dot product, Cross product, Vector-valued functions and space curves, Derivative and integral of vector- valued functions.

Analytic Geometry of Three Dimensions: Rectangular coordinates system in a space, Cylindrical and spherical coordinate system, Direction ratios and direction cosines of a line, Equation of straight lines and planes in three dimension, Cylinders and quadric surfaces.

Recommended Books:

1. Anton, H., Bevens, I. and Davis, S., *Calculus*, John Wiley & Sons, Inc., 12th edition, 2022.

2. Edward, C.H., *Calculus and Analytic Geometry*, Prentice Hall College Div. 3rd edition, 1990.

3. Hallett, D. H. and Gleason, A. M., *Calculus: Single and Multivariable*, Wiley, 8th edition, 2020.

4. Mendelson, E. and Ayres, F., *Calculus, Schaum's outlines series*, McGraw-Hill, 4th edition, 1999.

5. Thomas, G. B. and Finney, R. L., *Calculus*, Addison Wesley Publishing Company, 11th Edition, 2005.

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Course Title: Introduction to Graph Theory

Course Code: MATH-104

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

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

- Understand the basics of graph theory and their various properties.
- Understand the concepts of connectivity, planar graphs and colorings.
- Apply graph theory concepts to solve real world applications.

Course Contents:

Graph Terminology: History of graph theory, Definition of a graph, Directed graphs, Undirected graphs, Vertex, Edge, Adjacent (or neighbors), Neighborhood. Degree of vertices and edges, Handshaking Theorem, Adjacency matrix of a graph, Incidence matrix of a graph.

Simple Graphs: Types of simple graphs: Complete, Bipartite, Complete bipartite graphs, Wheels, Cubes. Subgraphs, Complement of a graph, Regular graphs, Representing graphs, Applications of simple graphs, Graph isomorphism.

Connectivity: Walks, Trails, Paths, Cycles, Connected and disconnected graphs, Edge and vertex connectivity, Bridge, Cut vertex, Euler and Hamiltonian paths and circuits.

Trees: Introduction to Trees, Binary tree, Forests, Applications of Trees, Spanning tree, Minimum spanning trees, Tree traversal.

Planar graphs: Planar and non-planar graphs, Euler formula, Dual graphs.

Graph coloring: Chromatic number, Chromatic index, Applications of graph coloring.

Network Flow: Digraphs, Weighted graphs, Maximum Flow, Max-Flow /Min-Cut Theorem, Algorithm to find Maximum flow in a Network.

Recommended Books:

1. Bondy J. A. and Murty, U. S. R., *Graph Theory with Applications*, American Elsevier Publishing Company, 1976.

2. Diestel, R., *Graph Theory*, Springer Berlin, Heidelberg, 2017.

3. Rosen, K., *Discrete Mathematics and Its Applications*, McGraw-Hill Education, 7th edition, 2011.

4. West, D. B., *Introduction to Graph Theory*, Pearson College Div., 2000.

5. Wilson, R. J., *Introduction to Graph Theory*, Pearson, 5th edition, 2010.

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Course Title: Multivariable Calculus

Course Code: MATH-201

Course Type: Major Math

Prerequisites: Single Variable Calculus

Credit Hours: 3 (3 + 0)

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

- Analyze three-dimensional vectors and surfaces.
- Apply calculus to vector-valued functions, including concepts such as arc length, curvature, and torsion.
- Utilize partial derivatives to solve optimization problems.
- Master the applications of multiple integrals and topics in vector calculus, including Green's, Stokes's, and the Divergence theorems.

Course Contents:

Preliminaries: Review of vectors in plane and space, Vector-valued function, Arc length, Curvature, Normal and binormal vectors, and Torsion.

Partial Derivatives: Functions of several variables, Limits and Continuity, Partial Derivatives, Higher order partial derivatives, Chain rule, Directional derivatives.

Applications of Partial Derivatives: Tangent planes and linear approximations, Gradient vector, Tangent planes and normal lines, Differentials and their applications, Maxima and minima of functions of two variables, Lagrange multipliers.

Multiple Integrals: Double integrals over rectangular domains and iterated integrals, Non-rectangular domains, Double integrals in polar coordinates, Triple integrals in rectangular, cylindrical and spherical coordinates, Three dimensional solid and moments of inertia, Applications of double and triple integrals. Change of variables in multiple integrals.

Vector Calculus: Divergence of a vector field, Curl of a vector field, Line integrals, Integration around closed curves, Green's theorem, Surface integrals, Divergence theorem and Stokes's theorem.

Recommended Books:

1. Anton, H., Bevens, I. and Davis, S., *Calculus*, John Wiley & Sons, Inc., 12th edition, 2022.

2. Edward, C.H., *Calculus and Analytic Geometry*, Prentice Hall College Div., 3rd edition, 1990.

3. Hallett, D. H. and Gleason, A. M., *Calculus: Single and Multivariable*, Wiley, 8th edition, 2020.

4. Mendelson, E. and Ayres, F., *Calculus, Schaum's outlines series*, McGraw-Hill, 4th edition, 1999.

5. Thomas, G. B. and Finney, R. L., *Calculus*, Addison Wesley Publishing Company, 11th Edition, 2005.

Course Title: Ordinary Differential Equations

Course Code: MATH-202

Course Type: Major Math

Prerequisites: Single Variable Calculus

Credit Hours: 3 (3 + 0)

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

- Understand formulation, classification of differential equations, existence and uniqueness of solutions.
- Provide skill in solving initial value and boundary value problems.
- Analyze mathematical models using linear differential equations to solve application problems.

Course Contents:

Preliminaries: Historical background and motivation, Basic mathematical models, Directional fields, Classification of differential equations, Existence and uniqueness of solutions, Introduction of initial value and boundary value problems.

First Order Ordinary Differential Equations: Basic concepts, Formation and solution of differential equations, Separable variables, Exact equations, Homogeneous equations, Linear equations, Integrating factors, Modeling with first-order ODEs, Differences between linear and nonlinear equations.

Second Order Linear Differential Equations: Initial value and boundary value problems, Homogeneous and non-homogeneous equations, Homogenous equations with constant coefficients, Fundamental solutions of linear homogenous equations, Linear independence and the Wronskian, Method of undetermined coefficients, Variation of parameters, Cauchy-Euler equation.

Higher- Order Linear Differential Equations: General theory of *n*th order linear equations, Homogenous equations with constant coefficients, The methods of undermined coefficients, Method of variation of parameters.

Series Solutions: Power series, Ordinary and singular points, Existence of power series solutions, Power series solutions, Types of singular points, Legendre equation, Bessel equation.

Recommended Books:

1. Boyce, W.E., *Elementary Differential Equations*, John Wiley & Sons Inc., 9th edition, 2008.
2. Bronson, R., *Schaum's Outline of Differential Equations*, McGraw Hill, 4th edition, 2014.
3. Ross, S. L., *Differential Equations*, John Wiley & Sons, 3rd edition, 1984.
4. Victor, H., Belozerova, T. and Khenner, M., *Ordinary and Partial Differential Equations*, A K Peters/CRC Press, 1st edition, 2013.
5. Zill, D. G., *Differential Equation with Boundary Value Problems*, Cengage Learning, 9th edition, 2017.

Course Title: Number Theory

Course Code: MATH-203

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

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

- Learn the concepts of divisibility, congruences, the Chinese Remainder Theorem, arithmetic functions.
- Comprehend the hard concepts in number theory with the help of theorems and to write clear and precise proofs.
- Develop and enhance student's interest and knowledge towards algebraic and computational number theory.

Course Contents:

Divisibility and Modular Arithmetic: Divisibility, Divisibility and Division Algorithms, Well ordering Principle, Bezout's Identity. Modular Arithmetic, Properties, Euclid's algorithm for the greatest common divisor, Extended Euclid's Algorithm, Least Common multiple, Solving Linear Diophantine Equations, Modular Division.

Primes and Congruences: Prime Numbers, prime-power factorization, Fermat and Mersenne primes, Primality testing and factorization, Congruences, Linear congruences, Simultaneous linear congruences, The Chinese Remainder Theorem, Fermat's little theorem, Wilson's theorem and Lagrange Theorem, Congruences with a Prime-Power Modulus, Pseudo primes and Carmichael numbers, Solving congruences modulo prime powers.

Arithmetic Functions: Sigma and Tao functions, Euler's Function-Euler's Totient function, Applications of Euler's Totient function, Mobius function and its properties, Mobius inversion formula, Bracket functions.

Primitive Roots: The order of an integer mod n, Primitive roots and their applications in solving higher order congruences.

Recommended Books:

1. Adler, A. and Cloury, J. E., *The Theory of Numbers*, Jones & Bartlett Pub, 1st edition, 1995.
2. Burton, D. M., *Elementary Number Theory*, McGraw Hill Company, 6th edition, 2007.
3. Hardy, G. H. and Wright, E. M., *An Introduction to the theory of numbers*, Oxford University Press, 6th edition, 2008.
4. Koblitz, N., *A Course in Number Theory and Cryptography*, Springer, 2nd edition, 1994.
5. Niven, I., Zuckerman, H.S. and Montgomery, H.L., *An Introduction to the theory of Numbers*, John Wiley and Sons, 5th edition, 1991.

Course Title: Real Analysis

Course Code: MATH-204

Course Type: Major Math

Prerequisites: Single Variable Calculus

Credit Hours: 3 (3 + 0)

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

- Understand the concepts of countable and uncountable sets, cardinal and Ordinal numbers and well-ordering principal
- Explore real numbers, sequences, limits, and key theorems in analysis.
- Analyze series and apply various convergence tests.
- Explore continuous functions, sequences and series of functions.
- Master the concepts of derivative and its application in extrema.

Course Contents:

Sets and Numbers: Countable and uncountable sets, Cardinal numbers, Arithmetic of cardinal numbers, Ordered sets, well-ordered sets, Bounded sets, Supremum and infimum, Ordinal numbers, Well-ordering theorem, Axiom of choice, Zorn's lemma.

Sequences and Series: The definition of a limit, Properties of limits, Monotonic sequences, Subsequences and the Bolzano-Weiertrass theorem, Cauchy sequences. Series of real numbers, Convergence of series, Special series, Convergence tests (Divergence, comparison, Cauchy Condensation, ratio, root, Leibniz alternating series test).

Continuous Functions: Functions, Limits of functions, Continuity, Properties of Continuous functions, Intermediate value theorem, Extreme value theorem, Fixed point theorems.

Sequences and Series of Functions: Definition of point-wise and uniform convergence, Examples of uniform convergence, Cauchy criterion for uniform convergence.

Derivatives: The derivative, Definition of the derivative, Differentiation and continuity, Derivative of inverse functions, The Chain Rule., Maximizers and minimizers, Rolle's Theorem and the Mean Value Theorem, The derivative of vector-valued functions of several variables. Applications in Extrema.

Recommended Books:

1. Bartle, G. R. and Sherbert, R. D., *Introduction to Real Analysis*, Wiley, 4th edition, 2011.
2. Fraenkal, A. A., *Abstract Set Theory*, North-Holland Publishing, Amsterdam, 1966.
3. Gaskill, H. S. and Narayanaswami, P. P., *Elements of Real Analysis*, Prentice Hall, 1st edition, 1997.
4. Parzynski, W. R., *Introduction to Mathematical Analysis*, Mcgraw Hill College, 1st edition, 1983.
5. Rudin, W., *Principles of Mathematical Analysis*, McGraw-Hill Publishing Company, 3rd edition, 1976.
6. Suppes, P., *Axiomatic Set Theory*, Dover Publications, Inc., New York, 1972.

Course Title: Fundamentals of Mechanics

Course Code: MATH-205

Course Type: Major Math

Prerequisites: Introduction to Physics

Credit Hours: 3 (3 + 0)

Course Objectives: This course will provide students with a solid foundation in mechanics, essential for advanced studies in mathematics and physics. After completion of this course, the students will be able to:

- Develop an understanding of vector algebra and calculus as applied to mechanics.
- Analyze rectilinear and curvilinear motion of particles.
- Comprehend the concepts of work, power, energy, and conservation principles in kinetics.
- Study the principles and various forms of simple harmonic motion.
- Explore the dynamics of central forces and planetary motion.

Course Contents:

Preliminaries: Introduction to vector algebra, Scalar and vector products, Triple products, Derivatives and integrals of vectors.

Kinematics: Rectilinear motion of particles, Uniform rectilinear motion, Uniformly accelerated rectilinear motion, Curvilinear motion of particles, Rectangular components of velocity and acceleration, Tangential and normal components, Radial and transverse components, Projectile motion.

Kinetics: Work, Power, Kinetic and potential energy, Conservative force fields, Conservation of energy, Impulse, Torque, Conservation of linear and angular momentum, Non-conservative forces.

Simple Harmonic Motion: The simple harmonic oscillator, Amplitude, Period, Frequency, Resonance and energy, The damped harmonic oscillator, Over damped, Critically damped and underdamped motion, Forced vibrations, The two and three dimensional harmonic oscillators.

Central Forces and Planetary Motion: Central force fields, Equations of motion, Potential energy of a particle in a central field, Orbits, Kepler's laws of planetary motion, Apsides and apsidal angles for nearly circular orbits, Motion in an inverse square field.

Recommended Books:

1. Aruldhas, G., *Classical Mechanics*, PHI Learning Private Limited, 2009.
2. Fowles, G. R., and Cassiday, G. L., *Analytical Mechanics*, Thomson Brooks/Coley, 7th edition, 2005.
3. Goldstein, H., *Classical Mechanics*, Addison-Wesley Publishing Co., 1980.
4. Greiner, W., *Classical Mechanics- Systems of Particles and Hamiltonian Dynamics*, Springer-Verlag, 2004.
5. Spiegel, M. R., *Theoretical Mechanics*, McGraw Hill Book Company, 1980.

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Course Title: Group Theory

Course Code: MATH-206

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

Course Objectives: By the end of the course students should be able to:

- Gain a thorough understanding of the fundamental concepts and various applications of groups.
- Provide basic concepts of group theory including cyclic groups, normal subgroups, group homomorphism.
- Enhance their capacity for mathematical reasoning, develop skills in construct- ing simple proofs, and cultivate the ability to critically evaluate the correctness and complete- ness of proofs within the domain of group theory.

Course Contents:

Preliminaries: Relations, Mappings, Binary operation, Groupoid, Semigroup,

Introduction to Groups: Definition of a Group and its examples, elementary properties of groups, Abelian groups, Cyclic groups, Dihedral groups, Quaternion groups, Matrix groups.

Subgroups: Definition of subgroup, Properties of subgroups, Cosets and Lagrange's Theorem, Centralizer of an element of a group, Centre of a group, Normalizer of a subset in a group, Commutator subgroup of a group.

Normal Subgroups and Factor Groups: Definition of normal subgroup, Characterization of normal subgroups, Factor groups, Simple groups, Direct product of two groups and examples.

Group Homomorphisms: Definition of group homomorphism, Kernel of a homomorphism, Properties of homomorphisms, Isomorphism theorems, Correspondence theorem, Automorphisms of a group, Conjugation, Conjugacy classes of groups.

Permutation Groups: Definition of permutation group, Cycles, Symmetric Groups, Conjugacy classes of Symmetric groups and Alternating groups, Cayley's theorem.

Group Action: Group actions and its examples, Orbit-Stabilizer theorem.

Recommended Books:

1. Fraleigh, J. B., *A First Course in Abstract Algebra*, Pearson, 7th edition , 2002.
2. Gallian, C. J., *Contemporary Abstract Algebra*, Chapman and Hall/CRC, 10th edition, 2020.
3. Herstein, I. N., *Topics in Algebra*, John Wiley & Sons, 2nd edition, 1991.

4. Rotman, J., *An Introduction to the Theory of Groups*, 4th edition, Springer, 1995.

5. Smith, G. C. and Tabachnikova, O. M., *Topics in Group Theory*, Springer, 2000.

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Course Title: Complex Analysis

Course Code: MATH-301

Course Type: Major Math

Prerequisites: Calculus

Credit Hours: 3 (3 + 0)

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

- Represent complex numbers algebraically and geometrically
- Understand Cauchy-Riemann equations, analytic functions and various properties of analytic functions.
- Understand Cauchy theorem and Cauchy integral formulas and apply these to evaluate complex contour integrals.
- Represent functions as Taylor and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

Course Contents:

Introduction to Complex Numbers: Algebra of complex numbers, Geometric representation of complex numbers, Conjugate and modulus of complex numbers, Polar form of complex numbers, Argument function, Roots of complex numbers.

Functions of Complex Variables: Definition of functions of a complex variable, limit and continuity, Branches of functions, Differentiable. Analytic functions, The Cauchy-Riemann equations, Entire functions, Harmonic functions. Elementary functions: Exponential, Trigonometric, Hyperbolic, Logarithmic and Inverse elementary functions. Definitions of Conformal mapping and Möbius transformation.

Complex Integrals: Contours and contour integrals, Upper bounds for Moduli of contour integrals, Cauchy-Goursat theorem, Cauchy integral formula, Liovilles theorem, Morereas theorem, Fundamental theorem of algebra.

Series: Power series, Radius of convergence and analyticity, Taylors and Laurents series.

Residues and Poles: Isolated singular points, Residues, Cauchys Residue Theorem, Types of singular points, Calculus of residues, Contour integration, Cauchys residue theorem with applications in computing real integrals.

Recommended Books:

1. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications*, McGraw Hill, 9th edition, 2013.

2. Kasana, H. S., *Complex Variables: Theory and Applications*, Prentice-Hall of India Pvt.Ltd, 2nd edition, 2005.

3. Pennisi, L., *Elements of Complex Variables*, Holt, Rinehart and Winston, 2nd edition, 1976.

4. Spiegel, M. R., *Complex Variables*, McGraw-Hill Education-Europe, 1980.

5. Zill, D. G. and Shanahan, P. D., *Complex Analysis: A First Course with Applications*, Jones & Bartlett Learning, 3rd edition, 2013.

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Course Title: Linear Algebra

Course Code: MATH-302

Course Type: Major Math

Prerequisites: Group Theory

Credit Hours: 3 (3 + 0)

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

- Analyze and solve complex systems using linear equations for practical applications utilizing MATLAB/Python for computational efficiency.
- Explore the structure and properties of vector spaces and linear transformations.
- Apply linear transformations, eigenvalues, and eigenvectors to real-world problems, enhancing skills in matrix diagonalization.
- Utilize linear algebra techniques in diverse applications such as fractals, chaos theory and cryptography.

Course Contents:

Systems of Linear Equations and Matrices: Definition of matrix, various types of matrices(Diagonal, Triangular, Symmetric Matrices), Algebra of matrices, Determinants, Systems of Linear Equations, Guassian elimination and Gauss Jordan method. Applications of linear systems: Network analysis (Traffic flow), Electrical circuits

Vector Spaces: Additive Abelian group, Definition of a field and examples, Real vector spaces, subspaces, Linear combination and spanning set, Linear independence and linear dependence, Basis, Dimension, Quotient space, Rank of a matrix and its applications.

Orthogonality in Vector spaces: Inner product, Orthogonality, Gram-Schmidt process, Orthogonal Complement, Method of least squares.

Eigenvalues and Eigenvectors: Eigenvalues and eigenvectors, Characteristic polynomial, Diagonalization of a matrix, Cayley-Hamilton Theorem.

Linear Transformations: Definition of linear transformations, Invertibility and singularity of linear transformations, Rank and nullity of linear transformations, Matrix of a linear transformation.

Applications of Linear Algebra: Fractals, Chaos theory, and Cryptography.

Recommended Books:

1. Anton, H. and Rorres, C., *Elementary Linear Algebra Applications Version*, John Wiley and Sons Inc. 9th Edition, 2005.

2. Friedberg, S. H., Insel, A. J. and Spence, L. E., *Linear Algebra*, Prentice Hall, 3rd Edition, 2000.

3. Kolman, B. and Hill, D. R., *Introduction Linear Algebra with Applications*, Prentice Hall International, Inc. 7th Edition, 2001.

4. Lipschutz, S., *Schaum's Outline of Beginning Linear Algebra*, Mc-Graw Hill Company, New York, 1996.

5. Nicholoson, W. K., *Elementary Linear Algebra*, PWS-Kent Publishing Company, Boston, 2004.

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Course Title: Partial Differential Equations

Course Code: MATH-303

Course Type: Major Math

Prerequisites: Ordinary Differential Equations

Credit Hours: 3 (3 + 0)

Course Objectives: Partial Differential Equations (PDEs) are at the heart of applied mathematics and many other scientific disciplines. After the completion of the course, students will be able to:

- Understand fundamental concepts of PDEs, identification and classification of their different types.
- Learn technique of separation of variables to solve partial differential equations and analyze the behavior of solutions in terms of eigen function expansions.
- Apply elementary solution techniques and be able to interpret the results and solve specific problems in major area of studies.

Course Contents:

First Order Partial Differential Equations: Introduction, Formation of PDEs, Linear PDEs of the first order, Cauchy's problem for quasilinear first-order PDEs, First order nonlinear equations, Special types of first order equations.

Second order Partial Differential Equations: PDEs of second order in two independent variables with variable coefficients, Linear transformation from one equation to another, normal form, Cauchy's problem for second order PDEs in two independent variables.

Adjoint Equations: Adjoint operator, Self-adjoint equation and operator, Linear PDEs in n independent variables, Lagrange's identity, Green's theorem for self-adjoint operator.

Boundary Value Problems: Laplace equation, Dirichlet problem for a circle, Poisson's integral for a circle, solution of Laplace equation in cartesian, Cylindrical, and spherical coordinates, The wave equation in one dimension, Wave equation in higher dimensions, The heat equation.

Recommended Books:

1. Dennemyer, R., *Introduction to Partial Differential Equations and Boundary Value Problems*, McGraw Hill, 1st edition, 1968.

2. Haberman, R., *Elementary Applied Partial Differential Equations*, Prentice Hall, 1997.

3. Pinsky, M. A., *Partial differential equations and boundary-value problems with applications*, Amer Mathematical Society, 3rd edition, 2011.

4. Sneddon, I. N., *Elements of Partial Differential Equations*, Dover Publishing, 2006.

5. Zauderer, E., *Partial Differential Equations of Applied Mathematics*, Wiley-Interscience, 2nd edition, 1998.

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Course Title: Computational Tools

Course Code: MATH-304

Course Type: Major Math

Prerequisites: Applications of ICT

Credit Hours: 3 (3 + 0)

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

- Write programs to solve engineering problems using MATLAB/Mathematica.
- Develop skills to analyze, decompose, and solve engineering problems algorithmically with MATLAB/Mathematica.
- Understand various programming constructs and their applications in computational problem-solving.
- Typeset articles, books and Theses in LaTeX and prepare presentations in Beamer.

Course Contents:

Introduction to MATLAB: MATLAB interface, Command Window, user input and output, Arithmetic, variables, operators and expressions, Errors in Input, Vectors and Matrices, Functions: Built-in Functions, User-Defined Functions. Graphics: two-dimensional plots, three-dimensional plot. Calculus with MATLAB Differentiation, Integration, Limits Sums and Products, Taylor Series.

Matlab Programming: Logical Operators, M-Files, Script M-Files, Function M-Files, Flow control: if statement, While loops, break, continue, For loops, Nested Loops, Array Functions.

Mathematica: Getting Acquainted, Basic Concepts, Lists, Two-Dimensional Graphics, Three-Dimensional Graphics, Equations, Algebra and Trigonometry, Differential Calculus, Integral Calculus, Multivariate Calculus, Ordinary Differential Equations.

LaTeX: A brief history of TeX and its evolution to LaTeX, Techniques for customizing page layouts and formatting documents, Inserting and formatting mathematical symbols and equations, adding and formatting tables, figures, and plots in a LaTeX document, Guidelines and best practices for writing reports, books, and theses in LaTeX.

Recommended Books:

1. Herniter, M.E., *Programming in MATLAB*, Cengage Learning, 1st edition, 2000.
2. Hunt, B.R., Lipsman, R. L. and Rosenberg, J. M., *A Guide to MATLAB: For Beginners and Experienced Users 2nd Edition*, Cambridge University Press, 2nd edition, 2006.
3. Goossens, M., Mittelbach, F. and Rahtz, S. et al., *The LaTeX Graphics Companion*, Addison-Wesley, 2nd edition, 2008.
4. Grätzer, G., *More Math into LaTeX*, Springer, 4th edition, 2007.
5. Muresan, M., *Introduction to Mathematica with Applications*, Springer Cham, 2017.

Course Title: Topology

Course Code: MATH-305

Course Type: Major Math

Prerequisites: N/A

Credit Hours: 3 (3 + 0)

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

- Define and distinguish between different types of topological spaces
- Apply the concepts of compactness and connectedness to solve problems
- Analyze and determine the continuity of functions in metric and topological spaces

- Recognize and create homeomorphisms
- Construct and identify examples of new topological spaces

Course Contents:

Topology: Definition and examples, Open and closed sets, Neighborhoods, Limit points, Closure of a set, Interior, Exterior and boundary of a set.

Bases and Subbases: Base and subbases, Neighborhood bases, First and second axioms of countability, Separable spaces, Lindelf spaces, Continuous functions and homeomorphism, Topological properties and classification of topological spaces.

Metric Spaces: Definition and examples, Open Ball, Closed Ball, Open Set, Metric topology, Metrizable topological spaces.

Construction of New Topological Spaces: Cartesian products, Induced topology, Ordered topology and quotient topology, Examples of topological spaces like $\mathbb{R}, \mathbb{R} \times \mathbb{R}, S^1, S^2$, torus, Cylinder and finite product spaces.

Separation Axioms: Separation axioms, Regular spaces, Completely regular spaces, Normal spaces.

Connectedness: Connected spaces, Connected components, Properties of connectedness, Image of a connected set through a continuous map, Path-connectedness, Examples of path-connected spaces, Connected subspaces of $\mathbb{R}$ under usual topology.

Compactness: Basic definition and examples of compact spaces, Key properties of a compact space, Image of a compact set through a continuous map, Compact subspaces of $\mathbb{R}^n$.

Recommended Books:

1. Dugundji, *Topology*, Allyn and Bacon Inc., Boston 1966.
2. Munkres, J., *Topology, a first course*, Prentice Hall Inc., 2nd edition, 2003.
3. Morris, S. A., *Topology Without Tears*, University of New England, 2018.
4. Simmon, G. F., *Introduction to Topology and Modern Analysis*, McGraw Hill Book Company, New York, 1963.
5. Willard, S., *General Topology*, Addison-Wesley Publishing Co., London, 1970.

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Course Title: Advanced Analysis

Course Code: MATH-306

Course Type: Major Math

Prerequisites: Real Analysis & Topology

Credit Hours: 3 (3 + 0)

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

- Understand and apply the concepts of Riemann integrals, Riemann-Stieltjes integrals and improper integrals.
- Study functions of bounded variation and their properties, including monotone functions and derivatives.
- Understand the concepts of Lebesgue measure, Lebesgue measurable functions and Lebsegue integration.

Course Contents:

Riemann-Stieltjes Integrals: Review of the Riemann integral, Definition of Riemann-Stieltjes integrals, Existence of upper and lower Riemann-Stieltjes integrals, Existence of Riemann-Stieltjes integrals, Properties of Riemann-Stieltjes integrals, Applications of Composition Rule, Riemann-Stieltjes integrals over a set of discontinuities, Relationship between Riemann integrals and Riemann-Stieltjes integrals, Fundamental theorem of calculus and its applications. Functions of Bounded Variation.

Improper Integrals: Points of infinite discontinuities and unbounded intervals. Types of improper integrals, Tests for convergence of improper integrals (Divergence, Comparison, Limit Comparison, Ratio, and Root tests), Beta and gamma functions and convergence of their integrals, Absolute and conditional convergence of improper integrals.

Lebesgue measurable sets: Sigma algebras and Borel sigma algebras, Definition and examples of Lebesgue measurable sets, definition of Lebesgue measure, Additivity of Lebesgue measure, Lebesgue measurable space, construction and Lebesgue measure of Cantor set, existence of non-Lebesgue measure sets.

Lebesgue measurable functions: Definition and examples of measurable functions, equivalent conditions for a measurable function, algebraic operations with measurable functions, Simple functions, Lebesgue measurable functions. Lebesgue Integration of simple functions and measureable function.

Recommended Books:

1. Axler, S., *Measure, Integration* & *Real Analysis*, Graduate Texts in Mathematics, Springer, 2020.

2. Bartle, G. R. and Sherbert, R. D., *Introduction to Real Analysis*, Wiley, 4th edition, 2011.

3. Gaskill, H. S. and Narayanaswami, P. P., *Elements of Real Analysis*, Prentice Hall, 1st edition, 1997.

4. Parzynski, W. R., *Introduction to Mathematical Analysis*, Mcgraw Hill College, 1st edition, 1983.

5. Rudin, W., *Principles of Mathematical Analysis*, McGraw-Hill Publishing Company, 3rd eEdition, 1976.

6. Tao, T., *An Introduction to Measure Theory*, American Mathematical Society, 2021.

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Course Title: Tensor Analysis

Course Code: MATH-307

Course Type: Major Math

Prerequisites: MATH-201

Credit Hours: 3 (3 + 0)

Course Objectives: The objectives of this course in Tensor Analysis are to:

- Equip students with a thorough understanding of tensor algebra and calculus.
- Enable students to manipulate tensors of various orders effectively.
- Apply tensor concepts in mathematical and physical contexts.
- Master fundamental concepts such as tensor notation, covariant and contravariant transformations, and differential operators in tensor form.
- Enhance analytical skills through theoretical study and practical applications.

Course Contents:

Introduction: Historical background, Importance of tensor analysis in various fields, Review of linear algebra: vectors and matrices, Basics of multi-variable calculus: partial derivatives, gradients, and Jacobians.

Curvilinear Coordinates: Transformation of Coordinates, Orthogonal curvilinear coordinates, Unit vectors in curvilinear systems, Arc length and volume elements, The gradient, divergence and curl, Special orthogonal coordinate systems, cylindrical, spherical, parabolic cylindrical, paraboloidal, elliptic cylindrical, prolate spheroidal, oblate spheroidal, ellipsoidal, bipolar coordinates.

Tensor Fundamentals and Basic Operations: Spaces of $N-$dimension, coordinate transformations, Einstein summation convention, contravariant and covariant vectors, Tensors of different ranks, Contravariant, covariant and mixed tensors, The Kronecker delta and Levi-Civita symbol, Tensors of rank greater than two, Symmetric and skew-symmetric tensors, Fundamental operations with tensors, Addition, subtraction, inner and outer products of tensors, Contraction theorem, quotient law.

Tensor Transformation and Metric Tensor: Tensor transformation laws, The line element and metric tensor, Conjugate or reciprocal tensors, Associated tensors, Christoffel's symbols, Transformation laws of Christoffel symbols, Geodesic Equation.

Advanced Tensor Calculus and Applications: Differentiation of tensor fields: Covariant and intrinsic derivatives and its applications. Lie derivatives: Scalar field, Vector fields, and Tensor fields, Riemannian metrics, Riemann curvature tensor and its components, The Ricci tensor, The Ricci scalar.

Recommended Books:

1. Chorlton, F., *Vector and tensor methods*, Ellis Horwood Publisher, 1977.
2. Spiegel, M. R., *Vector analysis- An introduction to tensor analysis*, McGraw Hill Book Company, 1981.
3. Joshi, A. W., *Matrices and tensors in physics*, Wiley, 1991.
4. Grinfeld, P., *Introduction to tensor analysis and the calculus of moving surfaces*, Springer, 2013.
5. Nguyen-Schäfer, H., and Schmidt, J. P., *Tensor analysis and elementary differential geometry for physicists and engineers*, Springer, 2014.

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Course Title: Rings and Modules

Course Code: MATH-308

Course Type: Major Math

Prerequisites: Group Theory & Linear Algebra

Credit Hours: 3 (3 + 0)

Course Objectives:

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

- Develop a solid understanding of the structure and theory of rings and modules for advanced mathematical exploration.
- Investigate integral domains and classify finitely generated modules as homomorphic images of free modules.
- Draw parallels between number systems and other algebraic structures to enhance algebraic comprehension.
- Pursue more advanced courses like Representation theory, Algebraic number theory and Homological Algebra.

Course Contents:

Ring theory: Ring structure with examples, Matrix rings, Quaternion rings, Special kinds of rings, Fields, Ideals, Quotient rings, Ring homomorphisms, Prime ideals and maximal ideals, Ring of polynomials, Division algorithm Factorization of polynomials, Divisibility in integral domains, Unique factorization domains, Euclidean domain, Principal ideal domain.

Module theory: Definition of module with examples, Submodules, Quotient modules, Direct sums of modules, Isomorphism theorems of modules, Composition series of modules, Schur's Lemma and its application, Zassenhaus butterfly lemma for modules, Modules with chain conditions, Finitely generated modules, Free modules, Exact sequences, Tensor product of modules.

Recommended Books:

1. Adhikari, M. R. and Adhikari, A., *Groups, Rings and Modules with Applications*, Hyderabad : Universities Press , 2003.

2. Beachy, J. A., *Introductory Lectures on Rings and Modules*, London Mathematical Society textbooks, 1999.

3. Cohen, P. M., *Introduction to Ring Theory*, Springer, 1st edition, 1999.

4. Dummit, D. S., Foote, R. M., *Abstract Algebra*, Third Edition, John Wiley & Sons, 2003.

5. Gallian, C. J., *Contemporary Abstract Algebra*, Chapman and Hall/CRC, 10th edition, 2020.

6. Herstein, I. N. *Topics in Algebra*, John Wiley & Sons, 2nd edition, 1991.

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Course Title: Methods of Mathematical Physics

Course Code: MATH-309

Course Type: Major Math

Prerequisites: Partial Differential Equations

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

- Understand and apply Fourier and Laplace transforms.
- Utilize advanced techniques for solving partial differential equations (PDEs).
- Understand and apply Green's functions and transform methods.
- Apply perturbation techniques for algebraic and differential equations.
- Understand variational methods and their applications.
- Enhance analytical and problem-solving skills in applied mathematics.

Course Contents:

Sturm Liouville Systems: Regular, periodic, and singular Sturm-Liouville systems and their solutions.

Laplace Transforms: Introduction and properties of Laplace transform, transforms of elementary functions, periodic functions, error function and Dirac delta function, inverse Laplace transform, convolution theorem, Hankel transforms for the solution of PDEs and their application to boundary value problems.

Fourier Transforms: Fourier integral representation, Fourier sine and cosine representation, Fourier transform pair, transform of elementary functions and Dirac delta function, finite Fourier transforms, Solutions of heat, wave and Laplace equations by Fourier transforms.

Green's Functions and Transform Methods: Expansion for Green's functions, transform methods, closed form Green's functions.

Perturbation Techniques: Perturbation methods for algebraic equations, perturbation methods for differential equations.

Variational Methods: Euler-Lagrange equations, integrand involving one, two, three and n variables, special cases of Euler-Lagrange equations, Necessary conditions for the existence of an extremum of a functional, constrained maxima and minima.

Recommended Books:

1. Boyce, W. E., *Elementary Differential Equations*, John Wiley & Sons Inc., 9th edition, 2008.

2. Bender, C. M. and Orszag, S. A., *Advanced Mathematical Methods for Scientists and Engineers*, Springer, Ist Edition, 1999.

3. Brown, J. W. and Churchill, R. V., *Fourier Series and Boundary Value Problems*, McGraw Hill, 8th edition, 2011.

4. Powers, D. L., *Boundary Value Problems and Partial Differential Equations*, Academic Press, 6th edition, 2009.

5. Krasnov, M. L., Makarenko, G. I. and Kiselev, A. I., *Problems and Exercises in the Calculus of Variations*, Imported Publications, Inc., 1985.

6. Snider, A. D., *Partial Differential Equations: Sources and Solutions*, Dover Publications, 2006.

Course Title: Functional Analysis

Course Code: MATH-401

Course Type: Major Math

Prerequisites: Topology & Linear Algebra

Credit Hours: 3 (3 + 0)

Course Objectives: Students will be able to:

- Define and identify complete and separable metric spaces.
- Apply linear algebra and analysis techniques to function spaces.
- Analyze and work with normed linear spaces, Banach spaces, and Hilbert spaces, including their properties and applications.

Course Contents:

Metric Space: Review of metric spaces, Continuity of metric spaces, Convergence in metric spaces, Cauchy Sequences, Complete metric spaces, Dense sets and separable spaces, Proofs about completeness and separability of some classes of metric spaces, no-where dense sets, Baire category theorem.

Normed Spaces: Normed linear spaces, Banach spaces, equivalent norms, Convex sets, Quotient spaces, Linear operator, Finite dimensional normed spaces, Continuous and bounded linear operators, Linear functionals, dual spaces.

Applications of Banach Spaces: Definition of fixed point and examples, Banach fixed point theorem, Classical Banach spaces, Distance measures.

Inner Product Spaces: Definition and examples, orthonormal sets and bases, Projections, Linear functionals on Hilbert spaces, Reflexivity of Hilbert spaces, The Riesz representation theorem, Annihilators and orthogonal complements, Direct decomposition.

Recommended Books:

1. Axler, S., *Measure, Integration* & *Real Analysis*, Graduate Texts in Mathematics, Springer, 2020.
2. Balakrishnan, A. V., *Applied Functional Analysis*, Springer-Verlag,2nd edition, 1981.
3. Conway, J. B., *A Course in Functional Analysis*, Springer-Verlag, 2nd edition, 1997.
4. Kreyszig, E., *Introduction to Functional Analysis with Applications*, John Wiley & Sons, Inc., 2004.
5. Yosida, K., *Functional Analysis*, Springer-Verlag, 5th edition, 1995.

Course Title: Differential Geometry

Course Code: MATH-402

Course Type: Major Math

Prerequisites: Tensor Analysis

Credit Hours: 3 (3 + 0)

Course Objectives: By the end of this course, students will be able to:

- Understand concepts about curves, surfaces, and their properties.
- Perform calculations involving the curvature and torsion of curves.
- Understand and compute different forms of surfaces.
- Analyze and solve problems related to geodesics and curvature of surfaces.
- Read and write rigorous mathematical proofs in the context of geometry.

- Build a solid foundation for further study in advanced mathematics, including courses on Riemannian geometry, topology, and manifold theory.

Course Contents:

Theory of Curves: Introduction to Differential Geometry, index notation and summation convention, plane curves and signed curvature, Space curves, arc length, tangent, normal and binormal, Osculating, normal and rectifying planes, Curvature and torsion, The Frenet-Serret theorem, Natural equation of a curve, Involutes and evolutes, helices, circles and cycloids, Fundamental existence theorem of space curves.

Geometry of Surfaces: Coordinate transformation, examples of surfaces, quadric surfaces, Tangent plane and surface normal, The first fundamental form and the metric tensor, Metric properties of surfaces, Computation of lengths, areas, and angles, Christoffel symbols of first and second kinds, The second fundamental form, Principal, Gaussian, mean, geodesic and normal curvatures, Gauss's Theorem Egregium, Gauss and Weingarten equations, Gauss and Codazzi equations.

Recommended Books:

1. Abbena, E., Salamon, S., & Gray, A., *Modern differential geometry of curves and surfaces with Mathematica*, Chapman and Hall/CRC, 2017.

2. Banchoff, T. F., & Lovett, S., *Differential geometry of curves and surfaces*, Chapman and Hall/CRC, 2022.

3. Lipschutz, M. M., *Schaum's outline of differential geometry*, McGraw Hill Book Company, 1969.

4. Pressley, A. N., *Elementary differential geometry*, Springer, 2010.

5. Toponogov, V. A., *Differential geometry of curves and surfaces*, Springer, 2005.

Course Title: Numerical Analysis

Course Code: MATH-403

Course Type: Major Math

Prerequisites: Single Variable Calculus & Linear Algebra

Credit Hours: 3 (3 + 0)

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

- Understand numerical methods for solving mathematical problems.
- Analyze and estimate errors in numerical computations.
- Solve non-linear equations and systems of linear equations.

- Explore various interpolation techniques and polynomial approximations.
- Apply computational tools for the solution of numerical methods.

Course Contents:

Number Systems and Error Analysis: Computer arithmetic, Floating point arithmetic, Sources of numerical error: Round-off Error, Truncation Error. Absolute, Relative and Percentage errors.

Methods for the Solution of Nonlinear Equations: Iterative methods and convergence, Bisection method, Fixed point iterative method, Regula falsi, Secant and Newton's method.

Numerical Solution of a System of Linear Equations: Direct methods: Gaussian elimination method, Gauss-Jordan method, Matrix inversion, LU-factorization, Doolittles, Crouts and Choleskys methods. Iterative methods: Gauss-Jacobi method and Gauss-Seidel method. Ill-condition system and condition number, Eigenvalues and eigenvectors, Power and Rayleigh quotient methods.

Interpolation and Polynomial Approximation: Difference operators, Interpolation with unequal intervals, Lagrange's interpolation formula, Newton's divided difference formula, Error in polynomial interpolation, Interpolation with equal intervals, Gregory Newton forward/backward interpolation formula, Error in polynomial interpolation, Central difference interpolation formulae Gauss's forward/backward interpolation formula, Stirling's formula, Laplace Everett's formula, Bessel's formula.

Recommended Books:

1. Burden, R. L. and Faires, J. D., *Numerical Analysis*, Cengage Learning, 10th edition, 2015.

2. Chapra, S. C. and Canale, R. P., *Numerical Methods for Engineers*, McGraw Hill, 7th edition, 2014.

3. Gerald, C. F. and Wheatley, P. O., *Applied Numerical Analysis*, Pearson College Div., 7th edition, 2003.

4. Mathews, J. H., *Numerical Methods for Mathematics*, Pearson College Div., 1992.

5. Vedamurthy, V. N. and Iyenger, N. Ch. S. N., *Numerical Methods*, Vikas Publishing House Pvt. Ltd, 2002.

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Course Title: Operations Research

Course Code: MATH-404

Course Type: Major Math

Prerequisites: Linear Algebra

Credit Hours: 3 (3 + 0)

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

1. Develop a comprehensive understanding of linear programming and its applications.
2. Develop skills to solve optimization problems using the simplex method and other advanced techniques.
3. Introduce transportation and assignment models and their real-world applications.
4. Develop problem-solving skills for network flow problems including the shortest-route and maximal-flow problems.

Course Contents:

Linear Programming (LP): Mathematical formulation of LP models, Graphical LP solution of maximization and minimization problems.

Simplex method: LP model in equation form, Transition from graphical to algebraic solution, Simplex method, Artificial starting solution, M-Technique and two-phase technique, Special cases in the simplex method (degeneracy, alternative optima, Unbounded solutions, Infeasible solutions).

Sensitivity Analysis: Graphical sensitivity analysis, Algebraic sensitivity analysis (changes in right-hand-side of constraints, Changes in objective coefficients).

Transportation Models: North-west corner method, Least-cost method, Vogel's approximations method, Method of multipliers, Assignment model, Transhipment model.

Network Models: Basic concepts and definitions, Applications of network models, Shortest-route algorithms for networks (Dijkstra's algorithm, Floyd's algorithm), Maximal-flow algorithm.

Recommended Books:

1. Fischetti, M., *Introduction to Mathematical Optimization*, Independently published, 2019.
2. Gillett, B. E., *Introduction to Operations Research*, McGraw-Hill Companies, 1976.
3. Hillier, F. S. and Lieberman, G. J., *Operations Research*, McGraw-Hill, 7th edition, 2002.
4. Taha, H. A., *Operations Research - An Introduction*, Pearson, 11th edition, 2022.
5. Winston, W. L. and Venkataramanan, M., *Introduction to Mathematical Programming. Operations Research*, Duxbury Press, 4th edition, 2002.

Course Title: Numerical Methods with Computer Programming

Course Code: MATH-405

Course Type: Major Math

Prerequisites: Numerical Analysis & Computational Tools

Credit Hours: 3 (3 + 0)

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

- Extend knowledge of numerical methods to differential equations, difference equations and advanced integration techniques.
- Explore numerical differentiation and integration.
- Understand ordinary differential equations using numerical methods.
- Study the formulation and solution of difference equations.
- Apply numerical methods to solve ordinary differential equations.

Course Contents:

Numerical Differentiation: Derivatives using Lagrange's interpolation formula, Newton's divided difference formula, Gregory Newton's forward/backward interpolation formula, Gauss's forward/backward interpolation formula, Stirling's formula, Laplace Everett's formula, Bessel's formula.
Lab Work: In MATLAB / Mathematica / Python.

Numerical Integration: Newton-Cotes formulae,Trapezoidal rule, Simpson rule, Weddle's rule, Boole's rule, Errors in quadrature formulae, Gaussian quadrature formulae.
Lab Work: In MATLAB / Mathematica / Python.

Formulation of Difference Equations: Analogy of difference equations, Linear homogeneous difference equations with constant coefficients, Linear non-homogeneous difference equations with constant coefficients.

Numerical Methods for Ordinary Differential Equations: Solutions of first order differential equations, Simultaneous first order differential equations, Higher order differential equations using Taylor's series method, Euler's method, Improved Euler's method, Modified Euler's method and Runge-Kutta methods, Predictor-corrector methods for solving initial value problems.
Lab Work: In MATLAB / Mathematica/ Python.

Recommended Books:

1. Burden, R. L. and Faires, J. D., *Numerical Analysis*, Cengage Learning, 10th edition, 2015.
2. Chapra, S. C. and Canale, R. P., *Numerical Methods for Engineers*, McGraw Hill, 7th edition, 2014.
3. Gerald, C. F. and Wheatley, P. O., *Applied Numerical Analysis*, Pearson College Div., 7th edition, 2003.
4. Mathews, J. H., *Numerical Methods for Mathematics*, Pearson College Div., 1992.
5. Vedamurthy, V. N. and Iyenger, N. Ch. S. N., *Numerical Methods*, Vikas Publishing House Pvt. Ltd, 2002.

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COURSE OUTLINES OF INTERDISCIPLINARY/ALLIED COURSES

Course Title: Digital Logic Design

Course Code: MAAL-301

Course Type: Allied/Interdisciplinary

Prerequisites: Applications of ICT

Credit Hours: 3 (3 + 0)

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

- Interpret, convert and represent different number systems and perform binary arithmetic.
- Design and analyze combinational logic circuits and sequential logic circuits.
- Design efficient combinational and sequential logic circuit implementations from functional description of digital systems.

Course Contents:

- **Number Systems:** Decimal, Binary, Octal, Hexadecimal, Conversions, Arithmetic operations.
- **Boolean Algebra and Logic Gates:** Digital logic gates, Boolean postulates, Boolean functions and their complements, Sum of MinTerms, Product of MaxTerms, Standard forms.
- **Gate Level Minimization:** Karnaugh maps, Two variable maps, Three variable maps, Four variable maps, Digital circuits using gates, Digital circuits using NAND gates.
- **Combinational Logic:** Analysis and design, Code converters, Half adder, Full adder, Multiplier Decoders and Encoders Multiplexers.
- **Registers and Counters:** Simple registers, Registers with parallel Load, Shift registers/Serial to parallel converters, Asynchronous/ Synchronous counter, Binary counter, Arithmetic Circuits, State Machines.

Recommended Books:

1. Brown, S. and Vranesic, Z., *Fundamentals of Digital Logic with Verilog Design*, McGraw Hill, 3rd edition, 2013.
2. Floyd, T., *Digital Fundamentals*, Pearson, 11th edition, 2014.
3. Morris Mano, M., Kime, C. and Martin, T., *Logic and Computer Design Fundamentals*, Pearson, 5th edition, 2015.
4. Tocci, R. J., Widmer, N. and Moss, G., *Digital Systems: Principles and Applications*, Pearson, 11th edition, 2010.

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Course Title: Decision Making Methods

Course Code: MACS-302

Course Type: Allied/Interdisciplinary

Prerequisites: N/A

Credit Hours: 3

Course Objectives: Multi-criteria decision making (MCDM) is a well-known branch of decision theory that aims at achieving multiple, and usually conflicting, objectives in decision problems. After completion of this course, the students will be able to:

- Learn how to make better decisions.
- Understand what informs decision-making styles.
- Learn how to better focus and identify specific decisions.

Course Contents:

- **Preliminaries**: Basic concepts of decision-making, Problem structuring, MCDM categories, Constructing the decision model, Role and types of criteria in MCDM problems, Normalization method, Weight assignment methods, The matrix representation of the MCDM problem, Fuzzy sets, Fuzzy linguistic set, Hesitant fuzzy set, Bipolar fuzzy sets.

- **Fuzzy decision making methods**: Fuzzy analytic hierarchy process, Fuzzy TOPSIS method, Fuzzy VIKOR method, Fuzzy WASPAS method, Fuzzy COPRAS method, Fuzzy EDAS method, TOPSIS method with bipolar fuzzy linguistic sets.

- **Fuzzy ELECTRE methodology**: Introduction to ELECTRE, Types of criterion used with ELECTRE, Fuzzy ELECTRE I method, Fuzzy ELECTRE II method, Fuzzy ELECTRE III method, Fuzzy ELECTRE IV method, Bipolar fuzzy ELECTRE methods.

Recommended Books:

1. Akram, M., Shumaiza and Alcantud, J.C.R., Multi-Criteria Decision Making Methods with Bipolar Fuzzy Sets, Springer, 2023.

2. Pedrycz, W., Ekel, P. and Parreiras, R., Fuzzy Multicriteria Decision-Making: Models, Methods and Applications, Wiley, 2010.

3. Tzeng, G.-H. and Huang, J.-J., Multiple Attribute Decision Making, Chapman and Hall/CRC, 2011.

4. Voskoglou, M. G., Fuzzy Methods for Assessment and Decision Making, Morgan Kaufmann, 2024.

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Course Title: Probability and Statistics

Course Code: MAAL-303

Course Type: Allied/Interdisciplinary

Prerequisites: Quantitative Reasoning

Credit Hours: 3 (3 + 0)

Course Objectives: Students will be able to:

- Understand the introduction and scope of statistics as a field of knowledge and relevance to other disciplines in the natural and social sciences.
- Master the concepts of probability, conditional probability, rules of probability and probability distributions.
- Understand the the concepts of regression analysis and correlation coefficient.

Course Contents:

Probability Theory: Axioms of probability, Addition and multiplication rules of probability, Conditional Probability, Bayes's rule.

Random Variables: Random variables, Discrete and continuous random variables, Mathematical expectations, Moments and moment generating functions, Bivariate random variable, Marginal and conditional probability distributions.

Discrete Probability Distributions: Uniform, Bernoulli and Binomial distribution, Hypergeometric and geometric distribution, Negative binomial and Poisson distribution.
Continuous Probability Distributions: Uniform and exponential distribution, Gamma and beta distributions, Normal distribution.

Regression and Correlation: Simple regression and least squares method, Scatter diagrams, Linear regression, Normal regression analysis, Correlation and its Coefficient, Normal correlation analysis.

Sampling Distributions: Population, Parameter and Statistic, Objects of Sampling, Sampling Distribution of mean, Standard errors, Sampling and non-sampling errors, Random Sampling with and without Replacement, Central Limit Theorem.

Statistical Inferences: Estimation, Types of estimation, Confidence interval, Tests of Hypothesis, Chi-square distribution.

Recommended Books:

1. Ash, R. B., *Basic Probability Theory*, Dover Publications Corporation, 2008.

2. Freund, J. E., *Mathematical Statistics*, Prentice Hall Inc., 1992.

3. Hogg, R. V. and Craig, A. T., *Introduction to Mathematical Statistics*, New York London, Collier-Macmillan, 3rd edition, 197.

4. Ross, S. A., *A First Course in Probability*, 8th Edition, Prentice Hall, 2010.

5. Walpole, R. E., *Introduction to Statistics*, Macmillan Publishing Company, 3rd edition, 1982.

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Course Title: Data Science

Course Code: MAAL-401

Course Type: Allied/Interdisciplinary

Prerequisites: Probability and Statistics

Credit Hours: 3 (3 + 0)

Course Objectives:
After completion of this course, students should be able to :

- Master fundamental Python programming concepts and efficiently use development environments for mathematical programming.
- Utilize libraries such as Matplotlib, NumPy, SciPy, SymPy and Pandas to perform and visualize advanced mathematical computations.
- Apply mathematical programming techniques to analyze and solve real-world problems.

Course Contents:

Introduction to Data Science : What is Data Science? Factors making data science ubiquitous. Applications of data science in the domains of social media, banking, e-commerce, web-based search engines, travelling, health care, automation, credit and insurance.

Six Phases of Data Science Life Cycle: Business Problem, Data Acquisition, Data Processing, Exploratory Data Analysis (EDA) and Visualization, Machine Learning (ML) Model Creation-Training-Evaluation, Deployment and Monitoring. Industry job roles and salary trends in data science domain.

Basics of Python Programming: History of Python, Overview of mathematical programming, Installing and using a Python development environment (Jupyter note book/CoLab). Python syntax and semantics, Data types and variables Control structures (loops, conditionals), functions, Modules and packages.

Container Types: Lists, Arrays, Tuples, Dictionaries, Sets, Container conversions.

Python Libraries for Data Science:
The `matplotlib` Library: Basic plotting with Matplotlib, Customizing plots (titles, labels, legends), Subplots and multiple plots 3D plotting and other advanced visualizations.
The `numpy` Library: NumPy arrays and operations, Mathematical functions in NumPy, Array manipulations and broadcasting, Linear algebra operations with NumPy, Universal functions.
The `scipy` Library: Key submodules in SciPy (optimize, integrate, interpolate, etc.), Numerical integration, Interpolation techniques, optimization problems, Differential equations.

The `sympy` **Library:** Basic elements of SymPy, Symbolic Linear Algebra, Calculus with `sympy`, Graphics in `sympy`, Three dimensional Graphs.
The Pandas Library: Series and DataFrames, Data manipulation and cleaning with Pandas, Merging, joining, and concatenating DataFrames, Grouping and aggregating data.

Mathematics for Data Science: Probability & Statistics, Differential Calculus, Linear Algebra.

Recommended Books:

1. Cielen, D., Meysman, A., and Ali, M., *Introducing Data Science*, Manning, 1st Edition, 2016.

2. Dietel, P. and Dietel, H., *Python for Programmers*, Pearson, 2019.

3. Führer, C., J. E. Solem, and Verdier, O., *Scientific Computing with Python 3*, Packt Publishing, 2nd edition, 2021.

4. Johansson, R., Urayasu-shi, Chiba, *Numerical Python: Scientific Computing and Data Science Applications with Numpy, SciPy and Matplotlib*, Pearson, 4th edition, 2017.

5. Hazrat, R., *A Course in Python*, Springer, 2023.

6. Seroul, R., *Programming for Mathematicians*, Springer, 2000.

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COURSE OUTLINES OF COMPUTER SCIENCE COURSES

Course Title: Programming Fundamentals

Course Code: MACS-301

Course Type: Computer Science

Prerequisites: Applications of ICT

Credit Hours: 3 (2 + 1)

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

- Write, compile and debug programs in C language.
- Use different data types in a computer program.
- Design programs involving decision structures, loops, arrays, and functions.
- Identify the difference between call by value and call by reference.
- Use pointers to understand the dynamics of memory.
- Perform file handling operations and manage memory dynamically.

Course Contents:

- **Introduction to the C Language:** Algorithm, Pseudo code, Flowchart, Background, C Programs, Identifiers, Data Types, Variables, Constants, Input / Output, Operators (Arithmetic, relational, logical, bitwise, etc.), Expressions, Precedence and Associatively, Expression Evaluation, Type conversions.

- **Control Statements:** Basic data types and variables, input/output constructs, arithmetic, comparison, and logical operators, conditional statements and execution flow for conditional statements, repetitive statements and execution flow for repetitive constructs.

- **Functions:**Introduction to Structured Programming, Functions – basics, user-defined functions, inter-function communication (call by value, call by reference), Standard functions, Storage classes – auto, register, static, extern, scope rules, arrays to functions, recursive functions, example C programs.

- **Arrays:** Basic concepts, one-dimensional arrays, two-dimensional arrays, multidimensional arrays, C programming examples.

- **Pointers:** Introduction (Basic Concepts), pointers to pointers, compatibility, Pointer Applications, Arrays and Pointers, Pointer Arithmetic, memory allocation functions, array of pointers, pointers to void, pointers to functions, command-line arguments, Introduction to structures and unions.

- **File Handling:** Basics of file operations, Reading from and writing to files, File pointers, Error handling in file operations, Binary and text file handling.

- **Memory Management:** Dynamic memory allocation, malloc, calloc, realloc, and free functions, Memory leaks and their prevention, Use of pointers in dynamic memory management.

Recommended Books:

1. Deitel, P. and H. Deitel, H., *C++ How to Program*, Pearson, 10th edition, 2016.
2. Gaddis, T., *Starting Out with C++ from Control Structures to Objects*, Pearson, 9th edition, 2017.
3. Hanly, J. R. and Koffman, E. B., *Problem Solving and Program Design in C*, Pearson, 7th edition, 2012.
4. Kernighan, B. W. and Ritchie, D. M., *C Programming Language*, Pearson, 2nd edition, 1988.

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Course Title: Object Oriented Programming

Course Code: MACS-401

Course Type: Computer Science

Prerequisites: Programming Fundamentals

Credit Hours: 3 (2 + 1)

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

- Understand the object oriented programming paradigm and concepts of objects and classes.
- Apply the concepts of object-oriented programming principles.
- Design daily-life applications using object oriented programming.

Course Contents:

Introduction: Object-oriented design, History, Advantages of object-oriented design.

Object Oriented Programming: Terminology and features, Classes, Objects, Data encapsulation, Constructors, Destructors, Access modifiers, Const vs non-const functions, Static data members & functions, Function overloading, Operator overloading, Identification of classes and their relationships, Composition, aggregation, Inheritance, Multiple inheritances, Polymorphism, Abstract classes, Interfaces.

Recommended Books:

1. Deitel, P. and H. Deitel, H., *C++ How to Program*, Pearson, 10th edition, 2016.
2. Gaddis, T., *Starting Out with C++ from Control Structures to Objects*, Pearson, 9th edition, 2017.
3. Hanly, J. R. and Koffman, E. B., *Problem Solving and Program Design in C*, Pearson, 7th edition, 2012.
4. Kernighan, B. W. and Ritchie, D. M., *C Programming Language*, Pearson, 2nd edition, 1988.

Course Title: Database Management System

Course Code: MACS-402

Course Type: Computer Science

Prerequisites: Applications of ICT

Credit Hours: 3 (2 + 1)

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

- Understand the basic concepts and the applications of database systems.
- Master the basics of SQL and construct queries using SQL.
- Understand the relational database design principles.
- Familiar with the basic issues of transaction processing.

Course Contents:

- **File Systems and Databases:** A file system critique, Database systems, Database approach vs file-based system, Database architecture, Three level schema architecture, Data independence, Database models.
- **Relational Database Management System (RDBMS):** Logical view of Data, Entities and Attributes, Tables and their Characteristics, Keys, Relational data model, Attributes, schemas, Tuples, Domains, Relation instances, Keys of relations, Integrity constraints.
- **Relational Algebra:** Relational database operators: Selection, Projection, Cartesian product, Types of joins.
- **Entity Relationship (E-R) Modeling:** Basic Modeling Concepts, Entity sets, Attributes, Relationship, Entity-relationship diagrams.
- **Normalization of Database Tables:** Objectives, Forms, Normalization and Database Design, functional dependencies, normal forms, Denormalization.
- **Structured Query Language (SQL):** Introduction, DDL Commands, Joins and subqueries in SQL, Grouping and aggregation in SQL, DML Commands, DCL Commands, Complex Queries and SQL Functions, Procedural SQL, Triggers, Stored procedures.
- **Transaction Management:** Transaction, ACID Properties of transaction, Recovery.

Recommended Books:

1. Coronel, C. and Morris, S., *Database Systems: Design, Implementation & Management*, 13th Edition, Cengage Learning, 2017.

2. Connolly, T. and Begg, C., *Database Systems: A Practical Approach to Design, Implementation and Management*, 6th Edition, Pearson, 2015.
3. Elmasri, R. and Navathe, S. B., *Fundamentals of Database Systems*, 7th Edition, Pearson, 2016.
4. Hoffer, J. A., Venkataraman, R. and Topi, H.,*Modern Database Management*, 12th Edition, Pearson, 2015.
5. McLaughlin, M., *Oracle Database 11g PL/SQL Programming*, 1st Edition, McGraw-Hill Education, 2008.

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Course Title: Artificial Intelligence

Course Code: MACS-403

Course Type: Computer Science

Prerequisites: Object Oriented Programming

Credit Hours: 3(2+1)

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

- Study the concepts of Artificial Intelligence.
- Learn the methods of solving problems using Artificial Intelligence.
- Learn the knowledge representation techniques, reasoning techniques and planning.

Course Contents:

- **Preliminaries**: Introduction to AI, Machine learning and deep learning. *Python for AI and Mathematics*: Basic Python programming and libraries for AI (numpy, scipy, matplotlib), Introduction to pandas and scikit-learn.
- **Linear algebra and optimization**: Vectors, Matrices, Linear algebra for AI. *Gradient descent and optimization*: Cost functions and optimization algorithms, Mathematical derivation of gradient descent.
- **Statistical inference and AI**: Random variables, Expectation, Variance, Hypothesis testing and AI model evaluation, Linear regression and its variants (Simple linear regression, Multiple linear regression, Ridge and Lasso regression, regularization techniques).
- **Supervised learning**: Logistic regression for classification, Sigmoid function, Binary classification, Mathematics behind the logistic regression model, Decision trees and random forests, Splitting criteria (entropy, Gini index), Random forests and ensemble methods, Support vector machines (SVM), Hyperplanes, margins, and the kernel trick, Mathematics behind SVM for classification and regression.
- **Neural networks**: Introduction to neural networks, Biological inspiration, Perceptron model, Feed forward neural networks, Mathematical formulation.

- **Back propagation and training neural networks**: Chain rule for gradients, Back propagation algorithm, Mathematical details of training a neural network.

- **Activation functions and their properties**: Mathematical behavior of activation functions and their influence on learning, Deep learning with Python, Building and training neural networks with Python, Hands-on coding session with simple examples.

Recommended Books:

1. Aggarwal, C.C., *Neural Networks and Deep Learning*, Springer, 2023.

2. Chollet, F., *Deep Learning with Python*, Manning Publications, 2021.

3. Deisenroth, M. P., *Mathematics for Machine Learning*, Cambridge University Press, 2020.

4. Liu, P. and Li, H.-X., *Fuzzy Neural Network Theory and Application*, World Sci. Pub. Com., 2004.

5. Russell, S., and Norvig, P., *Artificial Intelligence: A Modern Approach*, Pearson, 2020.

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Course Title: Data Structures and Algorithms

Course Code: MACS-404

Course Type: Computer Science

Prerequisites: Introduction to Graph Theory and Object Oriented Programming

Credit Hours: 3(2+1)

Course Objectives: This is a fundamental course on algorithms in computer science. After completion of this course, the students will be able to:

- Analyze the asymptotic performance of algorithms.
- Solve recurrence relations.
- Apply divide and conquer strategy.
- Understand the concepts of graphs and trees and related algorithms.

Course Contents:

- **Introduction:** What is an algorithm?, History, Properties of algorithms, The growth of functions.

- **Complexity of Algorithms:** Asymptotic notations, Basic definitions of algorithmic complexity (worst case, average case), Complexity of matrix multiplication, Complexity of searching and sorting algorithms.

- **Abstract Data Types(ADTs):** Array and Polynomial as an ADT, Sparse Matrices, and Representation of Arrays. Stack ADT: Linked lists and array implementations, Expressions, Postfix Notation, and Infix to postfix conversion

- **Recursion:** Recursive definition, Recursive algorithms, Divide-and-conquer algorithms, Recurrence relations. Methods for solving recurrences: Substitution method, Recursion tree method, Master method.
- **Hashing:** Hash Functions, Division, Overflow Handling, Chaining.
- **Graphs and Related Algorithms:** Graph terminology, Adjacency list, Adjacency matrix, and Adjacency list representation of graph. Elementary graph operations: Breadth first search and depth first search. Shortest path algorithms.
- **Trees and Related Algorithms:** Binary tree, Spanning Tree, Algorithms for spanning tree: Depth-first search algorithm, breadth-first search algorithm. Minimum spanning trees, Algorithms for Minimum Spanning Trees: Prim's algorithm, Kruskal's algorithm. Tree traversal (Inorder, Preorder an Postorder).

Recommended Books:

1. Adam B. Drozdek, *Data Structure and Algorithm in C++*, 4th edition, Cengage Learning, 4th edition, 2012.
2. Cormen, T. H., Leiserson, C. E. et al., *Introduction to Algorithms*, MIT Press, 4th edition, 2022.
3. Rosen, K., *Discrete Mathematics and Its Applications*, McGraw-Hill Education, 7th edition, 2011.
4. Samanta, D., *Classic Data Structures*, Prentice Hall, 2nd edition, 2009.
5. Weiss, M. A., *Data Structure and Algorithms in C++*, 3rd edition, Pearson Education, 2006.

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Course Title: Web Programming

Course Code: MACS-405

Course Type: Computer Science

Prerequisites: Programming Fundamentals

Credit Hours: 3 (2 + 1)

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

- Demonstrate and understand the basic concepts of web programming.
- Write well-structured, easily maintained, standards-compliant, web pages using HTML and CSS code.
- Use JavaScript to add dynamic content to pages that meet specific needs and interests.

Course Contents:

- **Introduction:** Web Applications, TCP/IP Application Services.

- **Web Servers:** Basic Operation, Virtual hosting, Chunked transfers, Caching support, Extensibility. SGML, HTML5, CSS3.
- **XML Languages and Applications:** Core XML, XHTML, XHTM MP.
- **Web Services:** SOAP, REST, WML, XSL. Operations, Processing HTTP Requests, Processing HTTP Responses, Cookie Coordination, Privacy and P3P, Complex HTTP Interactions, Dynamic Content Delivery. Server Configuration. Server Security.
- **Web Browsers Architecture and Processes:** Active Browser Pages: JavaScript, DHTML, AJAX. JSON.
- **Approaches to Web Application Development:** Programing in any Scripting language. Search Technologies, Search Engine Optimization. XML Query Language, Semantic Web, Future Web Application Framework.

Recommended Books:

1. Deitel, P. and H. Deitel, H., , *Java How to Program*, Pearson, 11th edition, 2017.
2. Hall, M. and Brown, L., *Core Servlets and JavaServer Pages*, Pearson, 2nd Edition, 2017.

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