Curriculum
of
BS Mathematics
(4 Years)

Department of Mathematics
University of the Punjab
Lahore

August 30, 2024.

SYLLABI FOR 4 YEAR BS MATHEMATICS
(SEMESTER SYSTEM PROGRAMME)

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

Programme	BS Mathematics
Duration	4 Years
Semesters	8
Credit Hours	133
Department	Mathematics
Faculty	Science

Introduction

The Department of Mathematics at the University of the Punjab, established in the 1880s, stands as one of the institution's oldest departments. Over its long history, it has produced numerous distinguished graduates who have excelled in mathematics and related fields such as mathematical and theoretical physics. For many years, the department operated on an inter-collegiate basis, with faculty from local colleges such as Government College, F.C. College, Dyal Singh College, Islamia College Civil Lines, and M.A.O. College, Lahore, teaching M.Sc. classes on the university premises.
In 1956, the department achieved significant progress by becoming an independent institution with the appointment of two full-time faculty members: one reader and one senior lecturer. Since then, the department has grown substantially and currently offers BS (4 years), BS (5 Semester) (Morning/Self-supporting), M.Phil., and Ph.D. programs. 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.

Vision

The Department 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 Department 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 Department 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 department's staff, acknowledging them as its greatest asset.

Admission Eligibility Criteria

- Intermediate or equivalent qualification with Mathematics having at least 44% 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

A course code is made of two parts:

1. **Letter Code:** It contains 2 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 Mathematics courses: The letter code MATH is used for all major Mathematics courses.
- Interdisciplinary/allied courses: The letter code MPHY is used for Physics courses and the letter code MACS is used for Computer Science courses.

2. **Numeric Code:** It consists of 3 digits. First digit from left represents the year with a value starting from 1, second digit represents subject/specilization, and third digit represents the sequence of the course within same subject category.

STRUCTURE OF BACHELOR DEGREE PROGRAM IN MATHEMATICS

A bachelor degree with a single major Mathematics consists of 133 credit hours. The breakup of credit hours is as under:

Degree Awarded:	BS Mathematics
Duration:	4 Years (8 Semesters)
Total Credit Hours:	133
Major Mathematics:	27(81 credit hours)
General Education Courses:	12 (30 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. 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/History	02
2	GSS- 101	Introduction to Economics/Sociology	02
3	GENG-101	Functional English	03
4	GENT-101	Entrepreneurship	02
5	GQR- 101	Quantitative Reasoning I	03
6	GCCE-101	Civics and Community Engagement	02
7	GICP-101	Ideology and Constitution of Pakistan	02
8	GISL-101	Islamic Studies	02
9	GNS- 201	Introduction to Physics	03(2+1)
10	GQR- 202	Quantitative Reasoning II	03
11	GENG-201	Expository Writing	03
12	GICT- 201	Applications of ICT	03(2+1)
	Total	**12**	**30**

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	Plane curves & Analytical Geometry	3
3	MATH-103	Introduction to Graph Theory	3
4	MATH-104	Discrete Mathematics	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	Classical Mechanics	3
19	MATH-303	Linear Algebra	3
14	MATH-304	Partial Differential Equations	3
15	MATH-305	Computational Tools	3
16	MATH-306	Topology	3
17	MATH-307	Advanced Analysis	3
18	MATH-308	Tensor Analysis	3
19	MATH-309	Rings and Modules	3
20	MATH-310	Methods of Mathematical Physics	3
21	MATH-311	Mathematical Computing with Python	3
22	MATH-401	Functional Analysis	3
23	MATH-402	Differential Geometry	3
24	MATH-403	Numerical Analysis	3
25	MATH-404	Operations Research	3
26	MATH-405	Analytical Dynamics	3
27	MATH-406	Numerical Methods with Computer Programming	3
	Total	**27**	**81**

List of Interdisciplinary/Allied Courses

The interdisciplinary/allied courses are given in Table 3. A student may choose any Four courses from the Table 3, selecting Two courses in each of the 7th and 8th semesters.

Table 3: List of Interdisciplinary/Allied Courses for 7th and 8th Semesters

Interdisciplinary	Course Code	Course Title	Credit Hours
	MPHY-410	Fluid Mechanics	3
	MPHY-411	Quantum Mechanics	3
Physics	MPHY-412	Special Theory of Relativity	3
	MPHY-413	Electromagnetic Theory	3
	MPHY-414	Introduction to Manifolds	3
	MPHY-415	Lie Symmetries	3
	MACS-410	Digital Logic Design	3
	MACS-411	Database Management System	3
	MACS-412	Introduction to Algorithms	3
	MACS-413	Programming Fundamentals	3
	MACS-414	Web Programming	3
Computer Science	MACS-415	Object Oriented Programming	3
	MACS-416	Quantum Computing	3
	MACS-417	Fundamentals of Fuzzy Systems	3
	MACS-418	Computer-Aided Geometric Design	3

Department of Mathematics, University of the Punjab, Lahore

Scheme of Studies for BS in Mathematics - With Effect From Fall 2024

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
MATH-101 (3) Single Variable Calculus	MATH-102 (3) Plane Curves & Analytic Geometry	MATH-201 (3) Multivariable Calculus	MATH-204 (3) Real Analysis	MATH-301 (3) Complex Analysis	MATH-307 (3) Advanced Analysis	MATH-401 (3) Functional Analysis	MATH-404 (3) Operations Research
GAH-101(2) GE(AH) (Philosophy /History)	MATH-103 (3) Introduction to Graph Theory	MATH-202 (3) Ordinary Differential Equations	MATH-205 (3) Fundamentals of Mechanics	MATH-302 (3) Classical Mechanics	MATH-308(3) Tensor Analysis	MATH-402 (3) Differential Geometry	MATH-405 (3) Analytical Dynamics
GENG-101(3) Functional English	MATH-104(3) Discrete Mathematics	MATH-203 (3) Number Theory	MATH-206 (3) Group Theory	MATH-303(3) Linear Algebra	MATH-309 (3) Rings and Modules	MATH-403 (3) Numerical Analysis	MATH-406 (3) Numerical Methods with Computer Programming
GQR- 101(3) Quantitative Reasoning I	GCCE-101(2) Civics and Community Engagment	GNS-201 3(2+1) Introduction to Physics	GQR- 202(3) Quantitative Reasoning II	MATH-304(3) Partial Differential Equations	MATH-310 (3) Methods of Mathematical Physics	XXXX-XXX (3) Allied Course I	XXX-XXX(3) Allied Course III
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) Computational Tools	MATH-311 (3) Mathematical Computing with Python	XXXX-XXX (3) Allied Course II	XXXX-XXX (3) Allied Course IV
GSS-101(2) GE(SS) (Economics/ Sociology)	GENT-101(2) Entrepreneurship	HQ-003 (0) Translation of Holy Quran	HQ-004 (1) Translation of Holy Quran	MATH-306 (3) Topology	HQ-006 (1) Translation of Holy Quran	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-005(0) Translation of Holy Quran		HQ-007(0) Translation of Holy Quran	HQ-008(1) Translation of Holy Quran

Knowledge Domains	Cr. Hours
Major Mathematics	81
General Education Courses	30
Interdisciplinary/Allied Courses	12
Field Experience/Internship	3
Capstone Project	3
Holy Quran (HQ)	4
Total	133

BS Mathematics

Categorization of Courses as per HEC Guidelines

		Category (Credit Hours)					
Semester	**Courses**	**General Education**	**Major Math**	**Interdisciplinary /Allied**	**Holy Quran**	**Internship/Cap. Project**	**Semester Load**
1	7	12	3	-------------	0	-------------	**15**
2	7	6	9	--------------	1	-------------	**16**
3	6	6	9	-------------	0	-------------	**15**
4	6	6	9	-------------	1	-------------	**16**
5	7	--	18	-------------	0	-------------	**18**
6	6	--	15	-------------	1	-------------	**16**
7	7	…	9	6	0	3	**18**
8	7	--	9	6	1	3	**19**
PU		30	81	12	4	6	**133**
HEC Guidelines		30	Min 72	Min 12	4	6	**120----144**

SEMESTER-WISE WORKLOAD

A bachelor degree with a single major Mathematics is structured to be comprised of Eight regular semesters over a period of Four years. The semester-wise workload is as under:

Semester I

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-101	Single Variable Calculus	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
GSS-101	Introduction to Economics	General Education	N/A	2
HQ-001	Translation of Holy Quran	Compulsory	N/A	0
Semester's Total Credits				**15**

Semester II

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-102	Plane Curves & Analytic Geometry	Major Math	MATH-101	3
MATH-103	Introduction to Graph Theory	Major Math	N/A	3
MATH-104	Discrete Mathematics	Major Math	N/A	3
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
Semester's Total Credits				**16**

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
HQ-003	Translation of Holy Quran	Compulsory	HQ-002	0
Semester's Total Credits				**15**

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
Semester's Total Credits				**16**

Semester V

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-301	Complex Analysis	Major Math	MATH-204	3
MATH-302	Classical Mechanics	Major Math	MATH-205	3
MATH-303	Linear Algebra	Major Math	MATH-206	3
MATH-304	Partial Differential Equations	Major Math	MATH-202	3
MATH-305	Computational Tools	Major Math	GICT-201	3
MATH-306	Topology	Major Math	N/A	3
HQ-005	Translation of Holy Quran	Compulsory	HQ-004	0
Semester's Total Credits				**18**

Semester VI

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-307	Advanced Analysis	Major Math	MATH-204, MATH-306	3
MATH-308	Tensor Analysis	Major Math	MATH-201	3
MATH-309	Rings and Modules	Major Math	MATH-206, MATH-303	3
MATH-310	Methods of Mathematical Physics	Major Math	MATH-304	3
MATH-311	Mathematical Computing with Python	Major Math	GICT-201, MATH-305	3
HQ-006	Translation of Holy Quran	Compulsory	HQ-005	1
Semester's Total Credits				**16**

Semester VII

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-401	Functional Analysis	Major Math	MATH-303	3
MATH-402	Differential Geometry	Major Math	MATH-308	3
MATH-403	Numerical Analysis	Major Math	MATH-101	3
XXXX-XXX	Elective Course I	Interdisciplinary/Allied		3
XXXX-XXX	Elective Course II	Interdisciplinary/Allied		3
INTE-401	Field Experience/ Internship	Mandatory	Semesters I-VI	3
HQ-007	Translation of Holy Quran	Compulsory	HQ-006	0
Semester's Total Credits				**18**

Semester VIII

Course Code	Course Title	Course Type	Prerequisite	Credit Hours
MATH-404	Operations Research	Major Math	MATH-303	3
MATH-405	Analytical Dynamics	Major Math	MATH-302	3
MATH-406	Numerical Methods with Comp. Prog.	Major Math	MATH-403	3
XXXX-XXX	Elective Course I	Interdisciplinary/Allied		3
XXXX-XXX	Elective Course II	Interdisciplinary/Allied		3
CAPP-401	Capstone Project	Mandatory	Semesters I-VII	3
HQ-008	Translation of Holy Quran	Compulsory	HQ-007	1
Semester's Total Credits				**19**

COURSE OUTLINES OF MAJOR MATHEMATICS COURSES

To be offered in Department 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 theorems 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.

Course Title: Plane Curves & Analytic Geometry

Course Code: MATH-102

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 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, and 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.

Course Title: Introduction to Graph Theory

Course Code: MATH-103

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.

Course Title: Discrete Mathematics

Course Code: MATH-104

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 the 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.

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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 tests).

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.

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, Group of integers modulo n $\mathbb{Z}_n$.

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.

Course Title: Complex Analysis

Course Code: MATH-301

Course Type: Major Math

Prerequisites: Real Analysis

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.

Course Title: Classical Mechanics

Course Code: MATH-302

Course Type: Major Math

Prerequisites: Fundamentals of Mechanics

Credit Hours: 3 (3 + 0)

Course Objectives: Classical mechanics will provide a comprehensive understanding of classical mechanics, essential for advanced studies in mechanics and engineering. After completion of this course, the students will be able to:

- Understand inertial and non-inertial reference systems, and analyze the dynamics of particles in rotating frames.
- Examine the center of mass and gravity for both discrete and continuous systems.
- Study the planar motion and general motion of rigid bodies in space.
- Apply Euler's equations to explore the rotational dynamics of rigid bodies, including gyroscopic motion and precession.

Course Contents:

Non Inertial Reference Systems: Inertial and non-inertial frames, Accelerated coordinate systems and inertial forces, Rotating coordinate systems, Velocity and acceleration in moving system, Coriolis, centripetal and transverse acceleration, Dynamics of a particle in a rotating coordinate system.

Centre of Mass and Gravity: Discrete and continuous systems, Density of rigid and elastic bodies, Centroid. Solid regions: region bounded by planes, semi-circular region, sphere, hemisphere, cylinder and cone.

Planar Motion of Rigid Bodies: Introduction to rigid and elastic bodies, degrees of freedom, translations, rotations, instantaneous axis and center of rotation. Motion of the center of mass, Eulers theorem and Chasles theorem, rotation of a rigid body about a fixed axis, moments and products of inertia. Hoop or cylindrical shell, circular cylinder, spherical shell, Parallel and Perpendicular axis theorem. Radius of gyration of various objects.

Motion of Rigid Bodies in Three Dimensions: General motion of rigid bodies in space, moments and products of inertia, inertia matrix, the momental ellipsoid and equimomental systems. Angular momentum vector and rotational kinetic energy. Determining principal axes and principal moments of inertia by diagonalizing the inertia matrix.

Euler's Rigid Body Dynamics: Eulers equations of motion, force free motion, free rotation of a rigid body with an axis of symmetry, free rotation of a rigid body with three different principal moments, the Euler angles, angular velocity and kinetic energy in terms of Euler angles, body and space cones, motion of a spinning top and gyroscopes, steady precession and sleeping top.

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, Singapore, 1980.

Course Title: Linear Algebra

Course Code: MATH-303

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.

Course Title: Partial Differential Equations

Course Code: MATH-304

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.

Course Title: Computational Tools

Course Code: MATH-305

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-306

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.

Course Title: Advanced Analysis

Course Code: MATH-307

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-308

Course Type: Major Math

Prerequisites: Multivariable Calculus

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-309

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.

Course Title: Methods of Mathematical Physics

Course Code: MATH-310

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: Mathematical Computing with Python

Course Code: MATH-311

Course Type: Major Math

Prerequisites: Applications of ICT

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.

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: Analytical Dynamics

Course Code: MATH-405

Course Type: Major Math

Prerequisites: Classical Mechanics

Credit Hours: 3 (3 + 0)

Course Objectives: This course focuses on the principles of Lagrangian and Hamiltonian dynamics, which are two reformulations of classical Newtonian mechanics using a mathematical framework of arbitrary coordinate systems for configuration space and scalar quantities such as kinetic energy and potential energy. This formulation generalizes to modern theories in robotics, aerospace, mechanical engineering, relativity and quantum mechanics. The course aims to achieve the following objectives:

- Understand coordinate transformations based on generalized coordinates, virtual work, D'Alembert's principle, and constrained systems (holonomic and non-holonomic).
- Derive Lagrange's equations of motion and apply Lagrange's theory to analyze holonomic and non-holonomic systems, and energy integrals.
- Explore Hamilton's theory: Calculus of variations, Principle of Least Action, phase space, Hamilton's principle and Hamilton's equations.
- Study canonical transformations, Lagrange and Poisson brackets, conservation laws, Noether's theorem, and its applications in dynamics.
- Apply Hamilton-Jacobi theory to solve problems involving Hamilton's principal and characteristic functions.

Course Contents:

Generalized Coordinates: Generalized coordinates, momenta and forces, classification into holonomic and non-holonomic systems, virtual work, D'Alemberts principle, and the $d\delta$ rule for path variations.

Lagranges Theory of Holonomic Systems: Lagrange equations, generalization of Lagrange equations, quasi-coordinates, Lagrange equations in quasi-coordinates, first integrals of Lagrange equations of motion, energy integral.

Hamiltons Theory: Hamiltons principle, generalized momenta and phase space, Hamiltons equations, Ignorable coordinates, Routhian function, Variational principles and Lagrange's equations, derivation of Lagrange's equations from Hamilton's Principle, derivation of Hamiltons equations from the variational principle.

Lagranges Theory of Non-Holonomic Systems: Lagrange equations for non-holonomic systems with and without Lagrange multipliers, extension of Hamiltons Principle for non-holonomic systems.

Canonical Transformations: The equations of canonical transformations, examples of canonical transformations, the Lagrange and Poisson brackets, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation.

Hamilton-Jacobi Theory: The Hamilton-Jacobi equation for Hamiltons principal function, the harmonic oscillator problem as an example of the Hamilton-Jacobi method, the Hamilton-Jacobi equation for Hamiltons characteristic function, separation of variables in the Hamilton-Jacobi equation.

Noether's Theorem and Its Applications: Introduction to Noether's theorem and its application in dynamics, emphasizing the connection between symmetries and conservation laws.

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. Wells, D. A., *Theory and Problems of Lagrangian Dynamics*, McGraw Hill Book Company, 1967.
4. Saletan, E. J., Jose, and J. V., *Classical Dynamics: A Contemporary Approach*, Cambridge University Press, 1998.
5. Spiegel, M. R., *Theoretical Mechanics*, McGraw Hill Book Company, 1980.

Course Title: Numerical Methods with Computer Programming

Course Code: MATH-406

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.

COURSE OUTLINES OF INTERDISCIPLINARY/ALLIED COURSES

The course outlines of interdisciplinary/allied courses are given below. A student may choose any Four courses, selecting Two courses in each of the 7th and 8th semesters.

Course Title: Fluid Mechanics

Course Code: MPHY-410

Course Type: Allied/Interdisciplinary

Prerequisites: Fundamentals of Mechanics

Credit Hours: 3 (3 + 0)

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

- Understand and use force analysis in static and moving fluids to analyze fluid flow systems.
- Know how to apply the various methods of analysis in fluid mechanics (the Reynolds Transport Equation -Control Volume Analysis and differential approach) to solve real-life fluid flow problems.
- Select and use flow visualization tools (e.g., Timelines, Streamlines, Pathlines, and Streaklines) to analyze and understand the main features of a certain fluid flow.
- Comprehends the concepts of boundary layer, displacement thickness, and flow separation and be able to use these concepts to simplify the analysis of real flows.
- Understand the concept of similarity and dimensional analysis and be able to use it to develop and carry out model-prototype analysis.

Course Contents:

- **Introduction:** Historical Background, Fluids and their properties, continuum concepts, Viscosity and Newton's viscosity law, Classification of fluid and flows.
- **Fluid Kinematics:** Lagrangian and Eulerian specifications, Local, convective and total rates of change, Flow along a curve, Circulation, Irrotational fluid motion, Velocity potential, Streamlines, Pathlines, Streaklines, Vorticity, Vortex lines and vortex sheets, Conservation of mass (Equation of continuity), Boundary conditions.
- **Fundamental Equations:** Surface and body forces, Hydrostatic equation, Conservation of linear momentum (Euler's equation of motion), Bernoulli's Equations, Stress and strain tensors, Constitutive equations, Navier-Stokes's equations, Energy equation.
- **Parallel Flows:** Steady unidirectional flow, Poiseuille flow, Couette flow, Hagen-Poiseuille flow, Stokes first problem, Stokes second problem.

Recommended Books:

1. Chia-Shun, Y., *Fluid Mechanics*, McGraw Hill Book Company, 1974.

2. Curie, I. G., *Fundamentals of Mechanics of Fluids*, CRC Press, 4th edition, 2012.

3. Pritchard, J., and Leylegian, J. C., *Fox and McDonald's Introduction to Fluid Mechanics*, John Wiley & Sons Inc., 8th edition, 2011.

4. H. Schlichting, K. Gersten, E. Krause and H. Oertel, Jr., *Boundary-Layer Theory*,Springer, 8th edition, 2004.

5. White, F., *Fluid Mechanics*, McGraw Hill, 8th edition, 2015.

Course Title: Quantum Mechanics

Course Code: MPHY-411

Course Type: Allied/Interdisciplinary

Prerequisites: Linear Algebra & Probability Theory.

Credit Hours: 3 (3 + 0)

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

- Recognize the limitations of classical mechanics which urge the need to develop new theory to address these limitations.
- Familiarize the students with the mathematical formalism of quantum mechanics to describe the dynamics of sub-atomic particles.
- Develop the interest in the applications of quantum mechanical formalism such as finding the allowed energy levels, shapes of atomic orbitals and spectral properties of Hydrogen atom.

Course Contents:

Preliminaries: Wave-particle duality, Young's double slit experiment, Bohr's atomic model, de Broglie hypothesis, Heisenberg uncertainty principle, Probability waves and Born's rule.

Mathematical Formalism of Quantum Mechanics: Observables and operators, Measurement in quantum mechanics, The state/wave function and expectation values, Schrodinger's wave equation, Time evolution of the state function and initial-value problem in quantum mechanics, Parity operators, Dirac Notation for state functions and operators.

Applications of Quantum Mechanics: Superposition principal and its physical interpretation. Commutation relations and Heisenberg uncertainty principle. Comparison of classical and quantum mechanical harmonic oscillator. Eigen functions of harmonic oscillator. Schrodinger's wave equation in three dimensions and its application to Hydrogen atom.

Recommended Books:

1. Bransden, B.H. and Joachain, C.J., *Quantum Mechanics*, Prentice Hall Publisher, 2nd Edition, 2000.

2. Liboff, R., *Introductory Quantum Mechanics*, 4th Edition, Pearson, 2002.
3. Griffiths, D. J. and Schroeter, D. F., *Introduction to Quantum Mechanics*, Cambridge University Press, 3rd Edition, 2018.
4. Sakurai, J. J. and Napolitano, J., *Modern Quantum Mechanics*, Cambridge University Press, 3rd Edition, 2020.
5. Zettili, N., *Quantum Mechanics: Concepts and Applications*, Wiley, 3rd Edition, 2022.

Course Title: Special Theory of Relativity

Course Code: MPHY-412

Course Type: Allied/Interdisciplinary

Prerequisites: Classical Mechanics

Credit Hours: 3 (3 + 0)

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

- Provide students with a thorough understanding of the Special Theory of Relativity.
- Cover the historical context, key principles, and mathematical formulations of the theory.
- Master Einstein's postulates and the fundamental concepts of spacetime.
- Understand Lorentz transformations and the invariance of the speed of light.
- Explore relativistic effects on time, space, energy, and momentum.
- Develop mathematical skills to analyze and solve relativistic problems.
- Highlight the applications and implications of relativity in modern physics.
- Enhance comprehension of phenomena such as time dilation, length contraction, and mass-energy equivalence.

Course Contents:

Introduction: Fundamental concepts: Inertial/Non-Inertial frame of references, Michelson-Morley experiment, Galilean transformation, Lorentz-Fitzgerald contraction, Ether theory.

Derivation of Special Relativity: Einstein's formulation of special relativity, The Lorentz transformation, Length contraction, time dilation and simultaneity, Lorentz invariance, The velocity addition formulae, Three dimensional Lorentz transformations.

The Four-Vector Formulation of Special Relativity: The four-vector formalism, Spacetime intervals and their invariance, The Lorentz transformations in 4-vectors, The Lorentz and Poincare groups, The null cone structure, Proper time.

Applications of Special Relativity: Relativistic kinematics, The Doppler shift in relativity, The Compton effect, Relativistic momentum and energy, The concept of mass in relativity, Particle scattering, Binding energy, particle production and particle decay.

Electromagnetism in Special Relativity: Review of electromagnetism, The electric and magnetic field intensities, The electric current, Introduction to the electromagnetic field tensor, Maxwell's equations and electromagnetic waves, The four-vector formulation of Maxwell's equations

Recommended Books:

1. Barton, G., *Introduction to the Relativity Principle*, Wiley, 1st edition, 1999.
2. Qadir, A., *Relativity : An Introduction To The Special Theory*, World Scientific Publishing Co., 1989.
3. Rindler, W., *Introduction to Special Relativity*, Clarendon Press, 2nd edition, 1991.
4. Rosser, W. G. V., *Introductory Special Relativity*, CRC Press, 1st edition, 1992.
5. Saleem, M., and Rafique, M., *Special Relativity*, Ellis Horwood Ltd., 1992.

Course Title: Electromagnetic Theory

Course Code: MPHY-413

Course Type: Allied/Interdisciplinary

Prerequisites: Fundamentals of Physics

Credit Hours: 3 (3 + 0)

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

- Develop a deep understanding of the behavior of electric and magnetic fields in various media.
- Enhance the ability to apply advanced mathematical techniques, such as vector calculus, differential equations, and complex analysis, to solve problems in electromagnetic theory.
- Analyze the principles of electromagnetic wave propagation, reflection, refraction, and transmission in different media.

Course Contents:

Electrostatic Fields: Coulomb's law, the electric field intensity and potential, Gauss's law and deductions, Poisson and Laplace equations, Conductors and condensers, Dipoles, the linear quadrupole, Potential energy of a charge distribution, Dielectrics, The polarization and the displacement vectors

Magnetostatic Fields: The Magnetostatic law of force, The magnetic induction, The Lorentz force on a point charge moving in a magnetic field, The divergence of the magnetic field, The vector potential, The conservation of charge and the equation of continuity, The Lorentz condition, The curl of the magnetic field, Ampere's law and the scalar potential.

Steady and Slowly Varying Currents: Electric current, linear conductors, Conductivity, resistance, Kirchhoff's laws, Current density vector, Magnetic field of straight and circular current, Magnetic flux, vector potential, Forces on a circuit in magnetic field.

Electromagnetic Waves: Plane electromagnetic waves in homogeneous and isotropic media, The Poynting vector in free space, Propagation plane electromagnetic waves in non-conductors, Propagation plane electromagnetic waves in conducting media.

Recommended Books:

1. Owen, G. E., *Introduction to Electromagnetic Theory*, Dover, 2003.
2. Corrison, D. and Lorrison, P., *Introduction to Electromagnetic Fields and Waves*, W. H. Freeman and Company, London, 1962.
3. Reitz, J. R., Milford, F. J. and Christy, R. W., *Foundations of Electromagnetic Theory*, Addison-Wesley Publishing Co., 2009.
4. Jackson, J. D., *Classical Electrodynamics*, Wiley, third edition, 2021.
5. Griffiths, D. J., *Introduction to Electrodynamics*, Prentice-Hall, 5th edition, 2023.

Course Title: Introduction to Manifolds

Course Code: MPHY-414

Course Type: Allied/Interdisciplinary

Prerequisites: Linear Algebra & Differential Geometry

Credit Hours: 3 (3 + 0)

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

- Describe basic ideas of smooth manifolds with examples
- Describe algebras and analysis on the manifolds
- Understand basic examples and structures of Lie groups

Course Contents:

Manifolds and Differentiable Structures: Basic definition and examples, Topological manifold, Smooth manifold, Atlas and charts, Smooth structures, Transition maps, Partial derivatives, Critical points, Immersion theorem.

Tangent and Cotangent Bundle: Tangent space of $\mathbb{R}^n$, Tangent space of an imbedded manifold, Vector bundle, Tangent and cotangent bundle of a manifold, Derivations and vector fields on a manifold.

Lie Groups: Basic definition and examples of a Lie group, Classical groups, Metric and norm on real and complex vector spaces, Inner product and bilinear forms, Classical groups, Infinitesimal transformations, Lie group generators.

Matrix Lie Groups: Definition of a matrix Lie group, Special linear groups, Orthogonal groups, Special orthogonal groups, Rotation groups, Generators of a matrix group, Lie algebra, Lie algebras as tangent to identity of a Lie group.

Applications of Manifolds to Physics: Kähler Manifold, Calabi-Yau manifold and its applications.

Recommended Books:

1. Anthony, W. K., *Lie Groups: Beyond an Introduction*, Birkhauser, 1996.
2. Brian, C. H., *Lie Groups, Lie Algebras, and Representations*, Springer, 2003.
3. Lee, J. M., *Introduction to Smooth Manifolds*, Springer, 2000.
4. Lovett, S., *Differential Geometry of Manifolds*, Chapman and Hall/CRC, 2nd Edition, 2019.
5. Tu, L. W., *Introduction to Manifolds*, Springer, 2nd edition, 2008.

Course Title: Lie Symmetries

Course Code: MPHY-415

Course Type: Allied/Interdisciplinary

Prerequisites: Algebra & ODEs

Credit Hours: 3 (3 + 0)

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

- Describe basic ideas and examples of Lie algebras
- Identify different low dimensional Lie algebras
- Understand basic ideas of Symmetries of differential equations

Course Contents:

Lie Algebras: Review of algebras, vector spaces and rings, Ideals, basic definition and examples of Lie algebras, Structure constants.

Classification of Lie Algebras: Solvable Lie algebras, Nilpotent Lie algebras, Cartan subalgebras, Killing form, The Cartan decomposition of a semisimple Lie algebra, The Lie algebra $sl(n,\mathbb{C})$, The root system and the Weyl Group, The Cartan Matrix and the Dynkin Diagram.

Symmetries: Symmetries of planar objects, definition and examples of Symmetries of an ordinary differential equation, Lie symmetries of ordinary differential equations.

Solution of Ordinary Differential Equations: Linearized symmetry conditions, infinitesimal generators, One parameter Lie group, reduction of order, invariant solution.

Recommended Books:

1. Erdman, K. and Wildon J., *Introduction to Lie Algebras*, Springer Undergraduate Mathematics Series, 2002.

2. Brian, C. H., *Lie Groups, Lie Algebras, and Representations*, Springer, 2003.

3. Peter, E. H., *Symmetry Methods for Differential Equations: A Beginner's Guide*, Cambridge University Press, 2000.

4. Hans, S., *Differential Equations: Their Solution Using Symmetries*, Cambridge University Press, 1989.

Course Title: Digital Logic Design

Course Code: MACS-410

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.

Course Title: Database Management System

Course Code: MACS-411

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:

- 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.

Course Title: Introduction to Algorithms

Course Code: MACS-412

Course Type: Allied/Interdisciplinary

Prerequisites: Introduction to Graph Theory

Credit Hours: 3 (3+0)

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.

- **Recursion:** Recursive definition, Recursive algorithms, Divide-and-conquer algorithms, Recurrence relations. Methods for solving recurrences: Substitution method, Recursion tree method, Master method.
- **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. Cormen, T. H., Leiserson, C. E. et al., *Introduction to Algorithms*, MIT Press, 4th edition, 2022.
2. Miller, B. and Ranum, D., *Problem Solving with Algorithms and Data Structures Using Python*, Franklin, Beedle & Associates, 2nd edition, 2011.
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 Structures and Algorithm Analysis in C*, Pearson, 2nd edition, 1996.

Course Title: Programming Fundamentals

Course Code: MACS-413

Course Type: Allied/Interdisciplinary

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.

Course Title: Web Programming

Course Code: MACS-414

Course Type: Allied/Interdisciplinary

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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Course Title: Object Oriented Programming

Course Code: MACS-415

Course Type: Allied/Interdisciplinary

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: Quantum Computing

Course Code: MACS-416

Course Type: Allied/Interdisciplinary

Prerequisites: Linear Algebra & Functional Analysis

Credit Hours: 3 (3 + 0)

Course Objectives: Students will be able to:

- Familiarize the students with classical computing concepts and their limitations.
- Discuss the preliminary ideas and concept used in quantum computing and information and to enable the students to compare classical and quantum computing paradigms.
- Provide various applications and examples of quantum computing which may enhance the students understanding and insight regarding latest trends in the field of quantum computing and quantum information theory.

Course Contents:

Preliminaries: Classical computer technology and historical background, Basic principles and postulates of quantum mechanics: Hilbert space, quantum states, evolution of quantum state, quantum measurement, superposition, operator function, density matrix representation.

Quantum States: Comparison of bits and qubits, Pure and mixed quantum states, Bloch sphere representation of pure and mixed quantum states, Entangled and separable quantum states, Quantum entanglement, EPR states and Bells inequality, Measures of quantum entanglement, No-cloning theorem, Schmidt decomposition, Positive operator valued measurements (POVM)

Quantum Gates and Logic: Single qubit operation, Controlled operations, Measurement universal quantum gates, CNOT gate quantum circuits comparison with classical computing

Applications of Quantum Computing: Deutsch algorithm, Deutsch-Jozsa algorithm, Simons problem, Quantum phase estimation algorithm, Quantum Fourier transform and eigen value problem, Quantum search algorithm, Quantum cryptography and Shors algorithm, Complexities of the quantum algorithms and quantum supremacy quantum error detection and correction

Recommended Books:

1. Bouwmester, P., Ekert, A. K. and Zeilinger, A., *The Physics of Quantum Information*, Springer, 1st Edition, 2000.

2. Brylinsky, R. K. and Chen, G., *Mathematics of Quantum Computation*, Chapman and Hall/CRC, 1st Edition, 2002.

3. Kaye, P., Laflamme, R. and Mosca, M., *An Introduction to Quantum Computing*, Oxford University Press, 1st Edition, 2007.

4. Nielson, M. A., Chuang, I. L., *Quantum Computation and Quantum Information*, Cambridge University Press, 10th Edition, 2011.

5. Rieffel, E. G. and Polak, W. H., *Quantum Computing: A Gentle Introduction*, The MIT Press, 1st Edition, 2014.

Course Title: Fundamentals of Fuzzy Systems

Course Code: MACS-417

Course Type: Allied/Interdisciplinary

Prerequisites: Quantitative Reasoning & Graph Theory

Credit Hours: 3 (3 + 0)

Course Objectives: A fuzzy system is a system of variables that are associated using fuzzy logic. A fuzzy controller uses defined rules to control a fuzzy system based on the current values of input variables. The study focuses mainly on fuzzy models based on Zadeh's compositional rule of inference. After completion of this course, the students will be able to:

- Describe the basic concepts of fuzzy sets and fuzzy logic.
- Utilize the fuzzy set theory on algebraic structures.
- Apply fuzzy methods to model and solve various engineering problems.

- Apply fuzzy inference systems in control systems and decision support systems.

Course Contents:

Fuzzy Set Theory: Fuzzy sets (membership function, cardinality, normality), Fuzzy set operations (union, intersection, complementation), Distances between fuzzy sets (Hamming distance, normalized Hamming distance, Euclidean distance, normalized Euclidean distance), Similarity measures. Fuzzy relation and composition, Fuzzy function. Fuzzy numbers (Triangular fuzzy number, Trapezoidal fuzzy number), Arithmetic operations of fuzzy numbers. Multipolar (m-polar) fuzzy sets.

Fuzzy Graph Theory: Fuzzy graphs, Regular fuzzy graphs, m-polar fuzzy graphs, Certain types of m–polar fuzzy graphs, m–polar fuzzy labeling graphs, Applications of m–polar fuzzy graphs.

Fuzzy Control Systems & Fuzzy Expert Systems: Review of classical logic, Fuzzy logic, Linguistic variable, Fuzzy truth qualifier, Fuzzy inference, Fuzzy rules and implication, Defuzzification, Fuzzy logic controller, Configuration of fuzzy logic controller, Fuzzy expert systems.

Recommended Books:

1. Akram, M., *m-Polar Fuzzy Graphs*, Studies in Fuzziness and Soft Computing, Springer, 2019.
2. Dubois, D. and Prade, H., *Fuzzy Sets and Systems: Theory and Applications*, Academic Press, 1980.
3. Lee, K. H., *First Course on Fuzzy Theory and Applications*, Springer Berlin, Heidelberg, 2009.
4. Klir, G. J. and Yuan, B., *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Pearson College Div., 1995.
5. Mathew, S., Mordeson, J. and Malik, D. S., *Fuzzy Graph Theory*, Studies in Fuzziness and Soft Computing, Physica Verlag, Heidelberg, 2018.
6. Zimmermann, H. -J. *Fuzzy Set Theory and Its Application*, Studies in Fuzziness and Soft Computing, Springer, 2001.

Course Title: Computer-Aided Geometric Design

Course Code: MACS-418

Course Type: Allied/Interdisciplinary

Prerequisites: Calculus & Linear Algebra

Credit Hours: 3 (3 + 0)

Course Objectives: This course provides an in-depth understanding of approximation techniques, including linear, bilinear, and multilinear interpolants, polynomial and spline-based methods, and parametric curves and surfaces, along with convergence properties and error estimation. Applications span computer-aided geometric design (CAGD), computer graphics (CG), computer-aided engineering (CAE), and differential geometry (geometric characteristics, quasi-minimal and quasi-harmonic surfaces). Students will gain theoretical and computational skills to tackle problems in geometric modeling, data fitting, and related areas. The course aims to achieve the following objectives:

- Understand various approximation techniques and their applications across different disciplines of mathematics.
- Understand linear, bilinear, and multilinear interpolants, the least squares method, polynomial, and spline-based approximations.
- Analyze convergence properties and error estimation for different approximation methods.
- Understand Bézier surfaces based on various Bernstein polynomials, Hermite interpolants, and Coons patches, and their geometric characteristics.

Course Contents:

Review of Interpolation: Linear, bilinear, trilinear, and multilinear interpolants, Lagrange's method, Divided difference method, Newton polynomials, Gausss forward interpolation formula, Gauss backward interpolation formula.

Hermite interpolation: Hermite interpolating polynomials, Convergence analysis and error estimation.

Polynomial Approximation: Introduction to curve fitting, Transformations for data linearization, Least squares method for linear and nonlinear functions, including polynomial, exponential, logarithmic, power, rational, sinusoidal, Gaussian, sigmoidal, hyperbolic, piecewise linear, and trigonometric functions. Padé approximation, Chebyshev polynomials, and Legendre polynomials.

Parametric Curves: Bézier and spline forms, including algebraic forms, Hermite splines, B-splines, control point representations, Bernstein polynomials and Bézier curves, rational functionals, and barycentric coordinates. Detailed analysis of quadratic and cubic forms with their matrix representations. General splines, cubic Hermite splines, and end conditions for cubic splines: clamped, natural, second derivative, periodic, and not-a-knot conditions.

Parametric Surfaces: Blending functions, Tensor product surfaces and their geometric interpretation. Various Bézier surfaces: Classical and generalized Bézier surfaces based on modified Bernstein polynomials (including q-Bernstein, (p,q)-Bernstein, shifted knots, and λ-Bernstein polynomials). Properties and algorithms: convex hull property, symmetry, affine transformation and invariance property, variation diminishing property, algorithms to compute Bézier curves and surfaces. Hermite cubic interpolants and bicubically blended Coons patches.

Recommended Books:

1. Bartels, R. H., Bealty, J. C. and Beatty, J. C., *An Introduction to Spline for use in Computer Graphics and Geometric Modeling*, Morgan Kaufmann Publisher, 2006.

2. Farin, G., *Curves and Surfaces for Computer Aided Geometric Design: A Practical Guide*, Morgan Kaufmann; 5th edition, 2001.

3. Mortenson, M. E., *Geometric Modeling*, Industrial Press, 2006.

4. Schumaker, L. L., *Spline Functions: Basic Theory*, John Wiley and Sons, 1993.

5. Yamaguchi, F., *Curves and Surfaces in Computer Aided Geometric Design*, Springer Berlin, Heidelberg, 2013.