SCHEM OF STUDIES
DEPARTMENT OF MATHEMATICS

FRIDAY, FEBRUARY 21, 2025

SCHEME OF STUDIES
FOR
PHD IN MATHEMATICS, MPHIL IN MATHEMATICS,
BACHELOR OF SCIENCE IN MATHEMATICS (AI / DATA SCIENCE / ECONOMICS),
AND LATERAL ENTRY

MIRPUR UNIVERSITY OF SCIENCE AND TECHNOLOGY (MUST)
ACDAMIC BLOCK II, JARIKAS CAMPUS, MIRPUR-10250
MIRPUR, AZAD JAMMU & KASHMIR

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1. Members of the Department Council

The following members were present in the meeting:

Sr. No.	Name	Status
01	Dr. Kalim Ul-Haq Tariq, Chairperson, Department of Mathematics, MUST, Mirpur AJK	Convener
02	Prof. Dr. Muhamamd Mushtaq, Department of Mathematics, University of Engineering & Technology, Lahore	Member / Subject Expert
03	Prof. Dr. Ibrar Hussain, Department of Humanities & Sciences, National University of Science & Technology, Islamabad	Member / Subject Expert
04	Dr. Syed Tahir Raza Rizvi, Associate Professor, Department of Mathematics, COMSATS University Islamabad, Lahore Campus	Member / Subject Expert
05	Ms. Rehanna Razaq, Assistant Professor Affiliated Colleges, Ghazi Ellahi Bhkash PGC, Mirpur AJK	Member
06	Dr. Syed Zakir Hussain Bukhari, Associate Professor, Department of Mathematics, MUST, Mirpur AJK	Member
07	Dr. Imtiaz Ahmad, Assistant Professor, Department of Mathematics, MUST, Mirpur AJK	Member
08	The Controller of Examinations, MUST, Mirpur AJK	Member
09	Representative of Alumni / Dr. Khizer Hayat, Assistant Professor University of Kotli, AJK	Member
10	Representative of Industry/ Dr. Ashfaq Ahmed, Associate Professor PGC Mirpur, AJK	Member
11	The Registrar / Nominee, MUST, Mirpur AJK	Observer
12	Director QEC / Nominee, MUST, Mirpur AJK	Observer
13	Dr. Taimoor Salahuddin, Assistant Professor Department of Mathematics, MUST, Mirpur AJK	Secretary

1.1 Introduction

The Department of Mathematics at MUST, Mirpur, AJ&K, was established in 2009. The first intake of the M.Sc program was inducted in the Spring 2010. The MS program was launched in the Spring 2011. In the Fall 2012, the Department launched its BS program. The PhD program was started in the Spring 2015.

1.2 University Vision Statement

To be a superior teaching and research institution, having transformative impact on society and action as a knowledge corridor between Azad Jammu and Kashmir, Pakistan and rest of the World.

1.3 University Mission Statement

MUST is committed to all-encompassing growth of its students, besides enabling them to tap the world of knowledge and assume leadership role in the future through a process of continual innovation in education, research, creativity, technological advancement and entrepreneurship.

1.4 Faculty Mission Statement

The Faculty is committed to developing knowledgeable, technically proficient professionals capable of addressing complex challenges through high-caliber research and elevated educational experiences. It strives to produce graduates who are articulate, thoughtful, and conscientious citizens, and to make a transformative societal impact by advancing science in service of sustainable and peaceful human development.

1.5 Department Mission Statement

The Department of Mathematics is committed to provide a supportive and conducive academic environment for learning through its various programs. The focus of these programs is to produce intellectual mathematicians equipped with critical thinking, problem solving skills, innovation, and high professional ethics who could bring positive changes in our society.

1.6 Bachelor of Science in Mathematics Program Statement

The Bachelor of Science in Mathematics (AI / Data Science / Economics) Later Entry program provides reasonable, high-quality education to the youth of Mirpur and nearby districts. It offers an extensive opportunity for the students to excel in Mathematics while meeting the growing societal demand for skilled mathematicians.

1.7 Master of Science in Mathematics Program Statement

The Master of Science in Mathematics program is aimed to produce technically skilled, informed professionals who are able to address challenging issues by providing excellence in research and advanced learning opportunities.

1.8 Doctor of Philosophy in Mathematics Program Statement

The Doctor of Philosophy in Mathematics program seeks to prepare highly skilled and knowledgeable professionals who can tackle complex challenges through innovative research and advanced academic training.

2. Admission Criteria for Bachelor of Science in Mathematics (AI / Data Science / Economics)

Sr. No.	Content	Required	Remarks
1	F.Sc.	Intermediate with Mathematics	
		DAE	
3	Intermediate or Equivalent	Intermediate with Science / General Science	Such students will be offered non-credit two courses of Mathematics during first year of the degree program.
2	Marks Requirement	45% marks in academic career	
4	BS Program or Equivalent (3 or 4-Years)	Must have passed courses of Mathematics having 400 marks	Such students may be allowed for admission in BS 5th Semester and will be offered deficiency courses during first two years (4-Semsters) of the degree program. Furthermore, the students of BS Mathematics who got admission during Fall 2023 and Fall 2024 are allowed to offer deficiency courses till the end of their degree programs. Note: The council recommended that the matter may be presented at faculty and academic council for admission in any Department of the FNAS.
5	ADS Program		

3. Scheme of Studies for Bachelor of Science in Mathematics (AI / Data Science / Economics)

Sr. No	Content	Description
1	Awarding Institute/Body	Mirpur University of Science and Technology (MUST)
2	Teaching Institute	Department of Mathematics, Mirpur University of Science and Technology (MUST), and affiliated colleges
3	Nomenclature	Bachelor of Science in Mathematics (AI / Data Science / Economics)
4	Starting Time for Program	Fall/Spring semester of each academic year
5	Duration of the Program	8-14 Semesters
6	Entrance Requirements	Intermediate or equivalent degree with science (Min 45% marks)
		No 3rd Division in Matric and Intermediate
		Entry Test conducted by the University with the following breakup: Mathematics: 30 %, English: 10%, two other subjects which the candidate have studied in intermediate with 30% weightage for each.
7	Merit Formula	Merit shall be determined on 20% of SSC, 50% of Intermediate and 30% of Entry Test marks.
8	Total Credit Hours	Course Work: 133 Credit Hours
		Capstone/ Project (Compulsory): 0-3 Credit Hours
		Internship (Compulsory): 0-3 Credit Hours
9	Entry and Exit Provisions	Entry for Associate Degrees Holders: 1) Students having completed Associate Degrees shall be allowed admission in the fifth semester of the undergraduate/equivalent degree program offered in the same discipline without any deficiency course. 2) Where the disciplines of the Associate Degree and the undergraduate/equivalent degree program are different, students shall be required to complete deficiency courses through a bridging semester before the fifth semester as determined by the admitting university. 3) The minimum eligibility for admission in the fifth semester in above cases is 2.00/4.00 CGPA in the prior qualification i.e., Associate Degree. Exiting from with an Associate Degree: Students enrolled in the undergraduate/equivalent degree program shall be allowed to exit from the program with an Associate Degree provided that the following requirements are met: 1) The student must have completed minimum of 60 credit hours in at least four (04) semesters of the undergraduate/equivalent degree program including general education courses comprised of 30 credit hours. 2) The minimum CGPA is maintained at 2.5 / 4.00. 3) The name of the subject field on the degree shall be the Associate Degree in Mathematics.

3.1 Program Educational Objectives (PEOs)

The program is design to achieve the following objectives to

1. Prepare the students to pursue higher education.
2. Educate the students with mathematics, communication, and teamwork skills.
3. Enable the students to pursue career in related field using mathematical and computational skills such as problem formulation, analysis, designing, development, application, and solution implementation.

3.2 Program Learning Outcomes (PLOs)

The students after complication of BS Mathematics program shell be able to

1. Go for higher education (MS/M.Phil, Ph.D.) in mathematical sciences/field of interest.
2. Apply diverse analytical tools and computational technologies.
3. Demonstrate oral and written communication skills.
4. Deliver teaching and non-teaching jobs in various disciplines of life.
5. Formulate and implement mathematical solutions of various problems.
6. Perform analytical background of the mathematical problem.
7. Complete various tasks individually as well as in teams.

3.3 Scope of the Program

The mathematical experts are in demand across all kind of industries, the world over. Our graduates will be able to seek career opportunities in:

a). Teaching at school, college, or higher level
b). R&D and strategic organizations like PAEC, NESCOM, SUPARCO, etc.
c). Banking sector, trading, and stock exchange businesses
d). Higher studies in national and international universities and institutes
e). Armed forces, civil services, oil and gas sector,

3.4 Program Objectives and Outcomes

Following table shows the link between program objectives and program outcomes:

Program Objectives	Program Outcomes						
	1	2	3	4	5	6	7
1	✓						
2		✓	✓	✓			
3		✓		✓	✓	✓	✓
4		✓		✓			

Table 1: Outcomes versus Objectives

4. Structure of Bachelor of Science in Mathematics (AI / Data Science / Economics)

Sr. No.	Category	No. of Courses	Credit Hours	Remarks
01	General Education Cluster	13	32	
02	Allied Courses	07	21	
03	Major Courses	24	72	
04	Internship / Field Experience	01	03	
05	Capstone Project	01	03	
06	Holy Quran	02	0-2	
Total Credit Hours		48	133	

4.1 Layout/Framework

Category	Course Title	Credit Hours	Total Credit Hours
Field Experience	Internship / Field Experience	03	03
Project	Capstone Project	03	03
Holy Quran	Understanding of Holy Quran-I	01	0-1
	Understanding of Holy Quran-II	01	0-1
General Education Cluster	The Fundamentals of Physics	03	32
	Ideology & Constitution of Pakistan	02	
	Arabic	02	
	Social Science*	02	
	Functional English	03	
	Expository Writing	03	
	Quantitative Reasoning I	03	
	Quantitative Reasoning II	03	
	Islamic Studies	02	
	Pakistan Studies	02	
	Application of information and communication technologies	03	
	Entrepreneurship	02	
	Civics and Community Engagement	02	
Interdisciplinary / Allied Courses	Statistics & Probability	03	21
	Introduction to Programing	03	
	Introduction to Mechanics	03	
	Advanced Programming	03	
	Introduction to Machine Learning	03	
	Introduction to Classical Mechanics	03	
	Scientific Writing and Research Methods	03	
Major Courses	Calculus-I	03	
	Calculus-II	03	

	Discrete Mathematics	03	72
	Calculus-III	03	
	Elementary Differential Equations	03	
	Linear Algebra	03	
	Ordinary Differential Equations	03	
	Data Structure and Algorithms	03	
	Abstract Algebra	03	
	Real Analysis-I	03	
	Topology	03	
	Partial Differential Equations	03	
	Real Analysis-II	03	
	Complex Analysis	03	
	Differential Geometry	03	
	Optimization Theory	03	
	Numerical Methods I	03	
	Elective-I (Semester-VI)	03	
	Elective-II (Semester-VII)	03	
	Elective-III (Semester-VII)	03	
	Elective-IV (Semester-VII)	03	
	Elective-V (Semester-VIII)	03	
	Elective-VI (Semester-VIII)	03	
	Elective-VII (Semester-VIII)	03	
Total Credit Hours of the Program			133

4.2 Semester-Wise Breakdown Bachelor of Science in Mathematics

1st Year

Semester-I

Course Code	Course Title	Category	Lec. Hrs.	Lab. Hrs.	Credit Hrs.
MATH-1101	Calculus-I	Major	3	0	3
MATH-1102	Introduction to Programing	Interdisciplinary	2	1	3
ENG-1107	Functional English	General Education	3	0	3
---------	Natural Science*	General Education	3	0	3
QTR- 1124	Quantitative Reasoning I	General Education	3	0	3
ICT-1126	Application of information and communication technologies	General Education	2	1	3
	*Natural Science Course				
*PHY-1118	The Fundamentals of Physics				
Total Credit Hours					**18**

Semester-II

---------	Arts and Humanities*	General Education	2	0	2
MATH-1201	Calculus-II	Major	3	0	3
MATH-1202	Discrete Mathematics	Major	3	0	3
ENG-1207	Expository Writing	General Education	3	0	3
PS-1217	Pakistan Studies	General Education	2	0	2
QTR-1224	Quantitative Reasoning II	General Education	3	0	3
UHQ-1230	Understanding of Holy Quran-I	General Education	0	1	1
	*Arts and Humanities Course				
*ARA-1201	Arabic				
Total Credit Hours					**17**

2nd Year

Semester-III

MATH-2301	Calculus-III	Major	3	0	3
MATH-2302	Linear Algebra	Major	3	0	3
MATH-2303	Elementary Differential Equations	Major	3	0	3
MATH-2304	Statistics & Probability	Interdisciplinary	3	0	3
ICP-2305	Ideology & Constitution of Pakistan	General Education	2	0	2
ISL-2312	Islamic Studies (Ethics for non-Muslim students)	General Education	2	0	2
---------	Social Science*	General Education	2	0	2
	*Social Science Courses				
PSY-2405	Educational Psychology	Social Science	2	0	2
OB-2406	Organizational Behavior	Social Science	2	0	2
EC-2307	Introduction to Environmental Sciences	Social Science	2	0	2
MATH-2308	Business Mathematics	Social Science	2	0	2
HRM-2309	HR Management	Social Science	2	0	2
IR-2310	International Relations	Social Science	2	0	2
LAW-2311	Introduction to Law	Social Science	2	0	2
SOC-2321	Sociology	Social Science	2	0	2
Total Credit Hours					**18**

Semester-IV

MATH-2401	Abstract Algebra	Major	3	0	3
MATH-2402	Numerical Methods	Major	3	0	3
DAT-2403	Data Structures & Algorithms	Major	3	0	3
MATH-2404	Ordinary Differential Equation	Major	3	0	3

ETRE-2408	Entrepreneurship	General Education	2	0	2
CCE-2425	Civic and Community Engagement	General Education	2	0	2
UHQ-2430	Understanding of Holy Quran-II	General Education	1	0	1
Total Credit Hours					**17**

3rd Year

Semester-V

MATH-3501	Real Analysis-I	Major	3	0	3
MATH-3502	Topology	Major	3	0	3
MATH-3503	Partial Differential Equations	Major	3	0	3
MATH-3504	Advanced Programming	Interdisciplinary	2	1	3
MATH-3505	Introduction to Mechanics	Interdisciplinary	3	0	3
Total Credit Hours					**15**

Semester-VI

MATH-3601	Real Analysis-II	Major	3	0	3
MATH-3602	Complex Analysis	Major	3	0	3
MATH-3603	Introduction to Machine Learning	Interdisciplinary	2	1	3
MATH-3504	Introduction to Classical Mechanics	Interdisciplinary	3	0	3
---------	Elective-I*	Major	3	0	3
	*Elective Course				
MATH-3605	Vector and Tensor Analysis	Major	3	0	3
Total Credit Hours					**15**

4th Year

Semester-VII

MATH-4701	Internship*	Internship	3	0	3
MATH-4702	Scientific Writing and Research Methods	Interdisciplinary	3	0	3
MATH-4703	Differential Geometry	Major	3	0	3
---------	Elective-II*	Major	3	0	3
---------	Elective-III*	Major	3	0	3
---------	Elective-IV*	Major	3	0	3
	*List of Elective Courses				
MATH-4704	Functional Analysis	Major	3	0	3
MATH-4705	Fluid Mechanics-I	Major	3	0	3
MATH-4706	Numerical Methods II	Major	3	0	3
MATH-4707	Mathematical Physics	Major	3	0	3
MATH-4708	Number Theory and Metric Spaces	Major	3	0	3
MATH-4709	Measure Theory	Major	3	0	3
MATH-4710	Discrete Structures	Major	3	0	3
MATH-4711	Special Functions	Major	3	0	3
MATH-4712	Quantum Mechanics-I	Major	3	0	3
MATH-4713	Ring Theory	Major	3	0	3
MATH-4714	Analytical Dynamics	Major	3	0	3
MATH-4715	Approximation Theory	Major	3	0	3
MATH-4716	Differential Geometry-II	Major	3	0	3
MATH-4717	Electromagnetic Theory-I	Major	3	0	3
MATH-4718	Introduction to Univalent Functions	Major	3	0	3
Total Credit Hours					**18**

Semester-VIII

MATH-4801	Capstone Project	Capstone	0	3	3
MATH-4802	Optimization Theory	Major	3	0	3
---------	Elective-V	Major	3	0	3
---------	Elective-VI	Major	3	0	3
---------	Elective-VII	Major	3	0	3
	*List of Elective Courses				
MATH-4803	Integral Equations	Major	3	0	3
MATH-4804	Fluid Mechanics-II	Major	3	0	3
MATH-4805	Dynamical Systems	Major	3	0	3
MATH-4806	Mathematical Modeling	Major	3	0	3
MATH-4807	Mathematical Systems Theory	Major	3	0	3
MATH-4808	Algebraic Topology	Major	3	0	3
MATH-4809	Special Functions	Major	3	0	3
MATH-4810	Quantum Mechanics-II	Major	3	0	3
MATH-4811	Introduction to Combinatorics	Major	3	0	3
MATH-4812	Variational Inequalities	Major	3	0	3
MATH-4813	Theory of Elasticity	Major	3	0	3
MATH-4814	Special Theory of Relativity	Major	3	0	3
MATH-4815	Fixed point Theory	Major	3	0	3
MATH-4816	Mathematical Statistics II	Major	3	0	3
MATH-4817	Fractional Calculus	Major	3	0	3
Total Credit Hours					**15**
Total Credit Hours of the Program					**133**

* The internship will be registered during 7th or 8th semester according to the approved policy of the University.

4.3 Semester-Wise Breakdown Bachelor of Science in Mathematics with AI

	Semester-VI				
MATH-3601	Real Analysis-II	Major	3	0	3
MATH-3602	Complex Analysis	Major	3	0	3
MATH-3603	Introduction to Machine Learning	Interdisciplinary	2	1	3
MATH-3504	Introduction to Classical Mechanics	Interdisciplinary	3	0	3
---------	Elective-I*	Major	3	0	3
	*Elective Course				
AI-3605	Artificial Neural Networks	Major	2	1	3
Total Credit Hours					**15**
	4th Year				
	Semester-VII				
MATH-4701	Internship*	Internship	3	0	3
MATH-4702	Scientific Writing and Research Methods	Interdisciplinary	3	0	3
MATH-4703	Differential Geometry	Major	3	0	3
---------	Elective-II*	Major	3	0	3
---------	Elective-III*	Major	3	0	3
---------	Elective-IV*	Major	3	0	3
	*List of Elective Courses				
AI-4719	Digital Logic Design	Major	2	1	3
DATS-4719	Data Science with Fundamentals	Major	3	0	3
DATS-4720	Platform and Architecture for Data Science	Major	3	0	3
DATS-4721	Big Data Analytics	Major	2	1	3
DATS-4722	Exploratory Data Analysis and Visualization	Major	3	0	3
Total Credit Hours					**18**
	Semester-VIII				
MATH-4801	Capstone Project	Capstone	0	3	3
MATH-4802	Optimization Theory	Major	3	0	3
---------	Elective-V	Major	3	0	3
---------	Elective-VI	Major	3	0	3
---------	Elective-VII	Major	3	0	3
	*List of Elective Courses				
AI-4818	Introduction to Artificial Intelligence	Major	3	0	3
AI-4819	Programming for Artificial Intelligence	Major	2	1	3
DATS-4818	Statistical Packages & Data Analysis (SPSS, R & Python)	Major	2	1	3
DATS-4819	Time Series Analysis	Major	3	0	3
Total Credit Hours					**15**
Total Credit Hours of the Program					**133**

* The internship will be registered during 7th or 8th semester according to the approved policy of the University.

4.4 Semester-Wise Breakdown Bachelor of Science in Mathematics with Data Science

Semester-VI

MATH-3601	Real Analysis-II	Major	3	0	3
MATH-3602	Complex Analysis	Major	3	0	3
MATH-3603	Introduction to Machine Learning	Interdisciplinary	2	1	3
MATH-3504	Introduction to Classical Mechanics	Interdisciplinary	3	0	3
---------	Elective-I*	Major	3	0	3
	*List of Elective Courses				
AI-3605	Artificial Neural Networks	Major	2	1	3
DATS-3605	Regression Model and Analysis	Major	3	0	3
Total Credit Hours					**15**

4th Year

Semester-VII

MATH-4701	Internship*	Internship	3	0	3
MATH-4702	Scientific Writing and Research Methods	Interdisciplinary	3	0	3
MATH-4703	Differential Geometry	Major	3	0	3
---------	Elective-II*	Major	3	0	3
---------	Elective-III*	Major	3	0	3
---------	Elective-IV*	Major	3	0	3
	*List of Elective Courses				
AI-4719	Digital Logic Design	Major	2	1	3
DATS-4719	Data Science with Fundamentals	Major	3	0	3
DATS-4720	Platform and Architecture for Data Science	Major	3	0	3
DATS-4721	Big Data Analytics	Major	2	1	3
DATS-4722	Exploratory Data Analysis and Visualization	Major	3	0	3
Total Credit Hours					**18**

Semester-VIII

MATH-4801	Capstone Project	Capstone	0	3	3
MATH-4802	Optimization Theory	Major	3	0	3
---------	Elective-V	Major	3	0	3
---------	Elective-VI	Major	3	0	3
---------	Elective-VII	Major	3	0	3
	*List of Elective Courses				
AI-4818	Introduction to Artificial Intelligence	Major	3	0	3
AI-4819	Programming for Artificial Intelligence	Major	2	1	3
DATS-4818	Statistical Packages & Data Analysis (SPSS, R & Python)	Major	2	1	3
DATS-4819	Time Series Analysis	Major	3	0	3
Total Credit Hours					**15**
Total Credit Hours of the Program					**133**

* The internship will be registered during 7th or 8th semester according to the approved policy of the University.

4.5 Semester-Wise Breakdown Bachelor of Science in Mathematics with Economics

	Semester-VI				
MATH-3601	Real Analysis-II	Major	3	0	3
MATH-3602	Complex Analysis	Major	3	0	3
MATH-3603	Introduction to Machine Learning	Interdisciplinary	2	1	3
MATH-3504	Introduction to Classical Mechanics	Interdisciplinary	3	0	3
---------	Elective-I*	Major	3	0	3
	* Elective Course				
ECON-3605	Econometrics and Big data	Major	2	1	3
Total Credit Hours					**15**
	4th Year				
	Semester-VII				
MATH-4701	Internship*	Internship	3	0	3
MATH-4702	Scientific Writing and Research Methods	Interdisciplinary	3	0	3
MATH-4703	Differential Geometry	Major	3	0	3
---------	Elective-II*	Major	3	0	3
---------	Elective-III*	Major	3	0	3
---------	Elective-IV*	Major	3	0	3
	*List of Elective Courses				
ECON-4719	Principles of Economics	Major	3	0	3
ECON-4720	Computational Economics	Major	2	1	3
ECON-4721	Principles of Microeconomics	Major	3	0	3
ECON-4722	Principles of Macroeconomics	Major	3	0	3
Total Credit Hours					**18**
	Semester-VIII				
MATH-4801	Capstone Project	Capstone	0	3	3
MATH-4802	Optimization Theory	Major	3	0	3
---------	Elective-V	Major	3	0	3
---------	Elective-VI	Major	3	0	3
---------	Elective-VII	Major	3	0	3
	*List of Elective Courses				
ECON-4818	Dynamic Economic Modeling	Major	3	0	3
ECON-4819	Intermediate Microeconomics	Major	3	0	3
ECON-4820	Intermediate Macroeconomics	Major	3	0	3
Total Credit Hours					**15**
Total Credit Hours of the Program					**133**

* The internship will be registered during 7th or 8th semester according to the approved policy of the University.

5. Detail of the Modified / New Courses for Bachelor of Science in Mathematics (4-Years Program)

Semester-I

Course Code: MATH-1101 **Title:** Calculus-I **Credit Hours:** 03

Course Outline:

Review Topics: Equations and inequalities**:** Solving linear and quadratic equations, linear inequalities. Division of polynomials, synthetic division. Roots of a polynomial, rational roots; Viete Relations. Descartes rule of signs. Solutions of equations with absolute value sign. Solution of linear and non-linear inequalities with absolute value sign.

Functions and Graphs: Domain and range of a function. Examples: polynomial, rational, piecewise defined functions, absolute value, functions, and evaluation of such functions. Operations with functions: sum, product, quotient and composition. Graphs of functions: linear, quadratic, piecewise defined functions.

Lines and System of Equations: Equation of a straight line, slope and intercept of a line, parallel and perpendicular lines. Systems of linear equations, solution of system of linear equations. Nonlinear systems: at least one quadratic equation.

Limits and Continuity: Functions, limit of a function. Graphical approach. Properties of limits. Theorems of limits. Limits of polynomials, rational and transcendental functions. Limits at infinity, infinite limits, one-sided limits. Continuity.

Derivatives: Definition, techniques of differentiation. Derivatives of polynomials and rational, exponential, logarithmic and trigonometric functions. The chain rule. Implicit differentiation. Rates of change in natural and social sciences. Related rates. Linear approximations and differentials. Higher derivatives, Leibnitz's theorem.

Applications of derivatives: Roll's Theorem, Cauchy's MVT, Increasing and decreasing functions. Relative extrema and optimization. First derivative test for relative extrema. Convexity and point of inflection. The second derivative test for extrema. Curve sketching. Indeterminate forms and L'Hopitals rule. Inverse functions and their derivatives.

Integration: Antiderivatives and integrals. Riemann sums and the definite integral. Properties of definite integral. The fundamental theorem of calculus. The substitution rule.

Texts and Reference Books

1. H. Anton*, Calculus, A New Horizon,* 6th Edition, John Wiley and Sons, New York, 1999
2. J. Stewart*, Calculus,* 3rd Edition, Brooks/Cole, 1995.
3. G. B. Thomas and A.R. Finney*, Calculus,* 10th Edition, Addison Wesley, USA, 2002.
4. Dr. B. H. Edwards, *Calculus*: 10th Edition, Brooks/Cole, 2013.
5. S.M Yousaf, Muhammad Amin, *Calculus*: 7th Edition, Ilmi Kitab Khana.

Code: MAT-1102 Title: Introduction to Programing Credit Hours: 2+1

Course Contents: Basic Commands, Matrix manipulation and basic notations, developing arrays, cell arrays, array functions, Two and three dimensional plotting of functions, Loops, Use of M-file and command window, use of different conditions, calculating limits, derivatives and integration by using MATLAB, Maximum and minima (using MATLAB), dealing with complex functions (by using MATLAB), Build in Solver for differential equations in MATLAB, Calculating inverse of matrices by MATLAB, Laplace and Fourier transformation by using MATLAB, simplifying linear equation with the help of MATLAB. Sequences, multiplication and addition of sequences by MATLAB, Polynomial functions using interpolation (MATLAB). Basic Concepts of Simulink.

Texts and Reference Books

1. Thomas, Calculus, 13th Edition. Addison Wesley Publishing Company, 2005
2. J. B. Fraleigh, A First Course in Abstract Algebra,8th edition Addison-Wesley Publishing Company, 2002.
3. T. Salahuddin, Numerical Techniques in MATLAB, Fundamental to advance Concepts, CRC, Taylor and Francis, 2023.

Course Code: ENG-1107 **Title:** Functional English **Credit Hours:** 03

Course Contents: Foundations of Functional English: Vocabulary building (contextual usage, synonyms, antonyms and idiomatic expressions)**,** Communicative grammar (subject-verb-agreement, verb tenses, fragments, run-ons, modifiers, articles, word classes, etc.)**,** Word formation (affixation, compounding, clipping, back formation, etc.)**,** Sentence structure (simple, compound, complex and compound-complex)**,** Sound production and pronunciation**.**

Comprehension and Analysis: Understanding purpose, audience and context**,** Contextual interpretation (tones, biases, stereotypes, assumptions, inferences, etc.)**,** Reading strategies (skimming, scanning, SQ4R, critical reading, etc.)**,** Active listening (overcoming listening barriers, focused listening, etc.)**.**

Effective communication: Principles of communication (clarity, coherence, body, conciseness, courteousness, correctness, etc.), Structuring documents (introduction, body, conclusion and formatting), Inclusivity in communication (gender-neutral language, stereotypes, cross-culture communication, etc.), Public speaking (overcoming stage fright, voice modulation and body language), Presentation skills (organization content, visual aids and engaging the audience), Information communication (small talk, networking and conversational skills), Professional writing (business e-mails, memos, reports, formal letters, etc.).

Text and Recommended Books:

1. "Understanding and Using English Grammar" by Betty Schrampfer Azar.
2. "English Grammar in Use" by Raymond Murphy.
3. "The Blue Book of Grammar and Punctuation" by Jane Straus.
4. "English for Specific Purpose: A Learning-Centered Approach" by Tom Hutchinson and Alan Waters.

5. "Cambridge English for Job-hunting" by Colm Downes.
6. "Practical English Usage" by Michael Swan.
7. "Reading Literature and Writing Argument" by Missy James and Alan P. Merickel.
8. "Improving Reading: Strategies, Resources, and common Core Connections" by Jerry Jhons and Susan Lenski.
9. "Comprehension: A Paradigm for Cognition" by Walter Kintsch.
   "Communication Skills for Business Professionals" by J.P. Verma and Meenakshi Raman.

Course Code: PHY-1118 **Title:** The Fundamentals of Physics **Credit Hours:** 03

Contents: This course introduces the core principles of physics necessary for understanding natural phenomena and supporting studies in allied sciences. Topics span mechanics, energy, heat, electricity, magnetism, waves, optics, and modern physics. Emphasis is placed on conceptual clarity, real-world relevance, and developing a scientific problem-solving mindset.

Texts and Recommended books:

1. F. W. Sears, M. W. Zemansky and H. D. Young, *University Physics*, 3th Edition, 1963.
2. R. A. Serway and J. W. Jewett, Principles of Physics, 5th Edition, Brooks Cole, 2012.
3. H. C. Ohanian and J. T. Market, *Physics for Engineers and Scientists*, 3rd Edition, W. W. Norton & Company, 2006.
4. R. D. Knight*, Physics for Scientists and Engineers*, 2th Edition, Addison-Wesley, 2007.

Course Code: QTR- 1124 **Title:** Quantitative Reasoning I **Credit Hours:** 03

Course Outline: Numerical Literacy: Number system and basic athematic operations, Units and their conversions, dimensions, area, perimeter and volume, Rates, ratios, proportions and percentages, Types and sources of data, Measurements scales, Tabular and graphical presentation of data, Quantitative reasoning exercises using number knowledge.

Fundamental Mathematical Concepts: Basics of geometry (lines, angles, circles, polygons, etc.)**,** Sets and their operations**,** Relations, functions, and their graphs, Exponents, factoring and simplifying algebraic expressions, Algebraic and graphical solutions of linear and quadratic equations and inequalities, Quantitative reasoning exercises using fundamental mathematical concepts.

Fundamental Statistical Concepts: Population and sample, Measure of central tendency, dispersion and data interpretation, Rules of counting (multiplicative, permutation and combination), Basic probability theory, Quantitative reasoning exercises using fundamental statistical concepts.

Texts and Reference Books

1. "Quantitative Reasoning: Tools for Today's Informed Citizen" by Bernard L. Madison, Lynn and Arthur Steen.
2. "Quantitative Reasoning for the Information Age" by Bernard L. Madison and David M. Bressoud.
3. Fundamentals of Mathematics" by Wade Ellis.
4. "Quantitative Reasoning: Thinking in Numbers" by Eric Zaslow.
5. "Thinking Clearly with Data: A Guide to Quantitative Reasoning and Analysis" by Ethan Bueno de Mesquita and Anthony Fowler.
6. "Using and Understanding Mathematics: A Quantitative Reasoning Approach" by Bennet, J. O., Briggs, W. L., & Badalamenti, A.
7. "Discrete Mathematics and its Applications" by Kenneth H. Rosen.
8. "Statistics for Technology: A Course in Applied Statistics" by Chatfield, C.
9. Statistics: Unlocking the Power of Data" by Robin H. Lock, Patti Frazer Lock, Kari Lock Morgan, and Eric F. Lock.

Course Code: ICT-1126 **Title:** Application of information and communication Technologies **Credit Hours:** 2+1

Contents: Introduction to Information and Communication Technologies: Components of Information and Communication Technologies (basics of hardware. Software, ICT platforms, networks, local and cloud data storage etc.). Scope of information Communication technologies (use of ICT in education, business, governance, healthcare, digital media and entertainment, etc.), Emerging technologies and future trends.

Basic ICT Productivity Tools: Effective use of popular search engines (e.g., Google, Bing, etc.) to explore World Wide Web, Formal communication tools and etiquettes (Gmail, Microsoft Outlook, etc.), Microsoft Office Suite (Word, Excel, PowerPoint), Google Workspace (Google Does, Sheets, Slides). Dropbox (Cloud storage and file sharing), Google Drive (Cloud storage with Google Does integration) and Microsoft OneDrive (Cloud storage with Microsoft Office integration), Evernote (Note-taking and organization applications) and OneNote (Microsoft's digital notebook for capturing and organizing ideas), Video conferencing (Google Meet, Microsoft Teams, Zoom, etc.), Social media applications (LinkedIn, Facebook, Instagram, etc.).

ICT in Education: Working with learning management systems (Moodle, Canvas, Google Classrooms, etc.), Sources of online education courses (Coursera, edX, Udemy, Khan Academy, etc.), Interactive multimedia and virtual classrooms.

ICT in Health and Well-being: Health and fitness tracking devices and applications (Google Fit, Samsung Health, Apple Health, Xiaomi Mi Band, Runkeeper, etc.), Telemedicine and online health consultations (OLADOC, Sehat Kahani, Marham, etc.).

ICT in Personal Finance and Shopping: Online banking and financial management tools (JazzCash, Easypaisa, Zong PayMax, ILINK and MNET, Keenu Wallet, etc.), E-commerce platforms (Daraz. pk, Telemart, Shophive, etc.).

Digital Citizenship and Online Etiquette: Digital identity and online reputation, Netiquette and respectful online communication, Cyberbullying and online harassment.

Ethical Consideration in Use of ICT Platforms and Tools: Intellectual property and copyrights issue, Ensuring originality in content creation by avoiding plagiarism and unauthorized use of information sources. Content accuracy and integrity (ensuring that the content shared through ICT platforms is free from misinformation, fake news, and manipulation).

Texts and Recommended books

1. Discovering Computers" by Vermaat, Shaffer and Freund.
2. "GO! With Microsoft Office" Series by Gaskin, Vargas and McLellan.
3. "Exploring Microsoft Office" Series by Grauer and Poastsy.
4. **"**Computing Essentials" by Morley and Parker.
5. "Technology in Action" by Evans, Martin, and Poatsy

Semester-II

Course Code: ARA-1201 **Title:** Arabic **Credit Hours:** 02

Course Contents:

الدرس االول	ما هذا ؟ ۔ هل تلک مدرسۃ ؟ ۔ تمرینات
الدرس الثانی	الضمائر المتصلۃ۔ تمرینات
الدرس الثالث	المرکب االضافی ۔ تمرینات
الدرس الرابع	المرکب التوصیفی۔ الرفع۔ تمرینات
الدرس الخامس	الضمائر المنفصلۃ ۔ حروف الجر۔ تمرینات
الدرس السادس	الجمع۔ تمرینات
الدرس السابع	الفعل الماضی۔ تمرینات
الدرس الثامن	الفعل المضارع ۔ تمرینات
الدرس التاسع	الفعل المضعف۔ الضمائر المتصلۃ باالفعال۔ تمرینات
الدرس العاشر	الفعل الصحیح۔ الفعل المعتل۔ تمرینات
الدرس الحادی عشر	المذکر والمونث ۔ االسماء الخمسۃ ۔ تمرینات
الدرس الثانیعشر	االعداد ۔ تمرینات
الدرس الثالث عشر	کم ۔ أيّ ۔ تمرینات
الدرس الرابع عشر	اسم الفاعل ۔ تمرینات
الدرس الخامس عشر	اعضاء الجسم ۔ االلوان ۔ بعض المصادر القیاسۃ۔ تمرینات
الدرس السادسعشر	لقاء فی المطار ۔ الحروف واالسماء مع الضمائر المتصلۃ۔ تمرینات
الدرس السابع عشر	الجملۃ االسمیۃ ۔ الجملۃ الفعلیۃ ۔ تمرینات
الدرس الثامن عشر	حروف الهجاء۔ وطریقۃ النطق بها۔ حروف المد ۔ ال ۔ القمریۃ ۔ والشمسیۃ ۔ تمرینات
الدرس التاسع عشر	)(االناشید المختارۃ ۔ تمرینات)ب(القصۃ :)قوۃ االخالص (۔تمرینات
الدرس العشرون	االحادیث النبویۃ

Text and Reference Books: Lisaan Ul Arabi, AIOU, Islamabad.

Course Code: MATH-1201 **Title:** Calculus-II **Credit Hours:** 03

Course Outline:

Techniques of integration: Integrals of elementary, hyperbolic, trigonometric, logarithmic and exponential functions. Integration by parts, substitution and partial fractions. Approximate integration. Improper integrals. Reduction Formulas, Gamma functions.

Applications of integrals: Area between curves, average value. Volumes. Arc length. Area of a surface of revolution. Applications to Economics, Physics, Engineering and Biology.

Infinite series: Sequences and series. Convergence and absolute convergence. Tests for convergence: divergence test, integral test, p-series test, comparison tests, alternating series test, ratio test, root test. Power series. Convergence of power series. Representation of functions as power series. Differentiation and integration of power series. Taylor and McLaurin series. Approximations by Taylor polynomials.

Conic section, parameterized curves and polar coordinates: Curves defined by parametric equations. Calculus with parametric curves: tangents, areas, arc length. Polar coordinates. Polar curves, tangents to polar curves. Area and arc length in polar coordinates.

Texts and Reference Books

1. H. Anton*, Calculus: A New Horizon,* 6th Edition, John Wiley and Sons, New York, 1999
2. J. Stewart*, Calculus,* 3rd Edition, Brooks/Cole, 1995.
3. G. B. Thomas and A. R. Finney*, Calculus,* 10th Edition, Addison Wesley, Reading, Ma, USA, 2002
4. M. Ryan, *Calculus, 2nd Edition,* For Dummies, 2016.
5. M. D. Spivak, *Calculus*, 4th Edition, Publish or Perish, 2008.

Course Code: MATH-1202 **Title:** Discrete Mathematics **Credit Hours: 03**

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

Understand the principles of combinatorics, set theory, and graph theory. Apply iscrete mathematical techniques to solve problems in computer science and cryptography. Analyze logical structures and use them in algorithmic problem-solving.

Texts and Reference Books

1. Mathematical Structure for Computer Science", Judith L. Gersting, W. H. Freeman & Company. (Any edition).
2. Any old or new discrete math textbook will do the job.

Course Code: ENG-1207 **Title:** Expository Writing **Credit Hours:** 03

Contents: Introduction to Expository Writing: Understanding expository writing (definition, types, purpose and applications), Characteristics of effective expository writing (clarity, coherence and organization), Introduction to paragraph writing

The Writing Process: Pre-writing techniques (brainstorming, free-writing, mind-mapping, listing, questioning and outlining etc.), Drafting (three stage process of drafting techniques), Revising and editing (ensuring correct grammar, clarity, coherence, conciseness etc.), Proof reading (fine-tuning of the draft), Peer review and feedback (providing and receiving critique). **Essay Organization and Structure:** Introduction and hook (engaging readers and introducing the topic). Thesis statement (crafting a clear and focused central idea). Body Paragraphs (topic sentences, supporting evidence and transitional devices). Conclusion (types of concluding paragraphs and leaving an impact). Ensuring cohesion and coherence (creating seamless connections between paragraphs). **Different Types of Expository Writing:** Description, Illustration, Classification, Cause and effect (exploring causal relationships and outcomes), Process analysis (explaining step-by-step procedures), Comparative analysis (analyzing similarities and differences). **Writing for Specific Purposes and Audiences:** Different types of purposes (to inform, to analyze, to persuade, to entertain etc.), Writing for academic audiences (formality, objectivity, and academic conventions), Writing for public audiences (engaging, informative and persuasive language), Different tones and styles for specific purposes and audiences. **Ethical Considerations:** Ensuring original writing (finding credible sources, evaluating information etc.), Proper citatio0n and referencing (APA, MLA, or other citation styles), Integrating quotes and evidence (quoting, paraphrasing, and summarizing), Avoiding plagiarism (ethical considerations and best practices)**. Suggested practical activities (Optional):** As part of the overall learning requirements, students will be required to build a writing portfolio having a variety of expository texts and present the same at the end of the course showcasing proficiency in expository writing.

Texts and Reference Books

1. The St. Martin's Guide to Writing by rise B. Axelrod and Charles R. Cooper.
2. They Say / 1 Say: The Moves That Matter in Academic Writing by Gerald Graff and Cathy Birkenstein.
3. Writing Analytically by David Rosenwasser and Jill Stephen.
4. Style: Lessons in Clarity and Grace by Joseph M. Williams and Joseph Bizup.
5. The Elements of Style by William Strunk Jr. and E.B. White.
6. Good Reasons with Contemporary Arguments by Lester Faigley and Jack Selzer.
7. Writing to Learn; How to Write – and Think – Clearly About Any Subject at All by William Zinsser.
8. The Norton Field Guide to Writing by Richard Bullock, Maureen Daly Goggin, and Francine Weinberg.
9. The Art of Styling Sentences by Ann Longknife and K.D. Sullivan.
10. Writing Today by Richard Jonson-Sheehan and Charles Paine

Course Code: PAK-1217 **Title:** Pakistan Studies **Credit Hours:** 02

Contents: Historical Perspective: Ideological Rationale with Special Reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-i-Azam Muhammad Ali Jinnah, Factors Leading to Muslim Separatism, Indus Civilization, Muslim Advent, Location and Geo-physical Features.
Political and Constitutional Phases: 1947-58, 1958-71, 1971-77, 1977-88, 1988-99, 1999 and onward

Economic Institutions and Issues, Society and Social Structure, Ethnicity, Foreign Policy of Pakistan and Challenges and Futuristic Outlook of Pakistan

Texts and Recommended books:

1. B. S. Javed, *State & Society in Pakistan,* The Macmillan Press Ltd, 1980.
2. A. S. Zaidi, *Issue in Pakistan's Economy,* Karachi: Oxford University Press, 2000.
3. M. Safdar, *Pakistan Political Roots & Development,* Lahore, 1994.
4. W. Wayne, *The Emergence of Banglades.,* Washington, Institute of PPR, 1972.

Course Code: QTR-1224 **Title:** Quantitative Reasoning II **Credit Hours:** 03

Course Outline: Logic, Logical and Critical Reasoning: Introduction and importance of logic, Inductive, deductive and abductive approaches of reasoning, Propositions, arguments (valid; invalid), logical connectives, truth tables and propositional equivalences, Logical fallacies, Venn Diagrams, Predicates and quantifiers, Quantitative reasoning exercises using logical reasoning concepts and techniques. **Mathematical Modeling and Analysis:** Introduction to deterministic models, Use of linear functions for modeling in real-world situations, Modeling with the system of linear equations and their solutions, Elementary introduction to derivatives in mathematical modeling, Linear and exponential growth and decay model, Quantitative reasoning exercises using mathematical modeling.
Statistical Modeling and Analysis: Introduction to probabilistic models, Bivariate analysis, scatter plots, Simple linear regression model and correlation analysis, Basics of estimation and confidence interval, testing of hypothesis (z-test; t-test), Statistical inference in decision making, Quantitative reasoning exercises using statistical modeling.

Texts and Reference Books

1. Using and Understanding Mathematics: A Quantitative Reasoning Approach by Bennett, O., Briggs, W. L., & Badalamenti, A.
2. Discrete Mathematics and its Applications by Kenneth H. Rosen.
3. "Discrete Mathematics with Applications" by Susanna S. Epp.
4. "Applied Mathematics for Business, Economics and Social Sciences" by Frank S Budnick.
5. "Elementary Statistics: A Step by Step Approach" by Allan Bluman.
6. Introductory Statistics" by Prem S. Mann.
7. "Applied Statistical Modeling" by Salvatore Babones.
8. "Barrons SAT" by Sharvon Weiner Green, M.A and Ira K. Wolf.

Course Code: UHQ-1230 **Title:** Understanding of Holy Quran-I **Credit Hours:** 01

Weeks	Lectures (1.5 hrs)	Units	Lessons	Assignments/Home Task	Linguistic Rules
1.	1.	1	1-6	Writing the meaning of Quranic words Lesson 1-8	Proper Noun Masculine & Feminine
	2.	1	9-14	Writing the meaning of Quranic words 9-14	Two kinds of plural Concept of (و) "And" Common Noun
2.	1.	1	15-17	Writing the meaning of Quranic words, phrases & translation of Sentences 15-17	Demonstrative Noun (This & That for Masculine (هذا- هذه) Demonstrative Noun (This & That for Feminine) (ذلك- تلك)
	2.	1	18-19 & Revision (Unit 1)	Writing the meaning of Quranic words, phrases & translation of Sentences 17-19	Laam for emphasis (التأكيد لام) Superlative Degree like أكبر Revision of all Quranic Sentences
3.	1.	Unit 2	1-3	Writing the meaning of Quranic words, phrases & translation of Sentences 1-3	Emphatic Particle إ ن Preposition "For" (اللام) Preposition (في)
	2.	2	4-6	Writing the meaning of Quranic words, phrases & translation of Sentences 4-6	Preposition (على- من- إلى)
4.	1.	2	7- 9	Writing the meaning of Quranic words, phrases & translation of Sentences 7-9	Preposition (الباء) Absolute Negation Particle Exceptive Particle (النافية لا (إلا) (النافية ما)(للجنس
	2.	2	10-13 & Revision (Unit 2)	Writing the meaning of Quranic words, phrases & translation of Sentences 10-1 3	Subordinating Conjunction(أن), Was (ن كا), Vocative Particle(النداء حرف)
5.	1.	Unit 3	1-2	Writing the meaning of Quranic phrases 1-2	Quranic Adjective Compounds (وموصوف صفة)
	2.	3	3-5	Writing the meaning of Quranic phrases & translation of sentences 3-5	Quranic Possessive Construction (إليه ومضاف مضاف)
6.	1.	3	6 -7	Writing the meaning of Quranic phrase translation of sentences 6-7	Quranic Possessive Construction (إليه ومضاف مضاف)
	2.	3	8-10 & Revision (Unit 3)	Writing the meaning of Quranic phrase & translation of Sentences 8-10	Active Participle (الفاعل اسم), Passive Participle (المفعول اسم), Dual (مثنى)
7.	1.	Unit 4	1-2	Writing the meaning of Quranic phrase & translation of Sentences 1-2	Personal Pronoun He (هو المنفصل) Possessive Pronoun His ـه المتصل)

	2.	4	3-4	Writing the meaning of Quranic phrase & translation of sentences 3 -4	Possessive Pronoun with prepositions like بيته في Pronoun "His" with prepositions like فيه منه، له،
8.	1.	4	5-8	Writing the meaning of Quranic sentences 5-8	Personal Pronoun You (المنفصل أنت) Possessive Pronoun Your ك المتصل) Possessive Pronoun with prepositions like بينك في Pronoun "your" with prepositions like لك، فيك منك،
9.	1.	4	9-12	Writing the meaning of Quranic phrases & sentences 9-12	Personal Pronoun She (المنفصل هي) Possessive Pronoun Her المتصل ها) Possessive Pronoun with prepositions like بيتها في Pronoun "Her" with prepositions like لها،
	2.	4	13-16	Writing the meaning of Quranic phrases & sentences 13-16	Personal Pronoun I (المنفصل أنا) Possessive Pronoun Her ي المتصل) Possessive Pronoun with prepositions like بيتي في Pronoun "My" with prepositions like لي
10.	1	4	17 & Revision Unit 4	Revision of all Quranic sentences of Unit 4	Adverb (حال)
	2.	Unit 5	1-2	Writing the meaning of Quranic phrases & sentences 1-2	Masculine Plural و السالم المذكر جمع المذكر جمع ر الج بحرف المسبوق السالم
11.	1.	5	3-4	Writing the meaning of Quranic phrases & sentences 3-4	Possessive Construction with Plurals جمع ة بالإضاف المسبوق السالم المذكر
	2.	5	5-6	Writing the meaning of Quranic phrases, sentences & verses 5-6	Personal Pronoun They (المنفصل هم) Possessive Pronoun Their المتصل هم)
12.	1.	5	7-8	Writing the meaning of Quranic phrases, sentences & verses 7-8	Possessive Pronoun with prepositions like بيتهم في Pronoun "Their" with prepositions like لهم
	2.	5	9-11	Writing the meaning of Quranic phrases, sentences & verses 9-11	Personal Pronoun You (المنفصل أنتم) Possessive Pronoun Your كم المتصل) Possessive Pronoun with prepositions like بيتكم في
13.	1.	5	12-14	Writing the meaning of Quranic phrases & sentences & verses 12-14	Pronoun "Your" with prepositions like م لك Personal Pronoun We (المنفصل نحن) Possessive Pronoun Our نا المتصل)

	2.	5	15-16	Writing the meaning of Quranic sentences & verses 15-16	Possessive Pronoun with prepositions like بيتنا في Pronoun "Our" with prepositions like النا
14.	1.	5	17-18	Writing the meaning of Quranic sentences & Verses 17-18	Demonstrative Pronoun These, Those (هؤلاء- أولئك)
	2.	5	19-23	Writing the meaning of Quranic sentences & Verses 19-23	بل، أن، أم،/أ إلا، / ،ما ما ليس، إنما، إلا، / إن) (كأن) سبحان، يومئذ، اليوم، أليس، ألا، ما كلا، نعم، بئس، إذن، قل، مابينهما، مرجع، مصير، ب، أعلم حسب، أدراك، (تمييز)دينا
15.	1.	5	Revision Unit 5		
	2.	5	1-3 (till Page 16)	Writing the meaning of Quranic Verbs &Translation of Quranic Sentences & Verses (1-3)	Introduction of Present Tense(مضارع فعل) & Verbal Sentence (فعلية جملة) Present Tense يعلم المضارع الفعل المفرد صيغة
16.	1.	6	3 (From Page 17) & 4 -5	Translation of Quranic Sentences & Verses 3-5	Present Tense يعلم المضارع الفعل المفرد صيغة
	2.	6	6	Translation of Quranic Sentences & Verses	Present Tense الفعل الجمع صيغة المضارع يعلمون

Texts and Recommended books
Course Book: Muallim ul Quran (Volume 1, 2 & 3) by Dr Ubaid ur Rahman
Helping Material:
Paper book: All volumes are available in printed book form.
Tutorial videos: Teaching video of each lesson available on YouTube.
Confirmation Videos: A complete series of confirmation videos of all lessons is available in which the student can confirm his answers.
A flipbook: A flipbook edition is also accessible.
Helping material: Helping material for the teachers like quizzes, question papers and images is available on website.

Semester-III

Course Code: MATH-2301 **Title:** Calculus-III **Credit Hours:** 03

Course Outline:

Multivariable functions and partial derivatives: Functions of several variables. Limits and Continuity. Partial derivatives, Composition and chain rule. Directional derivatives and the gradient vector. Implicit function theorem for several variables. Maximum and minimum values. Optimization problems. Lagrange Multipliers.

Vectors and analytic geometry in space: Coordinate system. Rectangular, cylindrical and spherical coordinates. The dot product, the cross product. Equations of lines and planes. Quadric surfaces.

Vector-valued functions: Vector-valued functions and space curves. Derivatives and integrals of vector valued functions. Arc length. Curvature, normal and binormal vectors.

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. Applications of double and triple integrals. Change of variables in multiple integrals.

Vector calculus: Vector fields. Line integrals. Green's theorem. Curl and divergence. Surface integrals over scalar and vector fields. Divergence theorem. Stokes' theorem.

Texts and Reference Books

1. H. Anton, *Calculus: A New Horizon,* 6th Edition, John Wiley and Sons, New York, 1999.
2. J. Stewart, *Calculus,* 3rd Edition, Brooks/Cole, 1995.
3. G. B. Thomas and A.R. Finney, *Calculus,* 10th Edition, Addison Wesley, Reading, Ma, USA, 2002.
4. M. Ryan, *Calculus, 2nd Edition,* For Dummies, 2016.

Course Code: MATH-2302 **Title:** Linear Algebra-I **Credit Hours:** 03

Course Outline: System of Linear Equations, Row Reduction, Echelon and Reduced Forms, Vector Equations and the Matrix Equation, Solution of Linear Systems and Applications, **Matrix Operations**, Inversion and Characterizations of Invertible Matrices, Matrix Factorization, Application of Matrices and Linear Equations, Determinants and Their Properties, Cramer's Rule, Volume and Linear Transformations,

Fields, Vector Spaces, Subspaces, Linear Dependence and Independence, Linear Span of a Subset of a Vector Space, Bases and Dimensions, Rank and Nullity

Texts and Reference Books

1. D. C. Lay, *Linear Algebra and its Applications*, Dorling Kindersley Publishing, 2003.
2. S. J. Leon, *Linear Algebra with Applications*, 6th Edition, Prentice Hall, 2002.
3. G .E. Shilov, *Linear Algebra*, Dover Publication, Inc., New York, 1997.
4. D. G. Zill and M. R. Cullen, Advanced Engineering Mathematics, PWS, Publishing Company, Boston, 1996.
5. G. Strang, *Linear Algebra,* 5th Edition, Wellesley-Cambridge Press, 2016.

Course Code: MATH-2303 **Title:** Elementary Differential Equation **Credit Hours:** 03

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

Formulate and solve first (linear and non-linear) and higher order differential equations. Apply differential equations to model real-world systems in applied sciences.

Analyze the behavior of solutions.

Texts and Reference Books

1. W. E. Boyce and R. de Prima, *Elementary Differential Equations*, 9th Edition, Wiley, 2008.
2. E. Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley, 2011.
3. D. G. Zill, *Differential Equations with Boundary-Value Problems,* 8th Edition, Brooks Cole, 2012.
4. S. J. Farlows, *An Introduction to Differential Equations and Their Applications*, Dover Publications, 2006.
5. M. E. Taylor, *An Introduction to Differential Equations,* 14th Edition, American Mathematical Society, 2011.

Course Code: MATH-2304 **Title:** Statistics & Probability **Credit Hours:** 03

Course Outline: The postulates of probability, some elementary theorems, Addition and multiplication rules, Baye's rule and future Baye's theorem, Random variables and probability functions, Uniform, Bernoulli and Binomial distribution, Hypergeometric and geometric distribution, Negative binomial and Poisson distribution, Uniform and exponential distribution, Gamma and beta distributions, Normal distribution, Moments and moment generating functions

Moments of binomial, hypergeometric, Poisson, gamma, beta and normal distributions

Texts and Reference Books

1. M. H. De-Groot and M. J. Schervish, *Probability and Statistics,* 3rd Edition, Addison Wesley, 2002.
2. A. Papoulis, *Probability, Random Variables, and Stochastic Processes*, 3rd Edition, Mc-Graw Hill, 1991.
3. T. Sincich, *Statistics by Examples*, Dellen Publishing Company, 1990.
4. A. S. Hirahi. *A Course in Mathematical Statistics,* 4th Edition, Ilmi Kitab Khana, Lahore, Pakistan, 2012.

5. S. M. Chaudhry and S. Kamal, *Introduction to Statistical Theory Part-II*, Ilmi Kitab Khana, Lahore, Pakistan, 2012.

Course Code: ICP-2305 **Title:** Ideology and constitution of Pakistan **Credit Hours:** 02

Contents: Introduction to the Ideology of Pakistan: Definition and significance of ideology.

Historical context of the creation of Pakistan (with emphasis on socio-political, religious, and cultural dynamics of British India between 1857 till 1947).

Contributions of founding fathers of Pakistan in the freedom movement including but not limited to Allama Muhammad Iqbal, Muhammad Ali Jinnah., etc, Contributions of women and students in the freedom movement for separate homeland for Muslims of British India.

Two-Nation Theory:
Evolution of the Two-Nation Theory (Urdu-Hindi controversy, Partition of Bengal, Simla Deputation 1906, Allama Iqbal's Presidential Address 1930, Congress Ministries 1937 Lahore Resolution 1940), Role of communalism and religious differences. **Introduction to the Constitution of Pakistan:** Definition and importance of a constitution, Ideological factors that shaped the Constitution(s) of Pakistan (Objectives Resolution 1949), Overview of constitutional developments in Pakistan. **Constitution and State Structure:** Structure of Government (executive, legislature, and judiciary), Distribution of powers between federal and provincial governments, 18th Amendment and its impact on federalism. **Fundamental Rights, Principles of Policy and Responsibilities:** Overview of fundamental rights guaranteed to citizens by Constitution of Pakistan 1973 (Articles 8-28), Overview of Principles of Policy (Articles 29-40), Responsibilities of the Pakistani citizens (Article 5). **Constitutional Amendments:** Procedures for amending the Constitution, Notable constitutional amendments and their implications.

Texts and Recommended books

1. "The Idea of Pakistan" by Stephen P. Cohen.
2. "Ideology of Pakistan" by Javed Iqbal.
3. "The Structure for Pakistan" by I.H. Qureshi.
4. "Pakistan the Formative Phase" by Khalid Bin Sayeed.
5. "Pakistan: Political Roots and Development" by Safdar Mahmood.
6. "Ideology of Pakistan" by Sharif-ul-Mujahid.
7. "The Struggle for Pakistan: A Study Homeland and Global Politics" by Ayesha Jalal.
8. "Jinnah, Pakistan and Islamic Identity: The Search for Saladin" by Akbar S. Ahmed.
9. "The Making of Pakistan: A Study in Nationalism" by K.K. Aziz.
10. "Pakistan: A New History" by Ian Talbot.
11. "Pakistan in the twentieth Century: A Political History" by Lawrence Ziring.
12. "The Constitution of Pakistan 1973". Original.
13. "Constitutional and Political Development of Pakistan" by Hamid Khan.
14. "The Parliament of Pakistan" by Mahboob Hussain.
15. "Constitutional Development in Pakistan" by G/W. Choudhury.
16. "Constitutional-Making in Pakistan: The Dynamics of Political Order" by G.W. Choudhury.

Course Code: ISL-2312 **Title:** Islamic Studies **Credit Hours:** 02

Contents: Introduction to Islam: Definition of Islam and its core beliefs, The Holy Quran (introduction, revelation, and compilation), Hadith and Sunnah (compilation, classification and significance), Key theological concept and themes (Tawhid, Prophethood, Akhairah etc.). **Sirah of the Holy Prophet (Peace Be Upon Him) as Uswa-i-Hasana:** Life and legacy of the Holy Prophet PBHU, Diverse roles of the Holy prophet PBHU (as an individual, educator, peace maker, leader etc.), **Islamic History and Civilization:** World before Islam, The Rashidun Caliphate and expansion of Islamic rule, Contribution of Muslim scientists and philosophers in shaping world civilization, **Islamic Jurisprudence (Fiqh):** Fundamental source of Islamic Jurisprudence, Pillars of Islam and their significance, Major School of Islamic Jurisprudence, Significance and principle of Ijtihad. **Family and Society in Islam:** Status and rights of women in Islamic teachings, Marriage, family and gender roles in Muslim society, Family structure and values in Muslim society. **Islam and the Modern World:** Relevance of Islam in the modern world (globalization, challenges and prospects), Islamophobia, interfaith dialogue and multiculturalism, Islamic viewpoint towards socio-culture and technological change.

Texts and Recommended books

1. "The Five Pillars of Islam: a Journey through the Divine Acts of Worship" by Muhammad Mustafa Al-Azami.
2. "The Five Pillars of Islam: a Framework for Islamic Values and Character Building" Musharraf Hussain.
3. "Towards Understanding Islam" by Abul A' la Mawdudi.
4. "Islami Nazria e Hayat" by Khurshid Ahmad.
5. An Introduction to Islamic Technology" by Jhon Renard.

Course Code: HRM-2308 **Title:** HR Management **Credit Hours:** 02

Course Contents: Introduction to HRM, Human Resource Planning, Job Design and Analysis, Recruitment & Selection, Motivation & Reward System, Career Planning & Development, Training & Development, Performance Appraisal, Compensation Management & Employee Relation, Employee Health and Safety.

Text and Reference books

1. R. A. Noe, P. M. Wright, J. R. Hollenbeck and B. Gerhart , *Human Resource Management* , 10th edition, McGraw-Hill Education, 2016.
2. R. L. Mathis and P. Meglich, *Human Resource Management*, 15th edition, South-Western College Pub, 2016.
3. B. Wolfe, *The Little Black Book of Human Resources Management,* Create Space Independent Publishing Platform, 2015.
4. J. H. Jackson, *Human Resource Management*, 14th Edition, South-Western College Pub, 2013.

Course Code: PSY-2405 **Title:** Educational Psychology **Credit Hours:** 02

Course Contents: Introduction, Nature and Application of Psychology with Special Reference to Pakistan, Historical Background (A Brief Survey), Methods of Psychological Study, Biological Basis of Behavior, Vision, Audition, Perception, Attention, Motives, Emotions, Learning, Memory, Tools of Thinking, Individual Differences

Texts and Recommended books

1. R. C. Atkinson and E. E. Smith *Introduction to psychology*, Harcourt Brace College Publishers, 2000.
2. L.D. Fernald and P.S. Fernald, *Introduction to psychology*, USA: W M C Brown Publishers, 2005.
3. W. E. Glassman, *Approaches to psychology*, Open University Press, 2000.
4. N. Hayes *Foundation of psychology*, 3rd Edition, Thomson Learning, 2000.
5. B. B. Lahey, *Psychology: An introduction*, 8th Edition, Mc Graw Hill Companies, Inc. (2004).

Course Code: OB-2406 **Title:** Organizational Behavior **Credit Hours:** 02

Course Contents:

Introduction to HRM, Human Resource Planning, Job Design and Analysis, Recruitment & Selection, Motivation & Reward System, Career Planning & Development, Training & Development, Performance Appraisal, Compensation Management & Employee Relation, Employee Health and Safety.

Texts and Recommended books

1. Garry Dessler, *Human Resource Management*.
2. Garry Dessler, *Human Resource Management.*
3. Dale S. Beach, *Personnel The Management of people at work*.
4. Holdin, *Human Resource Management*.

Course Code: MATH-2308 **Title:** Business Mathematics **Credit Hours:** 02

Course Contents: Basic mathematical concepts and their application in various business real numbers, Linear equations and their applications, System of linear equations, Functions (linear functions, quadratic and polynomial functions, exponential and logarithmic functions), Matrix algebra, Differentiation and Integration, Mathematics of finance, Ratios, Proportions and Percentages, Principle of simple Interest, Principle of compound Interest, Annuities, Loans and Mortgages, Investment decisions, Discrete and continuous variables, Linear equations and inequalities and graphs, Progression of Sequence and Series and their applications in business, Permutations, Combination and their applications in business and finance.

Texts and Recommended books

1. Frank S. *Budnick: Applied Mathematics for Business and Economics and Social sciences*.
2. E. K. Bowen and G. D. Prichett, *Mathematics with applications in Management and Economics*, 6th Edition, McGraw-Hill Inc, 1986.
3. G. Clendenen and S. A. Salzman*, Business Mathematics,* 13th Edition, Pearson, 2014.
4. C. D. Miller, G. Clendenen and S. A. Salzman, *Business Mathematics,* 12th Edition, Pearson, 2011.

Course Code: IR-2310 **Title:** International relations **Credit Hours:** 02

Course Contents: Meaning, Definition, Nature, and Scope of International Relations, Evolution and Development of International Relations, Significance of International Relations, Concept of Nation State, Historical context of contemporary IR, International Relations Theories, International System and Sub-Systems, State and Non-state Actors, IO, IL and NGO, The Concept of War and Peace in International Relations, The Role of Economics in International Relations(IPE), Human Rights in International Relations, Latest/emerging concepts and trends(environment, global health), National Interest, Foreign Policy and Diplomacy, Power and Balance of Power, Regionalism and Globalization.

Texts and Recommended books

1. Karen A. Mingst, and Ivan M. Arreguín-Toft, Essentials of International Relations (London: Oxford Publishers, 2016)
2. Richard Devetak and Jim George, An Introduction to International Relations (Cambridge: Cambridge University Press, 2017)
3. Theodore Columbus, Introduction to International Relations: Power and Justice (New Delhi: Prentice Hall, 1992)
4. Joshua Goldstine, International Relation (Washington DC: Pearson Education, 2003)

5. Mark R. Amstutz, International Conflict and Cooperation: An Introduction to World Politics (Chicago: Brown & Benchmark, 1995)
6. Martin Griffiths, and Terry O'. Callaghan, International Relations: The Key Concepts (London, Rutledge, 2003)
7. Paul Wilkinson, International Relations: A Very Short Introduction (Oxford: Oxford University Press, 2007)

Course Code: LAW-2311. **Title:** Introduction to Law **Credit Hours:** 02

This includes definitions of law, its scope, and its various purposes and functions. Sources of Law, Legal Systems, Legal Theory, Structure of Legal Systems, Islamic Law, Law and Society, Specific Areas of Law, Legal Skills.

Texts and Reference Books

1. About Law" by Tony Honoré
2. "Landmarks in the Law" by Lord Denning
3. "Letters to a Law Student" by Nicholas McBride

Course Code: SOC-2321 **Title:** Introduction to Sociology **Credit Hours:** 02

Course Contents: Introduction: Definition, Scope, and Subject Matter, Sociology as a Science, Historical back ground of Sociology, Basic Concepts, Group, Community, Society, Associations, Non-Voluntary, Voluntary, Organization, Informal, Formal, Social Interaction, Levels of Social Interaction, Process of Social Interaction , Cooperation, Competition, Conflict, Accommodation, Acculturation and diffusion, Assimilation, Amalgamation, Social Groups, Definition & Functions, Types of social groups, In and out groups, Primary and Secondary group, Reference groups, Informal and Formal groups, Pressure groups, Culture, Definition, aspects and characteristics of Culture, Material and non-material culture, Ideal and real culture, Elements of culture, Beliefs, Values, Norms and social sanctions, Organizations of culture, Traits, Complexes, Patterns, Ethos, Theme, Other related concepts, Socialization & Personality, Deviance and Social Control, Collective Behavior.

Texts and Reference Books

1 Anderson, Margaret and Howard F. Taylor. 2001. *Sociology the Essentials*. Australia: Wadsworth.
2 Brown, Ken 2004. *Sociology*. UK: Polity Press
3 Macionis, John J. 2006. 10th Edition *Sociology* New Jersey: Prentice-Hall
4 Tischler, Henry L. 2002. *Introduction to Sociology* 7th Ed. New York: The Harcourt Press.
5 Frank N Magill. 2003. *International Encyclopedia of Sociology*. U.S.A: Fitzroy Dearborn Publishers
6 Macionis, John J. 2005. *Sociology* 10th ed. South Asia: Pearson Education

Semester-IV

Course Code: MATH-2401 **Title:** Abstract Algebra **Credit Hours:** 03

Course Outline: Sets and Structures, Basic Axioms and Order of a Group, Subgroups, Subgroups Generated by Subset of a Group, System of Generators, Cyclic Group, Cosets, Lagrange's Theorem, Permutations, Even and Odd Permutations, Cycles, Lengths of Cycles, Transpositions, Symmetric and Alternating Group, Normalizers and Centralizers of a Subset of a Group, Centre of a Group, Normal Subgroup, Quotient Groups, Conjugacy Relation between Elements and Subgroups, Homomorphism and Isomorphism between Groups, Homomorphism and Isomorphism Theorems,

Texts and Reference Books

1. J. B. Fraleigh, *A First Course in Abstract Algebra*, Addison Wesley, 2002.
2. N. Jacobson, *Basic Algebra*, Vol. 1, W.H. Freeman and Company, 1985
3. S. Lang, *Algebra*, Springer-Verlag, 2002.
4. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, Wiley, 2003.
5. J. A. Gallian, Contemporary abstract algebra, D.C. Heath, 1986.

Course Code: MATH-2402 **Title:** Numerical Methods **Credit Hours:** 03

Course Outline: Computer Arithmetic, Approximations and Errors; Methods for the Solution of Non-Linear Equations and Their Convergence: Bisection Method, Regula-Falsi, Fixed Point Iteration, Newton-Raphson, Secant and Householder's Method, Error Analysis for Iterative Methods Interpolation and Polynomial Approximation: Lagrange Interpolation, Newton's Divided Difference, Forward-Difference and Backward-Difference Formulae, Hermite Interpolation, Numerical Integration and Error Estimates: Rectangular Rule, Trapezoidal Rule, Simpson's One-Three and Three-Eight Rules. Numerical Solution of Systems of Algebraic Linear Equations: Gauss-Elimination Method, Gauss-Jordan Method, Matrix Inversion, LU-Factorization, Doolittle's, Crount's, Cholesky's Methods, Gauss-Seidel and Jacobi Methods, IVP for ODEs: Elementary theory of ivps, Introduction to Single-Step Numerical Methods for solution of ivps, Picard's method, Euler's Method, Second and higher order Taylor's methods, RK-methods (mid-point, modified Euler, Heun's, and RK-4 methods), Multi-Step methods for numerical solutions of odes (2-, 3-, 4-, and 5-step Adam-Bashforth and Adam-Moulton methods), Extension of Euler and RK-4 methods for numerical solutions of higher order odes and system of first order odes.

Texts and Reference Books

1. K. E. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edition, John Wiley and Sons, New York, 1989.
2. R.L. Burden and J.D. Faires, *Numerical Analysis*, 5th Edition, PWS Publishing Company, 1993.
3. S.C. Chapra and R.P. Canale, *Numerical Methods for Engineers*, Mc-Graw Hill, New York, 1988.
4. A. Greenbaum and T. P. Chartier, *Numerical Methods,* 2012 Edition, Princeton University Press, 2012.
5. J. Lambert, *Numerical Methods for Ordinary Differential Systems*, Wiley, 1991.

Course Code: MATH-2403 **Title:** Data Structure and Algorithms **Credit Hours:** 03

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

Understand fundamental data structures like arrays, stacks, queues, and trees. Apply algorithmic techniques to solve sorting, searching, and optimization problems. Analyze the time and space complexity of algorithms for efficiency.

Texts and Reference Books

1.Introduction to Algorithms" by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein
2. Algorithms Unlocked" by Thomas H. Cormen
3. The Algorithm Design Manual" by Steven S. Skiena

Course Code: MATH-2404 **Title:** Ordinary Differential Equations **Credit Hours:** 03

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

Understand SL-boundary value problems and series solution methods. Apply differential equations to model dynamic systems. Analyze the behavior of solutions using phase plane analysis.

Texts and Reference Books

1. W. E. Boyce and R. de Prima, *Elementary Differential Equations*, 9th Edition, Wiley, 2008.
2. E. Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley, 2011.
3. D. G. Zill, *Differential Equations with Boundary-Value Problems,* 8th Edition, Brooks Cole, 2012.
4. S. J. Farlows, *An Introduction to Differential Equations and Their Applications*, Dover Publications, 2006.
5. M. E. Taylor, *An Introduction to Differential Equations,* 14th Edition, American Mathematical Society, 2011.

Course Code: ETRE-2408 **Title:** Entrepreneurship **Credit Hours:** 02

Course Contents: Introduction to Entrepreneurship: Definition and concept of entrepreneurship, Why to become an entrepreneur? Entrepreneurial process, Role of entrepreneurship in economic development. Entrepreneurial Skills: Characteristics and qualities of successful entrepreneurs (including stories of successes and failures), Areas of essential entrepreneurial skill and ability such as creative and critical thinking, innovation and risk taking abilities etc. Opportunity Recognition and Idea Generation: Opportunity identification, evaluation and exploitation, Innovative idea generation techniques for entrepreneurial ventures. Marketing and Sales: Target market identification and segmentation, Four P's of Marketing, Developing a marketing strategy, Branding. Financial Literacy: Basic concepts of income, savings and investments, Basic concepts of assets, liabilities and equity, Basic concepts of revenue and expenses, Overview of cash-flows, Overview of banking products including Islamic modes of financing, Sources of funding for startups (angle financing, debt financing, equity financing etc.). Team Building for Startups: Characteristics and features of effective teams, Team building and effective leadership for startups. Regularity Requirements to Establish Enterprises in Pakistan: Types of enterprises (e.g., sole proprietorship; partnership; private limited companies etc.), Intellectual property rights and protection, Regulatory requirements to register an enterprise in Pakistan, with special emphasis on export firms, Taxation and financial reporting obligation.

Texts and Reference Books

"Entrepreneurship: Successfully Launching new Ventures" by Bruce R. Barringer and R. Duane Ireland.

1. "Entrepreneurship: Theory, Process, and Practice" by Donald F. Kuratko.
2. "New Venture Creation: Entrepreneurship for the 21st Century" by Jeffry A. Timmons, Stephen Spinelli Jr., and Rob Adams.
3. "Entrepreneurship: A Real-World Approach" by Rhonda Abrams.
4. "The Lean startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses" by Eric Ries.

Course Code: CCE-2425 **Title:** Civic and Community Engagement **Credit Hours:** 02

Course Contents: Civics and Citizenship: Concepts of civics, citizenship and civic engagement, Foundations of modern society and citizenship, Types of citizenship: active, participatory, digital, etc. **State, Government and Civil Society:** Structure and functions of government in Pakistan, The relationship between democracy and civil society, Right to vote and importance of political participation and representation. **Rights and Responsibilities:** Overview of fundamental rights and liberties of citizens under Constitution of Pakistan 1973, Civic responsibilities and duties, Ethical considerations in civic engagement (accountability, non-violence, peaceful dialogue, civility, etc.)**. Community Engagement:** Concept, nature and characteristics of community, Community development and social cohesion, Approaches to effective community engagement, Case studies of successful community driven initiatives. **Advocacy and Activism:** Public discourse and public opinion, Role of advocacy in addressing social issues, Social action movements. **Digital Citizenship and Technology:** The use of digital platforms for civic engagement, Cyber ethics and responsible use of social media, Digital divides and disparities (access, usage, socioeconomic, geographic, etc.) and their impacts on citizenship, **Diversity, Inclusion and Social Justice,** Understanding diversity in society (ethnic, cultural, economic, political etc.), Youth, women and minorities' engagement in social development, Addressing social inequalities and injustices in Pakistan, Promoting inclusive citizenship and equal rights for societal harmony and peaceful coexistence.

Texts and Reference Books

1. "Civics Today: Citizenship, Economics, & You" by McGraw-Hill Education.
2. "Citizenship in Diverse Societies" by Will Kymlicka and Wayne Norman.
3. "Engaging Youth in Civic Life" by James Youniss and Peter Levine.
4. "Digital Citizenship on Action: Empowering Student to Engage in Online Communities" by Kristen Mattsen.
5. "Globalization and Citizenship: In the Pursuit of a Cosmopolitan Education" by Graham Pike and David Selby.
6. "Community Engagement: Principles, Strategies, and Practices" by Becky J. Feldpausch and Susan M. Omilian.
7. "Creating Social Change: A Blueprint for a better world" by Matthew Clarke and Marie-Monique Steckel.

Course Code: UHQ-2430 **Title:** Understanding of Holy Quran-II **Credit Hours:** 01

Course Outline:

Weeks	Lectures	Units	Lessons	Assignments/Home Task	
1.	1.	6	6	Understanding & Translation of Verses	Present Tense صيغة جمع مذكر غائب مثل يعبدون
	2.	6	7-8	Understanding & Translation of Verses	Present Tense صيغة جمع مذكر غائب مثل يعبدون
2.	1.	6	9-10	Understanding & Translation of Verses	Present Tense صيغة مفرد مذكر مخاطب (تعبد) وجمع مذكر مخاطب (تعبدون)
	2.	6	11-12	Understanding & Translation of Verses	Present Tense صيغة جمع مذكر مخاطب (تعبدون)
					المتكلم (أعبد)صيغة
3.	1.	6	13	Understanding & Translation of Verses	Present Tense صيغة جمع المتكلم (نعبد)
	2.	6	14-15	Understanding & Translation of Verses	Negative Imperative صيغة المفرد وصيغة الجمع لا تعبدْ، لا تعبدوا
4.	1.	6	16-17	Understanding & Translation of Verses	Conditional Sentences & masdar moawal (موؤل مصدر)
	2.	6	18-19	Understanding & Translation of Verses	Laam uttaleel (التعليل لام) & Laam ul jhood(الجحود لام)
5.	1.	6	20-21	Understanding & Translation of Verses	Present with object pronouns & Passive Voice
	2.	6	Revision (Unit 6)		
6.	1.	Unit 7	1 (sec 1-3)	Understanding & Translation of Verses	Past Tense الغائب المفرد صيغة
	2.	6	1 (Sec 4-5)	Understanding & Translation of Verses	Past Tense المفرد غائبللصيغة
7.	1.	6	1 (Sec 5-6)	Understanding & Translation of Verses	Past Tense للغائب المفرد صيغة
	2.	6	1 (Sec 7-9)	Understanding & Translation of Verses	Past Tense للغائب المفرد صيغة
8.	1.	7	Revision	Understanding & Translation of Verses	Past Tense للغائب المفرد صيغة
9.				Understanding & Translation of Verses	Past Tense للغائب الجمع صيغة ا عبدو
				Understanding & Translation of Verses	Past Tense للغائب الجمع صيغة ا عبدو

10.	1.	7	2 (sec 4-5)	Understanding & Translation of Verses	Past Tense للغائب الجمع صيغة ا عبدو
	2.	7	2 (sec 6-7)	Understanding & Translation of Verses	Past Tense للغائب الجمع صيغة ا عبدو
11.	1.	7	3 (sec 1-2)	Understanding & Translation of Verses	Past Tense للمتكلم الجمع صيغة ا عبدن
	2.	7	3 (sec 2-3)	Understanding & Translation of Verses	Past Tense للمتكلم الجمع صيغة ا عبدن
12.	1.	7	3 (sec 3-4)	Understanding & Translation of Verses	Past Tense للمتكلم الجمع صيغة ا عبدن
	2.	7	3 (sec 4-5)	Understanding & Translation of Verses	Past Tense للمتكلم الجمع صيغة ا عبدن
13.	1.	7	4 (sec 1-2-3)	Understanding & Translation of Verses	Past Tense للمخاطب الجمع صيغة م عبدت
	2.	7	4 (sec 4-5)	Understanding & Translation of Verses	Past Tense الجمع للمخاطبصيغة م عبدت
14.	1.	7	5-6	Understanding & Translation of Verses	Past Tense دبع ت ةغيص ملكتملا بطاخملاو دبع ت ،
	2.	7	7	Understanding & Translation of Verses	Past Tense ةغيص ثنؤملا بئاغلل بع د تْ
15.	1.	7	8	Understanding & Translation of Verses	Passive Voice (Past Tense) للمفرد مجهول فعل
	2.	7	9	Understanding & Translation of Verses	Passive Voice (Past Tense) الجمع مجهول فعل
16.	1.	8	1-4	Understanding & Translation of Verses	Imperative Verb for singular فعل للمفرد الأمر
	2.	7	5-8	Understanding & Translation of Verses	Imperative Verb for plural الأمرفعل للجمع

Texts and Reference Books

Course Book: Muallim ul Quran (Volume 3, 4 & 5) by Dr Ubaid ur Rahman
Helping Material:
Paper book: All volumes are available in printed book form.
Tutorial videos: Teaching video of each lesson available on YouTube.
Confirmation Videos: A complete series of confirmation videos of all lessons is available in which the student can confirm his answers.
A flipbook: A flipbook edition is also accessible.
Helping material: Helping material for the teachers like quizzes, question papers and images is available on website.

Semester-V

Course Code: MATH-3501 **Title:** Real Analysis-I **Credit Hours: 03**

Course Outline: Supremum and Infimum, Completeness Properties of the Real Numbers, Limits and Continuity, Properties of Continuous Functions on Closed Bounded Intervals, Derivatives in One Variable, The Mean Value Theorem, Sequences and Series of Functions, Power Series, Pointwise and Uniform Convergence, Riemann Integrations

Texts and Reference Books

1. H. L. Royden, *Real Analysis*, Mc-Millan Publishing Company, Inc., New York, 1968.
2. W. Rudin, *Principles of Real Analysis,* Mc-Graw Hill, 1995.
3. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd Edition, John Wiley and Sons, 1999.
4. R. L. Brabenec, *Introduction to Real Analysis*, PWS Publishing Company, 1994.
5. E. D. Gaughan, *Introduction to Analysis*, 5th Edition, Brooks/Cole, 1997.

Course Code: MATH-3502 **Title:** Topology **Credit Hours:** 03

Course Outline: Overview of Metric Spaces, Convergence, and Continuity in Metric Spaces, Topological Spaces, Sub-Spaces, Closed Sets, Closures and Interiors of Sets, Boundary of a Set, Limit Point, Bases and Sub-bases, Neighborhood Base, First and Second Countable Spaces, Continuous Functions and Homeomorphism, Product Topology

T_0, T_1, T_2 Spaces and Their Characterizations and Basic Properties, Regular and Completely Regular Spaces, Normal and Completely Normal Spaces

Compact / Countable Spaces and Their Properties, Connected Spaces

Texts and Reference Books

1. C. W. Patty, *Foundation of Topology*, 2nd Edition, The Jones and Bartlett Publishers, 2009.
2. J. Dugundji, *Topology,* W.M. C. Brown Publisher, 1990.
3. J. R. Munkres, *Topology: A First Course in Topology,*2nd Edition, Prentice Hall Inc. Englewood Cliffis, New Jessy, 2005.
4. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata Mc-Graw Hill, 1963.
5. Munkres, *Topology,* 2nd Edition, Pearson India, 2015.

Course Code: MATH-3604 **Title:** Advanced Programming **Credit Hours**: **2+1**

Course Outline (Matlab, Maple, Mathematica)**:** A list of contents is given below. However, the instructor may add or remove some of the contents depending on the need of the students.

Curve sketching (only graphs of functions of one variable in Cartesian Coordinates) by using standard procedure, Intro to MATLAB (history, installation, interface, using product help, etc), MATLAB vs Maths syntax, sketching plane curves and sufaces in MATLAB, use of MATLAB in linear algebra, symbolic computations using MATLAB, creating script and function m-files, MATLAB codes for Bisection, Newton-Raphson, secant, Regula-Falsi, Jacobi, GS, Trapezoidal, Simson, Interpolation methods, Euler, and RK-4 methods. A brief introduction to Maple/Mathematica, comparison between similar features of MATLAB and Maple/Mathematica.

The following points are important for teaching this course:

1. The course should be taught in a computer lab setting
2. At the completion of this course, the students must be able to utilize the software to solve computationally difficult problems
3. The students should have a good command on at least two of the three programs mentioned above

Texts and Reference Books

1. T. Salahuddin, Numerical Techniques in MATLAB, CRC, 2024.
2. D. M. Etter, D. Kuncicky and D. Hull, *Introduction to Matlab-6*, Prentice Hall, 2001.

Course Code: MATH-3605 **Title:** Introduction to Mechanics **Credit Hours:** 03

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

Understand the basic principles of statics and dynamics in mechanical systems. Apply the laws of motion to solve problems involving forces, energy, and momentum. Analyze mechanical systems and predict their behavior under different conditions.

Texts and Reference Books:

1. A. Bedford and W. Fowler, *Dynamics Engineering Mechanics*, Addision-Wesley, Reading, USA.
2. T. L. Chow, *Classical Mechanics*, John Wiley and Sons, New York, 1995.
3. H. Goldstein, *Classical Mechanics*, 2nd Edition, Addison Wesley, Reading, Ma, USA, 1980.
4. J. B. Marion, *Classical Dynamics of Particles and Fields*, 2nd Edition, Academic Press, New York, 1970.
5. J. R. Taylor, *Classical Mechanics*, University Science Books, 2005.

Course Code: MATH-3503 **Title:** Partial Differential Equation **Credit Hours:** 03

Course Outline: First order PDEs: Introduction, formation of PDEs, solutions of PDEs of first order, The Cauchy's problem for quasilinear first order PDEs, First order nonlinear equations, Special types of first order equations, **Second order PDEs:** Basic concepts and definitions, Mathematical problems, Linear operators, Superposition, Mathematical models: The classical equations, the vibrating string, the vibrating membrane, conduction of heat solids, canonical forms and variable, PDEs of second order in two independent variables with constant and variable coefficients, Cauchy's problem for second order PDEs in two independent variables

Methods of separation of variables and Green's Functions: Solutions of elliptic, parabolic and hyperbolic PDEs in Cartesian and cylindrical coordinates

Texts and Reference Books

1. P. Duchaure and D. Zachmann, *Partial Differential Equations*, Mc-Graw Hill, 1986.
2. J. Fritz, *Partial Differential Equations*, Spriger-Verlag, New York, 19.
3. R. Haberman, *Elementary Applied Partial Differential Equations*, Prentice Hall Inc., 1983.
4. M. Humi and W.B. Miller, *Boundary Value Problems and Partial Differential Equations*, PWS-Kent Publishing Company, Bostan, 1992.
5. E. Zauderer, *Partial Differential Equations of Applied Mathematics*, John Wiley and Sons, Englewood Cliff, New York, 1983.

Semester-VI

Course Code: MATH-3601 **Title:** Real Analysis-II **Credit Hours:** 03

Course Outline: The Riemann-Stieltjes Integrals: Definition and existence of integrals. Properties of integrals. Fundamental theorem of calculus and its applications. Change of variable theorem. Integration by parts. **Functions of Bounded Variation:** Definition and examples. Properties of functions of bounded variation. **Improper Integrals:** Types of improper integrals, tests for convergence of improper integrals. Beta and gamma functions. Absolute and conditional convergence of improper integrals. **Sequences and Series of Functions:** Power series, definition of point-wise and uniform convergence. Uniform convergence and continuity. Uniform convergence and differentiation. Examples of uniform convergence.

Texts and Reference Books

1. H. L. Royden, *Real Analysis*, Mc-MillanPublishing Company, Inc., New York, 1968.
2. W. Rudin, *Principles of Mathematical Analysis*, Mc-Graw Hill, New York, 1987.
3. T. M. Apostol, *Mathematical Analysis*, 6th Edition, Addison Wesley, 1982.
4. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd Edition, John Wiley and Sons, 1999.
5. S. Lang, *Real Analysis*, Springer-Verlag, London, 1987.

Course Code: MATH-3602 **Title:** Complex Analysis **Credit Hours:** 03

Course Outline: The Algebra and the Geometry of Complex Numbers, Complex Functions, Parametric Curves in the Complex Plane, Linear Mappings, Special Power Functions, Reciprocal Functions, Limit and Continuity, Complex Functions as Vector Fields, Derivative, Analytic Functions, Cauchy-Riemann Equations, Complex Exponential, Logarithmic, Trigonometric, Hyperbolic Functions and Their Derivatives, Harmonic Functions, Contour Integrals, the Cauchy-Goursat Theorem, Cauchy Integral Formulas, the Morera Theorem, Maximum Modulus Principle, The Liouville Theorem, Fundamental Theorem of Algebra, Convergence of Sequences and Series, The Taylor and the Laurent Series, Uniqueness of Representation, Zeros of Analytic Functions Residues, Poles and the Residue Theorem, Evaluation of Improper Integrals, Integrals Around a Branch Point, The Argument Principle and the Rouche's Theorem

Texts and Reference Books

1. R.V. Churchill and J.W. Brown, *Complex Variables and Applications*, 5th Edition, Mc-Graw Hill, New York, 1989.
2. E. Hille, *Analytic Function Theory*, Vol. I and II, Chelsea Publishing Company, New York, 1974.
3. J. E. Marsden, *Basic Complex Analysis*, W. H. Freeman and Company, 1982.
4. D. G. Zill, and P. D. Shanahan, *A First Course in Complex Analysis with Applications*, Jones and Bartlet Publishers, Sudbury, Massachusetts, 2008.
5. L. V. Ahlfors, *Complex Analysis,* 3rd Edition, McGraw Hill Education (India) Private Limited, 2013.

Course Code: MATHS-3603 **Title:** Introduction Machine Learning **Credit Hours:** 2+1
Course Outline: By the end of this course, the students will be able to:
Understand the key concepts of supervised, unsupervised, and reinforcement learning. Apply machine learning algorithms to analyze data and make predictions.
Analyze the performance and limitations of machine learning models.
Texts and Reference Books

1. Mathematics for Machine Learning, Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Cambridge University Press 2020.
2. Hand on Machine Learning with Scikit-Learn and Tensor Flow, Aurelien Geron, O'Reilly Media, 2017.
3. Machine Learning: An Algorithmic Perspective, Stephen Marsland, CRC Press, Ist Edition 2015.

Course Code: MATH-3604 **Title:** Introduction to Classical Mechanics **Credit Hours:** 03
Course Contants: By the end of this course, the students will be able to:
Understand Newton's laws of motion and their applications to mechanical systems. Apply Lagrangian and Hamiltonian mechanics to solve advanced dynamics problems. Analyze the conservation of energy and momentum in physical systems.

Texts and Reference Books:

6. A. Bedford and W. Fowler, *Dynamics Engineering Mechanics*, Addision-Wesley, Reading, USA.
7. T. L. Chow, *Classical Mechanics*, John Wiley and Sons, New York, 1995.
8. H. Goldstein, *Classical Mechanics*, 2nd Edition, Addison Wesley, Reading, Ma, USA, 1980.
9. J. B. Marion, *Classical Dynamics of Particles and Fields*, 2nd Edition, Academic Press, New York, 1970.
10. J. R. Taylor, *Classical Mechanics*, University Science Books, 2005.

Course Code: MATH-3505 **Title:** Vector and Tensor Analysis **Credit Hours:** 03
Course Outline: Algebra of vectors, Geometry of vectors, Vector differentiation and integration, Gradient, divergence and curl, line, surface and volume integrals, curvilinear coordinates, Introduction to general tensors, Summation Convention, Kronecker Delta, Levi-Civita Symbol, Vectors as Quantities Transforming Under Rotations with Notation, The Spherical-Polar and the Cylindrical-Coordinate Meshes, Alternating Symbol, Relation between Alternating Symbol and Kronecker Delta, Tensors of First, Second and Higher Orders, Algebra of Tensors, Contraction of Tensor, Quotient Theorem, Symmetric and Skew-Symmetric Tensors, Invariance Property, Isotropic Tensors, Differentiation of Tensors, Application of Tensors in Modeling Anisotropic Systems, Study of Physical Tensors, Diagonalization of Inertia Tensor as Aligning Coordinate Frame with Natural Symmetries of the System.

Texts and Reference Books

1. D.E. Bourne and P.C. Kendall, *Vector Analysis and Cartesian Tensors*, 2nd Edition, Thomas Nelson, 1977.
2. G. E. Hay, *Vector and Tensor Analysis*, Dover Publications, Inc., New York, 1979.
3. N.A. Shah, *Vector and Tensor Analysis*, A-One Publishers, Lahore, 2005.
4. S. Sokolnikoff, *Tensor Analysis: Theory and Application*, John Wiley and Sons, New York, 1951.
5. J. L. Synge and A. Schild, *Tensor Calculus*, Courier Dover Publications, 1978.

Semester-VII

Course Code: MATH-4703 **Title:** Differential Geometry **Credit Hours:** 03
Course Outline: Historical Background, Motivation and Applications, Index Notation and Summation Convention, Space Curves, The Tangent Vector Field, Reparametrization; Arc Length, Curvature, Principal Normal, Binormal, Torsion, The Osculating, The Normal and the Rectifying Planes, The Frenet-Serret Theorem, Spherical Images, Sphere Curves, Spherical Contacts, Fundamental Theorem of Space Curves, Line Integrals and Green's Theorem, Local Surface Theory, Coordinate Transformations, The Tangent and the Normal Planes, Parametric Curves, The First Fundamental Form and the Metric Tensor, Normal and Geodesic Curvatures, Gauss's Formulae, Christoffel Symbols of First and Second Kinds, Parallel Vector Fields Along a Curve and Parallelism, The Second Fundamental Form and the Weingarten Map, Principal, Gaussian, Mean and Normal Curvatures, DupinIndicatrices, Conjugate and Asymptotic Directions, Isometries and the Fundamental Theorem of Surfaces

Texts and Reference Books

1. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice Hall, 1976.
2. A. Goetz, *Introduction to Differential Geometry*, Addison Wesley, 1970.
3. R. S. Millman and G. D. Parker, *Elements of Differential Geometry*, Prentice Hall, 1977.
4. A. N. Pressley, *Elementary differential geometry*, 2nd Edition, Springer-Verlag, 2012.
5. D. J. Struik, *Lectures on Classical Differential Geometry*, Addison Wesley, Massachusetts, 1977.

Course Code: MATH-4707 **Title:** Mathematical Physics **Credit Hours:** 03

Course Outline: Definition and Properties of Laplace and Inverse Laplace Transforms, s-shifting property of LT, existence and uniqueness theorem, LT of derivatives and integrals and solution of ivps, unite step function and t-shifting property of LT, solution of circuit problems by using LT, Dirac Delta Function and its properties, LT of periodic functions, Convolution Theorem, Convolution of discontinuous functions, solution of integral equations by LT, differentiation and integration of LT, Laguerre's equation and polynomials, Applications of Laplace Transforms to systems of ODEs and PDEs, Fourier Series of 2pi and 2L periodic functions, Convergence and sum of FS, even and odd functions and half-range expansions of FS, solution of odes and pdes by using FS, Fourier Integrals, Fourier Sine and Cosine integrals, Fourier sine and cosine transforms, Fourier sine and cosine transforms of derivatives, existence of FT, FT of derivatives, Convolution theorem, Discrete and Fast Fourier Transforms, solution of odes and pdes by using FT.

Texts and Reference Books

1. E. Kreyszig, *Advanced Engineering Mathematics,* 10th Edition, Wiley, 2011.
2. E. L. Butkov, *Mathematical Physics*, Addison Wesley, 1973.
3. R. P. Kanwal, *Linear Integral Equations*, Academic Press, 1971.
4. T. Myint-U and L. Denbnath, *Partial Differential Equations*, Elsevier Science Publishing, 1987.
5. I. Stakgold, *Boundary Value Problems of Mathematical Physics*, Vol. II, Mc-MillanPublishing Company, Inc., New York, 1968.

Course Code: MATH-4704 **Title:** Functional Analysis **Credit Hours:** 03

Course Outline: Definition and Examples of Normed Spaces, Banach Spaces, Characterization of Banach Spaces, Bounded Linear Transformations, Bounded Linear Operators, Functional and Their Examples, Various Characterization of Bounded (Continuous) Linear Operator, The Space of All Bounded Linear Operators, The Open Mapping and Closed Graph Theorems, The Dual (Conjugate) Spaces, Reflexive Spaces, Hahn-Banach Theorem (Without Proof), Some Important Consequences of the Hahn- Banach Theorem. Inner Product Spaces, Hilbert Spaces, Orthonormal Bases, Convexity in Hilbert Spaces, Operators in Hilbert Spaces, Invariant Sub-Spaces, Decomposition of Hilbert Spaces, Finite Dimensional Spectral Theory and Spectral Mapping Theorem.

Texts and Reference Books

1. E. Kreyszig, *Introductory Fundamental Analysis with Applications,* John Wiley and Sons, 1978.
2. I. J. Maddox, *Elements of Functional Analysis*, Cambridge University Press, 1970.
3. W. Rudin, *Functional Analysis*, Mc-Graw Hill, 1983.
4. G. F. Simmon, *Introduction to Topology and Modern Analysis*, Mc-Graw Hill, New York, 1983.
5. J. Muscat, *Functional Analysis*, 2014 Edition, Springer, 2014.

Course Code: MATH-4709 **Title:** Measure Theory **Credit Hours:** 03

Course Outline: Definition and Examples of Algebra and σ-Algebra, Basic Properties of Measurable Spaces, Definition and Examples of Measure Spaces, Outer Measure, Lebesgue Measure, Measurable Sets, Complete Measure Spaces

Measurable Functions: Some Equivalent Formulations of Measurable Functions, Examples of Measurable Functions, Various Characterizations of Measurable Functions, Properties that Hold Almost Everywhere

Definition of Lebesgue Integral, Basic Properties of Lebesgue Integrals, Comparison between Riemann Integration and Lebesgue Integration, L_2-Spaces

Texts and Reference Books

1. D. L. Cohn, *Measure Theory*, Birkhauser, 1980.
2. P. R. Halmos, *Measure Theory*, D. Van Nostrand, 1950.
3. H. L. Royden, *Real Analysis*, Mc-MillanPublishing Company, Inc., New York, 1968.
4. T. Tao, *An Introduction to Measure Theory,* American Mathematical Society, 2011.
5. P. R. Halmos, *Measure Theory,* 2nd Edition, Springer, 1978.

Course Code: MATH-4706 **Title:** Numerical Methods-II **Credit Hours:** 03

Course Outline: Stability, consistency, and convergence of SS and MS methods, stiff odes, region of absolute stability and A-Stability,

BVPs for odes: Discussion on Problem Behavior and Stability, Shooting method and finite difference methods for Linear and Non-Linear BVPs, Rayleigh-Ritz method for Linear and Non-Linear BVPs.

Texts and Reference Books

1 U. Ascher and L. Petzold, *Computer Methods for ODEs and DAEs*, SIAM, 1998.
2 R.L. Burden and J.D. Faires, *Numerical Analysis*, 5th Edition, PWS Publishing Company, 1993.
3 U. Ascher, R. Matteij and R. Russell, *Numerical Solution of BVPs for ODEs*, Prentice Hall, 1988.
4 J. Lambert, *Numerical Methods for Ordinary Differential Systems*, Wiley, 1991.
5 A. Greenbaum and T. P. Chartier, *Numerical Methods,* 2012 Edition, Princeton University Press, 2012.

Course Code: MATH-4705 **Title:** Fluid Mechanics-I **Credit Hours:** 03

Course Outline: Fields and Continuum Concepts, Lagrangian and Eulerian Specifications, Local, Convective and Total Rates of Change, Conservatoin of Mass, Equation of Continuity, Boundary Conditions, Nature of Force in a Fluid Field and Their Effects: Surface and Body Forces, Stress at a Point, Viscosity and Newton's Viscosity Law, Viscous and Inviscid Flows, Laminar and Turbulent Flows, Compressible and Incompressible Flows

Irrotational Fluid Motion: Velocity Potential from an Irrotational Velocity Field, Streamlines. Vortex Lines and Vortex Sheets, Kelvins Minimum Energy Theorem, Conservation of Linear Momentum, Bernoullis Theorem and Its Applications, Circulations, Rate of Change of Circulation (Kelvins Theorem), Axially Symmetric Motion, Stokes Stream Function

Two-Dimensional Motion: Stream Function, Complex Potential and Complex Velocity, Uniform Flows, Sources, Sinks and Vortex Flows, Flow in a Sector, Flow Around a Sharp Edge, Flow Due to a Doublet

Texts and Reference Books

1. I. G. Curie, *Fundamentals of Mechanics of Fluids*, 3rd Edition, CRC, 2002.
2. I. L. Distsworth, *Fluid Mechanics*, Mc-Graw Hill, 1972.
3. R.W. Fox, A.T. Mc-Donald and P.J. Pritchard, *Introduction to Fluid Mechanics*, John Wiley and Sons, 2003.
4. H. Schlichting, K. Gersten, E. Krause and H. Oertel, Jr, *Boundary-Layer Theory*, 8th Edition, Springer-Verlag, 2004.
5. Y. C-Shun, *Fluid Mechanics*, Mc-Graw Hill, 1974.

Course Code: MATH-4708 **Title:** Number Theory and Metric Spaces **Credit Hours:** 03

Course Outline: Divisibility, Euclidean Algorithm, GCD and LCM of two Integers, Properties of Prime Numbers, Fundamental Theorem of Arithmetic (UFT), Congruence Relation, Residue System, Euler's Phi-Function, Solution of System of Linear Congruence, Congruences of Higher Degree, Chinese Remainder Theorem, Fermat's Little Theorem, Wilson's Theorem and Applications, Primitive Roots and Indices, Integers Belonging to a Given Exponent (mod p), Primitive Roots of Prime and Composite Moduli, Indices.

Preliminary Concepts, Definition and Examples of Metric Spaces, Open and Closed Spheres and Sets, Convergent Sequences, Cauchy Sequences, Cantor's Intersection Theorem, Complete Metric Spaces, Dense and Nowhere Dense Subsets, Continuous and Uniform Continuous Functions and Their Properties,

Texts and Reference Books

1. C. W. Patty, *Foundation of Topology*, 2nd Edition, The Jones and Bartlett Publishers, 2009.
2. J. Dugundji, *Topology,* W.M. C. Brown Publisher, 1990.
3. E. Kreyszig, *Introductory Fundamental Analysis with Applications,* John Wiley and Sons, 1978.
4. M. O. Searcoid, *Metric Spaces*, 2007 Edition, Springer, 2006.
5. P. K. Jain, *Metric Spaces,* 2nd Edition, Alpha Science Intl Ltd, 2004.
6. G. A. Jones and J. M. Jones, *Elementary Number Theory*, Springer-Varlog, London Limited, 1998.
7. M. B. Nathanson, *Methods in Number Theory*, Springer-Verlag, New York, 2000.
8. A.N. Parshin and I.R. Shafarevich, *Number Theory-I, Fundamental Problems, Ideas and Theories*, Springer-Veriag, Berlin Heidelberg, 1995.
9. K. H. E. Rosen, *Elementary Number theory and its Applications*, 4th Edition, Addison Wesley, Reading, Ma, USA, 2000.
10. T. Andreesco and D. Andrica, *Number theory,* 2009 Edition, Birkhauser*,* 2009.

Course Code: MATH-4710 **Title:** Discrete Structures **Credit Hours:** 03

Course Outlines: Set and Relations:Basic Notions, Set Operations, Venn Diagrams, Extended-Set Operations, Indexed Family of Sets, Countable and Uncountable Sets, Relations, Cardinality, Equivalence Relations, Congruence, Partitions, Partial Order, Representation of Relations, Mathematical Induction

Elementary Logic:Logics of Order Zero and One, Propositions and Connectives, Truth Tables, Conditionals and Bi-Conditionals, Quantifiers, Methods of Proof, Proofs Involving Quantifiers

Texts and Reference Books

1. K. H. Rosen, *Discrete Mathematics and its Applications*, 12thEdition, Mc-Graw Hill, New York, 1999.
2. K. A. Ross and C. R. B. Wright, *Discrete Mathematics*, Prentice Hall, Englewood Cliffs, NJ, USA, 2003.
3. H. Fell and J. A. Aslam, *Discrete Structures,* 5th Edition, Cognella Academic Publishing, 2016.
4. S. S. Epp, *Discrete Mathematics with Applications,* 4th Edition, Brooks Cole, 2010.
5. B. Kolman and R. C. Busby, *Discrete Mathematical Structures,* 6th Edition, Pearson, 2017.

Course Code: MATH-4711 **Title:** Special Functions **Credit Hours:** 03

Course Outline: Infinite Products: introduction, Definition of an infinite product, A necessary condition for convergence, Associated series of logarithms, Convergences types, The Gamma and Beta Functions: The Euler constant, The Gamma function, A series for logarithmic differential of Gamma function, The order symbols o and O, Evaluation of certain infinite products,The Beta Function, Factorial function, Asymptotic Series: Definition of an asymptotic expansion, Algebraic properties, Term by term integration, Uniquenesss, The Hypergeometric function : Simple integral form, The function F(a,b;c,z) and its properties, The Hypergeometric differential equation, Logarithmic solution of the hypergeometric function, F(a,b;c,z) as a function of parameters, Elementary series manipulation, Kummer Theorem, Generalized Hypergeometric functions, the exponential and binomial functions, A differential equation,Saalschutz theorem, Contour integral integrals of Barnes' type, the Barnes integrals

and the generalized hypergeometric function, Bessel Functions and its properties, The Confluent Hypergeometric unctions and its properties, Generating Functions.

Texts and Reference Books

1. E. D. Rainville, *Special Funcgions*, 1st Edition, The Macemillean Company New York, 1965.
2. L. J. Slater, and D. Lit, *Confluent Hyper Geometric Functions*, Cambridge University Press, London, 1960.
3. A. Erdeyli, *Higher Transcendental Functions*, Volume I, II, & III, McGraw Hill Book Company, Inc. 1953.
4. J. E. Andrews, R. Asky and R. Roy, *Special Functions,* 1st Edition, Cambridge University Press, 2001.
5. C. Viola, *Special Functions,* 1st Edition, Springer, 2016.

Course Code: MATH-4712 **Title:** Quantum Mechanics-I **Credit Hours:** 03

Course Outline: Black Body Radiation, Photoelectric Effect, Compton Effect, Bohr's Theory of Atomic Structure, Wave-Particle Duality, The De Broglie Postulate, Heisenberg Uncertainty Principle, The Postulates of Quantum Mechanics, Operators, Eigen-functions and Eigenvalues: Observables and Operators. Measurement in Quantum Mechanics, The State Function and Expectation Values Time, Development of the Stat Function (Schrodinger Wave Equation), Solution to the Initial-Value Problem in Quantum Mechanics, Parity Operators

Function Spaces and Hermitian Operators: Particle in a Box, Dirac Notation, Hilbert Space. Hermitian Operators, Properties of Hermitian Operators, Additional One-Dimensional Problems: Bound and Unbound States: General Properties of the One Dimensional Schrodinger Equation, Unbound States, One-Dimensional Barrier Problems, The Rectangular Barrier, Tunneling

Texts and Reference Books

1. D. R. Bes, *Quantum Mechanics: A Modern a Concise Introductory Course*, Springer-Verlag, 2004.
2. H. D. Dehmen, *The Picture Book of Quantum Mechanics*, Springer-Verlag, 2001.
3. H. F. Hameks, *Quantum Mechanics: A Conceptual Approach*, Wiley- IEEE, 2004.
4. R. L. Liboff, *Introduction Quantum Mechanics*, Addison Wesley Publishing Co., 2003.
5. V. K. Thankappan, *Quantum Mechanics*, New Age Publishers, 1993.

Course Code: MATH-4713 **Title:** Ring Theory **Credit Hours:** 03

Course Outline: Rings: Definition, examples. Quadratic integer rings. Examples of non-commutative rings. The Hamilton quaternions. Polynomial rings. Matrix rings. Units, zero-divisors, nilpotents, idempotents. Subrings, Ideals. Maximal and prime Ideals. Left, right and two-sided ideals;.

Operations with ideals. The ideal generated by a set. Quotient rings. Ring homomorphism. The isomorphism theorems, applications. Finitely generated ideals. Rings of fractions.

Integral Domain: The Chinese remainder theorem. Divisibility in integral domains, greatest common divisor, least common multiple. Euclidean domains. The Euclidean algorithm. Principal ideal domains. Prime and irreducible elements in an integral domain. Gauss lemma, irreducibility criteria for polynomials. Unique factorization domains. Finite fields. Polynomials in several variables. Symmetric polynomials. The fundamental theorem of symmetric polynomials.

Texts and Reference Books

1. J. B. Fraieigh, *A First Course in Abstract Algebra*, Addison Wesley, 2002.
2. B. Hartley and T. O. Hawkes, *Ring, Modules and Linear Algebra*, Chapman and Hall, 1980.
3. S. Lang, *Algebra*, Springer-Verlag, 2002.
4. S. J. Leon, *Linear Algebra with Applications*, 6th Edition, Prentice Hall, 2002.
5. P. M. Cohn, Introduction to *Ring Theory,* 1st Edition, Springer, 2002.

Course Code: MATH-4714 **Title:** Analytical Dynamics **Credit Hours:** 03

Course Outline: Constraints, Generalized Coordinates, Generalized Forces, General Equation of Dynamics, Lagrange's Equations, Conservation Laws, Ignorable Coordinates, Explicit Form of Lagrange's Equation in Terms of Tensors. Hamilton' Principle of Least Action, Hamilton's Equations of Motion, Hamilton-Jacobi Method, Poisson Brackets (P.B's); Poisson's Theorem; Solution of Mechanical Problems by Algebraic Technique Based on (P.B's) Small Oscillations and Normal Modes, Vibrations of Strings, Transverse Vibrations Normal Modes, Forced Vibrations and Damping, Reflection and Transmission at a Discontinuity, Longitudinal Vibrations, Rayleigh's Principle

Texts and Reference Books

1. F. Chorlton, *Textbook of Dynamics*, Van Nostrand, 1963.
2. W. Chester, *Mechanics*, George Allen and Unwin Ltd. London, 1979.
3. H. Goldstein, *Classical Mechanics*, Cambridge University Press, 1980.
4. G. Meirovitch, *Methods of Analytical Dynamics*, Mc-Graw Hill, 1970.
5. H. Baruh, *Analytical Dynamics,* 1st Edition, WCB/McGraw-Hill, 1998.

Course Code: MATH-4715 **Title:** Approximation Theory **Credit Hours:** 03

Course Outline: Best Approximations in Normal Spaces, Existence Theorem, Approximation by Algebraic Polynomials, Uniqueness, Strict Convexity, Lemma Convexity, Uniqueness Theorem, Hilbert Space, Uniform Approximation, External Point, Haar Condition, Extreme Points, Best Approximation, Characterization of Best Approximation, A Brief Introduction to Interpolation, Chebyshev Polynomials, Chebyshev Theorem, Least Squares Approximation, Gram-Schmidt Orthonormalization Process, Orthogonal Function, Pade Approximation, Remex Algorithm

Texts and Reference Books

1. N. I. Achieser, *Theory of approximation*, Dover Publications, Inc., New York, 2004.
2. J. R. Rice, *The Approximation of Functions*, Vol. I, Addison Wesley Publishing Company, 1964.
3. T. J. Rivlin, *An Introduction to the Approximation of Functions*, Dover Publications, Inc., New York, 1981.
4. M. J. D. Powell, *Approximation Theory and Methods*, Cambridge University Press, 1988.
5. E. W. Cheney, *Introduction to Approximation Theory*, AMS, 2000.

Course Code: MATH-4716 **Title:** Differential Geometry-II **Credit Hours:** 03

Course Outline: Definition and Examples of Manifolds, Differential Maps, Sub-Manifolds, Tangents, Coordinate Vector Fields, Tangent Spaces, Dual Spaces, Multi-Linear Functions, Algebra of Tensors, Vector Fields, Tensor Fields, Integral Curves, Flows, Lie Derivatives, Brackets, Differential Forms, Introduction to Integration Theory on Manifolds, Riemannian and Semi-Riemannian Metrics, Flat Spaces, Affine Connections, Parallel Translations, Covariant Differentiation of Tensor Fields, Curvature and Torsion Tensors, Connection of a Semi-Riemannian Tensor, Killing Equations and Killing Vector Fields, Geodesics, Sectional Curvature

Texts and Reference Books

1. R. Abraham, J. E. Marsden and T. Ratiu, *Manifolds, Tensor Analysis and Applications*, Addison Wesley, 1983.
2. R. L. Bishop and S. I. Goldberg, *Tensor Analysis on Manifolds*, Dover Publications, Inc., New York, 1980.
3. M. P. Do Carmo, *Riemannian Geometry*, Birkhauser, 1992.
4. D. Langwitz, *Differential and Riemannian Geometry*, Academic Press, 1970.
5. E. Kreysizg, *Differential Geometry,* 1st Edition, Dover Publications, 1991.

Course Code: MATH-4717 **Title:** Electromagnetic Theory-I **Credit Hours:** 03

Course Outline: Electromagnetic Fields, Coulomb's Law, The Electric Field Intensity and Potential, Gauss's Law and Deductions, Piosson and Laplace Equations, Conductors and Condensers, Dipoles, The Linear Quadrupole, Potential Energy of a Charge Distribution, Dielectrics, The Polarization and Displacement Vectors, General Solutions of Laplace's Equation. Solutions of Laplace's Equation in Spherical Coordinates, Legendre's Equation, Legendre's Polynomials, Electromagnetic 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 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.

Texts and Reference Books

1. D. Corrisonand P. Lorrison, *Introduction to Electromagnetic Fields and Waves*, W.H. F. and company, London, 1962.
2. D. J. Griffiths, *Introduction to Electrodynamics*, Prentice-Hall, 1999.
3. J. D. Jackson, *Classical Electrodynamics*, Wiley, 1999
4. G. E. Owen, *Introduction to ElectromagneticTheory*, Dover, 2003.
5. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundations, of Electromagnetic Theory*, Addison-Wesley Publishing, 1993.

Course Code: MAT-4718 **Title:** Introduction to Univalent Functions **Credit Hours:** 03

Course Outline: Basic Concepts: **Complex Analysis Review:**A brief refresher on essential concepts from complex analysis, such as analytic functions, Cauchy-Riemann equations, and conformal mappings. **Univalent Functions Definition:** Formal definition of univalent (or injective) functions and their significance in complex analysis. Exploring Möbius transformations and their role as automorphisms of the unit disk. A crucial theorem stating that any simply connected domain (other than the whole plane) can be conformally mapped to the unit disk. Properties of Univalent Functions: **Area Theorem:** A fundamental theorem providing an upper bound on the area of the image of a univalent function. Studying bounds on the Taylor series coefficients of univalent functions. Analyzing how univalent functions affect the size and shape of geometric figures. **Extremal Problems:** Investigating problems where one seeks to find the maximum or minimum value of a functional defined on a class of univalent functions. **Boundary Behavior:** Examining the behavior of univalent functions near the boundary of their domain, including angular limits and derivatives. Special Classes of Univalent Functions: Functions whose images are starlike with respect to a point. Functions whose images are convex sets. A broader class of univalent functions related to convex functions. Functions that map the upper half-plane to itself. Advanced Topics (Time Permitting): A powerful technique for constructing and analyzing univalent functions, particularly those with slit images. A famous conjecture (now a theorem) about the coefficient estimates for univalent functions. Studying the behavior of univalent functions using integral means.

Texts and Reference Books

1. Derek K. Thomas (Author), Nikola Tuneski, Univalent Functions: A Primer (De Gruyter Studies in Mathematics.
2. James A. Jenkins, Univalent Functions and Conformal Mapping.

Semester-VIII

Course Code: MATH-4802 **Title:** Optimization Theory **Credit Hours:** 03

Course Outline: Linear Programming: Simplex Method, Duality Theory, Dual and Primal-Dual Simplex Methods Unconstrained Optimization: Optimality Conditions, One-Dimensional Problems, Multi-Dimensional Problems and the Method of Steepest Descent, Constrained Optimization with Equality Constraints, Optimality Conditions, Lagrange Multipliers, Hessians and Bordered Hessians, Inequality Constraints, the Kuhn-Tucker Theorem and Applications

Texts and Reference Books

1. L. Elsgolts, *DEs and the Calculus of Variations*, Mir Publishers Moscow, 1970.
2. B. S. Gotfried and J. Weisman, *Introduction to Optimization Theory*, Prentice Hall, Englewood Cliffs, NJ, USA, 1973.
3. D. G. Luenberger, *Introduction to Linear and Non-Linear Programming*, Addision Wesley, Reading, Ma. USA, 1973.
4. H. T. Jongen and K. Meer, *Optimization Theory*, 2004 Edition, Springer, 2004.
5. A. Beck, *Introduction to Nonlinear Optimization: Theory, Algorithms, and Applications with MATLAB*, SIAM-Society for Industrial and Applied Mathematics, 2014.

Course Code: MATH-4803 **Title:** Integral Equations **Credit Hours:** 03

Course Outline: Linear integral equations of the first and second kind. Relationship between differential equation and Volterra integral equation. Neumann series. Fredholm Integral equation of the second kind with separable Kernels. Eigenvalues and eigenvectors. Iterated functions. Quadrature methods. Least square methods. Homogeneous integral equations of the second kind. Fredholm integral equations of the first kind. Fredholm integral equations of the second kind. Abel's integral equations. Hilbert Schmidt theory of integral equations with symmetric Kernels. Regularization and filtering techniques, Introduction to Wiener-Hopf Technique.

Texts and Reference Books

1. J. J. Abdul, *Introduction to Integral Equations with Applications*, Marcel Dekker Inc. New York, 1985.
2. V. Lovitt, *Linear Integral Equations*, Dover Publications, Inc., New York, 1950.
3. B. Noble, *Methods Based on the Wiener-Hopf Technique*, Pergamon Press, 1988
4. F. Smith, *Integral Equations*, Cambridge University Press, 2003
5. F. G. Tricomi, *Integral Equations*, Interscience, 1957.

Course Code: MATH-4804 **Title:** Fluid Mechanics-II **Credit Hours:** 03

Course Outline: Circular Cylinder without Circulation, Circular Cylinder with Circulation Blasius Theorem, Kutta Condition and the Flat-Plate Airfoil, Joukowski Airfoil, Vortex Motion, Karman's Vortex Street, Method of Images, Velocity Potential, Stoke's Stream Function, Solution of the Potential Equation, Uniform Flow Source and Sink, Flow Due to A Doublet Viscous Flows of Incompressible Fluids: Constitutive Equations, Navier-Stokes's Equations, Exact Solutions of Navier-Stokes's Equations, Steady Unidirectional Flow, Poiseuille Flow, Coquette Flow, Flow between Rotating Cylinders, Stoke's First Problem, Stoke's Second Problem

Simplified Approach to Fluid Flow Problems: Similarity from Differential Equations, Dimensional Analysis, One Dimensional Steady Compressible Flow

Texts and Reference Books

1. I. G. Curie, *Fundamentals of Mechanics of Fluids*, 3rd Edition, CRC, 2002.
2. I. L. Distsworth, *Fluid Mechanics*, Mc-Graw Hill, 1972.
3. R.W. Fox, A.T. Mc-Donald and P.J. Pritchard, *Introduction to Fluid Mechanics*, John Wiley and Sons, 2003.
4. H. Schlichting, K. Gersten, E. Krause and H. Oertel, Jr, *Boundary-Layer Theory*, 8th Edition, Springer-Verlag, 2004.
5. Y. C-Shun, *Fluid Mechanics*, Mc-Graw Hill, 1974.

Course Code: MATH-4801 **Title:** Capstone Project **Credit Hours:** 03

Course Outline:

The objective of this course is to train students to learn and use the tools required for writing their project report and the tools for doing their research work. They will do the literature survey, work on some research problem and write a project report by the end of the course.

Texts and Reference Books

As per requirements of the topic of the Project.

Course Code: MATH-4806 **Title:** Mathematical Modeling **Credit Hours:** 03

Course Outline: Introduction to modeling. Basic Guide line of mathematical modeling, Collection and interpretation of data, Technique of mathematical modeling, Classification of mathematical modeling, modeling through algebra, modeling through Geometry, modeling through Trigonometry, modeling through Calculus, Limitation of modeling, Development of Models', , Discrete and Continuous models,, Linear Growth and Decay Model, Non-linear Growth and decay models, Mathematical modeling in population dynamic, Traffic flow models.

Texts and Reference Books

1. D. Edwards and M. Hamson, *Mathematical modeling Skills*, MacMillan Press Ltd., 1996
2. F. R. Giordano, M. D. Weir, and W. P. Fox, *A First Course in Mathematical modeling,* Thomson Brooks/Cole, 2003
3. J. N. Kapur, *Mathematical modeling*, New Age International Limited, 2015.
4. S. Banerjee, *Mathematical modeling* (Modell analysis and Application)
5. J. J. Batzel, M. Bachar, and F. Kappel, *Mathematical Modeling and Validation in Physiology*, 2013

Course Code: MATH-4817 **Title:** Introduction to Fractional Calculus **Credit Hours:** 03

Course Outline: Foundations and Preliminaries: Introduction to Fractional Calculus: Review of Integer-Order Calculus: Brief review of differentiation and integration with integer orders, setting the stage for generalization. Special Functions: Introduction to Gamma, Beta, and Mittag-Leffler functions, which are essential for fractional calculus. Laplace and Fourier Transforms: ractional Derivatives and Integrals: Riemann-Liouville Fractional Integral: Definition and properties. Riemann-Liouville Fractional Derivative: Definition and properties, including the relationship between Riemann-Liouville integrals and derivatives. Definition and properties, with a focus on its advantages in applications. Grunwald-Letnikov Fractional Derivative: An alternative definition and its relation to other definitions. Definition and properties of Weyl fractional integrals and derivatives.

Texts and Reference Books

1. Xiao-Jun Yang, General Fractional Derivatives: Theory, Methods and Applications.
2. Samko, Kilbas,Fractional Integrals and Derivatives: Theory and Applications.

Course Code: MAT-4808 **Title:** Algebraic Topology **Credit Hours:** 03

Course Outline: Path Wise Connectedness with Examples, Notion of Homotopy, Homotopy Classes and its Application, Path Homotopy, Path Homotopy Classes, Fundamental Groups, Covering Mapping with Examples, Covering Spaces, Lifiting Properties of Covering Spaces and its Application, Fundamental Group of a Circle (s)

Text and Reference Books

1. M. J. Greeberge*, Algebraic Topology,* A first Course, Benjamin Commings, 1967.
2. C.A. Kosniowski*, First course in Algebraic Topology*, Cambridge University press, 1980.
3. A. H. Wallace, *Algebraic Topology*, Homology and Cohomology, Benjamin, 1968.
4. A. Hatcher, *Algebraic Topology*, 1st Edition, Cambridge University Press, 2001.
5. W. Fulton, *Algebraic Topology*, Springer, 1997.

Course Code: MATH-4807 **Title:** Mathematical Systems Theory **Credit Hours:** 03

Course Outline: Conservation laws and phenomenological principles, some principles and laws of thermodynamics, mechanics, and electromagnetism and their applications in modelling, Linearization, matrix exponentials and solution of linear differential equations, LTV systems, Impulse and step responses, Stability, controllability, and observability of LTI systems, Realization theory and Hankel matrices, Feedback and stabilizability, observers and state reconstruction, detectability, separation principle and compensation, disturbance rejection,

Laplace transforms and LTI systems, transfer functions and transfer matrices, transfer functions and minimal realizations of SISO and MIMO systems, Abstract systems description and behavioral modeling, polynomial representations of systems, brief discussion of nonlinear, descriptor, stochastic, distributed parameter, and discrete event systems, optimal control theory, parameter estimation, filter theory, model reduction, and adaptive and robust control

Texts and Reference Books

1. G. J. Olsder, J. W. van der Woude, J. G. Mask, and D. Jeltsema, *Mathematical Systems Theory*, 4th Edition, VSSD, 2011.
2. I. D. Hinrichsen and A. J. Pritchard, *Mathematical Systems Theory*, Springer
3. J. W. Polderman and J. C. Willems, *Introduction to Mathematical Systems Theory,* 2nd Edition, Springer, 2008.
4. J. Zabczyk, *Mathematical Control Theory,* 1st Edition, Birkhauser, 2007.
5. E. D. Sontag, *Mathematical Control Theory,* 2nd Edition, Springer, 1998.

Course Code: MAT-4805 **Title:** Dynamical Systems **Credit Hours:** 03

Course Outline: Introduction: Preliminary ideas, Autonomous equations, Autonomous systems in plane, Flows and evolution. Linear systems: Linear changes of variables, Similarity types for 2×2 real matrices, Phase portraits for canonical systems in the plane, Classification of simple linear phase portraits in the plane, The evolution operators, Affine systems, Linear systems of dimension greater than two. Nonlinear systems in the plane: Local and global behavior, Linearization at a fixed point, The linearization theorem, Non-simple fixed points, Stability of fixed points, Ordinary points and global behavior, First integrals, Limit points and limit cycles. Flows on non-planar phase spaces: Fixed points, closed orbits, Attracting sets and attractors, Further integrals. Applications: Linear models, Affine models, Nonlinear models, Relaxation oscillation, Piecewise modeling. Dynamical systems with Python: Differential equations, Planar systems, Interacting species, Limit cycles.

Text and Reference Books

1. M W. Hirsch, S Smale and R L Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, Third Edition, 2013
2. G C Layek , An Introduction to Dynamical Systems and Chaos, Springer, 2016.
3. R C Robinson, An Introduction to Dynamical Systems: Continuous and Discrete, 2nd Edition, 2004.
4. S Lynch , Dynamical systems with applications using Python, Birkhauser Boston, 2018.

Course Code: MATH-4810 **Title:** Quantum Mechanics-II **Credit Hours:** 03

Course Outline: Harmonic Oscillator and Problems in Three-Dimensions: The Harmonic Oscillator, Eigen-Functions of the Harmonic Oscillator, The Harmonic Oscillator in Momentum Space, Motion in Three Dimensions, Spherical Symmetric Potential and the Hydrogen Atom, Angular Momentum: Basic Properties, Eigenvalues of the Angular Momentum Operators, Eigen-Functions of the Orbital Angular Momentum Operators L_2 and Lz, Commutation Relations between Components of Angular Momentum and Their Representation in Spherical Polar Coordinates

The Scattering Cross-Section, Scattering Amplitude, Scattering Equation, Born Approximation, Partial Wave Analysis, Time Independent Perturbation of Non-Degenerate and Degenerate Cases, Time-Dependent Perturbations

Texts and Reference Books

1. D. R. Bes, *Quantum Mechanics: A Modern a Concise Introductory Course*, Springer-Verlag, 2004.
2. H. D. Dehmen, *The Picture Book of Quantum Mechanics*, Springer-Verlag, 2001.
3. H. F. Hameks, *Quantum Mechanics*, *A Conceptual Approach*, Wiley- IEEE, 2004.
4. R. L. Liboff, *Introduction Quantum Mechanics*, Addison Wesley Publishing Company, 2003.
5. V. K. Thankappan, *Quantum Mechanics*, New Age Publishers, 1993.

Course Code: MATH-4811 **Title:** Introduction to Combinatorics **Credit Hours:** 03

Course Outline: Two Basic Counting Principle, Permutations, Combinations, The Injective and Bijective Principles, Arrangements and Selections with Repetitions, Graphs in Combinatorics, The Binomial Theorem, Combinatorial Identities, Properties of Binomial Coefficients, Multinomial Coefficients, The Multinomial Theorem, The Pigeonhole Principle, Examples, Ramsay Numbers, The Principle of Inclusion and Exclusion, Generalization, Integer Solutions, Surjective Mapping. Stirling Numbers of the Second Kind, The Sieve - Eratosthenes, Euler Φ–Function, The Problem Des-Menages

Ordinary Generating Functions, Modeling Problems, Partition of Integers, Exponential Generating Functions

Linear Homogeneous Recurrence Relations, Algebraic Solutions of Linear Recurrence Relations and Constant Functions, The Method of Generating Functions, A Non-Linear Recurrence Relation and Catalaa Numbers

Texts and Reference Books

1. V. K. Balakrishnan, *Theory and Problems of Combinatorics*, Schaum's Outline Series, Mc-Graw Hill, Singapore, 1995.
2. C. C. Chen and K. M. Koh, *Principles and Techniques in Combinatorics*, World Scientific Publishing Company, Pvt. Ltd, Singapore, 1992.
3. C. L. Liu, *Introduction to Combinatorial Mathematics*, Mc-Graw Hill, New York, 1968.
4. A. Tucker, *Applied Combinatorics*, John Wiley and Sons, New York, 1985.
5. R. A. Brualdi, *Introductory Combinatorics*, 5th Edition, Pearson, 2009.

Course Code: MATH-4812 **Title:** Variational Inequalities **Credit Hours:** 03

Course Outline: Variational Inequalities in Fixed Points, The Characterization of the Projection onto a Convex Set, A First Theorem about Variational Inequalities, Variational Inequalities, Some Problems which Lead to Variational Inequalities, Variational Inequalities in Hilbert Space, The Obstacle Problem, Variational Inequalities for Monotone Operators, Penalization

Texts and Reference Books

1. C. Baiocchi and A. Capelo, *Variational and Quasi-Variational Inequalities*: *Applications to Free Boundary Problems*, John Wiley and Sons, New York, 1984.
2. V. Barbu, *Optimal Control of Variational Inequalities*, Pitman Adv. Pub. Program, Boston, 1984.
3. G. Isac, *Complementarity Problems and Variational Inequalities*, Springer-Verlag, 2006.
4. D. Kinderlehrer and G. Stampacchia, *An Introduction to Variational Inequalities and Their Applications*, Academic Press, New York, 1980.
5. M. A. Noor, *Principles of Variational Inequalities,* Lambert Academic Publishing, Saarbrucken, Germany, 2009.

Course Code: MATH-4813 **Title:** Theory of Elasticity **Credit Hours:** 03

Course Outline: Cartesian Tensors, Analysis of Stress and Strain, Generalized Hooke's Law, Crystalline Structure, Point Groups of Crystals, Reduction in the Number of Elastic Moduli Due to Crystal Symmetry, Equations of Equilibrium, Boundary Conditions, Compatibility Equation, Plane Stress and Plane Strain Problems, Two Dimensional Problem in Rectangular and Polar Coordinates, Torsion of Rods and Beams

Texts and Reference Books

1. E. Dieulesaint and D. Royer, *Elastic Waves in Solids*, John Wiley and Sons, New York, 1980.
2. Y. C. Funk, *Foundations of Solid Mechanics*, Prentice-Hall, Englewood Cliffs, 1965.
3. Sokolinikoff, *Mathematical Theory of Elasticity*, Mc-Graw Hill, New York.
4. S. P. Temoshenko and J. N. Goodier, *Theory of Elasticity,* 3rd Edition, Mcgraw Hill Education (India) Private Limited, 2015.
5. A. I. Lurie and A. Belyaev, *Theory of Elasticity,* 2005 Edition, Springer, 2005.

Course Code: MATH-4814 **Title:** Electromagnetic Theory-II **Credit Hours:** 03

Course Outline: The Faraday Induction Law, Induced Electromotance in a Moving System, Inductance and Induced Electromotance, EnerguStoted in a Magnetic Field, The Equations of Electromagnetism, Electromagnetic Waves: Plane Electromagnetic Waves in Free Space and Isotropic Media, The Poynting Vector in Free Space, Propagation of Electromagnetic Waves in NON-Conductors, Propagation of Plane Waves in Conducting Media, Reflection and Reffraction of Plane Waves, Guided Waves, Coaxial Line, Hollow Rectangular Wave Guide, Radiation of Electromagnetic Waves, Electromagnetic Field of a Moving Charge

Texts and Reference Books

1. D. Corrison and P. Lorrison, *Introduction to Electromagnetic Fields and Waves* , W.H. Freeman and company, London, 1962.
2. D. J. Griffiths, *Introduction to Electrodynamics*, Prentice-Hall, 1999.
3. J. D. Jackson, *Classical Electrodynamics*, Wiley, 1999
4. G. E. Owen, *Introduction to ElectromagneticTheory*, Dover, 2003.
5. J. V. Stewart, *Intermediate Electromagnetic Theory*, World Scientific, 2001.

Course Code: MATH-4815 **Title:** Special Theory of Relativity **Credit Hours:** 03

Course Outline: Historical Background and Fundamental Concepts of Special Theory of Relativity, Lorentz Transformations (for Motion Along One Axis), Length Contraction, Time Dilation and Simultaneity, Velocity Addition Formulae, 3-Dimensional Lorentz Transformation, Introduction to 4-Vector Formalism, Lorentz Transformations in the 4-Vector Formalism, The Lorentz and Poincare Groups, Introduction to Classical Mechanics, Minkowski Space-Time and Null Cone, 4-Velocity, 4-Momentum and 4-Force, Application of Special Relativity to Doppler Shift and Compton Effect, Particle Scattering, Binding Energy, Particle Production and Decay, Electromagnetism in Relativity, Electric Current, Maxwell's Equations and Electromagnetic Waves, The 4-Vector Formulation of Maxwell's Equations, Special Relativity with Small Acceleration

Texts and Reference Books

1. H. Goldstein, *Classical Mechanics*, Addison Wesley, New York, 1962.
2. D. Inverno, *Introducing Einstein's Relativity*, Oxford University Press, 1992.
3. J. D. Jackson, *Classical Electrodynamics*, John Wiley and Sons, New York, 1962.
4. A. Qadir, *Relativity: An Introduction to the Special Theory*, World Scientific, 1989.
5. W. Rindler, *Essential Relativity*, Springer-Verlag, 1977.

Course Code: MATH-4817 **Title:** Fractional Calculus **Credit Hours:** 03

Course Outline: Special functions of fractional calculus: Gamma function, MIttag-Leffler function, Wright function. Fractional derivatives and integrals: Grunwald-Letnikov fractional derivatives, Riemann-Liouville fractional derivatives, geometric and physical interpretation of fractional integration and differentiation, sequential fractional derivatives, properties of fractional derivatives, Laplace, Fourier and Mellin transforms of fractional derivatives. Linear fractional differential equations: Equation of a general form, existence and uniqueness theorem as a method of solution, dependence of a solution on initial conditions, Laplace transform method, standard fractional differential equations, sequential fractional differential equations. Some methods for solving fractional order equations: Mellin transform, power series, orthogonal polynomials, numerical evaluation of fractional derivatives, approximation of fractional derivatives.

Text and Reference Books

1. Fractional Differential Equations, I. Podlubny, Academic Press, 1998.
2. The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, K.B. Oldham and J. Spanier, Dover Publications, 2006.
3. An Introduction to the Fractional Calculus and Fractional Differential Equations, K.S. Miller and B. Ross, Wiley-Interscience, 1993.
4. Basic Theory of Fractional Differential Equations, Y. Zhou, World Scientific, 2014.

6. Detail of Courses for Students Without Mathematics at Intermediate Level

The outlines of two non-credit additional Mathematics courses will be offered for those students who have not studied Mathematics at intermediate level are given below.

Course Code: MATH-1101NC **Title:** Pre-Algebra **Credit Hours:** 03

Course Outline: This course is designed to give introduction to the ground knowledge of basic mathematics along with concept mathematical techniques. Firstly, course reviews some basic concepts of numbers, sets and functions. Secondly some basic concepts of matrices, determinants and quadratic equations have been utilized. Thirdly, sequences and series are introduced. Fourthly, some fundamental concepts for Mathematical Induction and Binomial Theorem will be elaborated. Finally, fundamentals of trigonometry and their applications will also be discussed.

It includes the following major topics:

- Number Systems, Sets Functions and Groups
-Matrices, Determinants and Quadratic Equation
- Sequences and Series
- Mathematical Induction and Binomial Theorem
- Fundamentals of Trigonometry and their Applications

Recommended Books

1. Calculus, by Thomas Finney, 11th edition, 2005
2. Calculus, by Howard Anton , 10th edition, 2012
3. Calculus with Analytical Geometry, by Earl W. Swokowski, 2nd Edition, 1979

Course Code: MATH-1201NC **Title:** Pre-Calculus **Credit Hours:** 03

Course Outline: This course is designed to give introduction to the ground knowledge of basic calculus along with concept of motion and rate of change of the bodies and calculating velocities, acceleration and areas by evaluating derivatives and different integration techniques. Firstly, course reviews some basic concepts of functions and curves, evaluating limit of the function of single variable, concept of continuity of the function and derivatives of the functions. Secondly different integrations techniques have been utilized to find the areas under the curve in form of definite integrals. Thirdly, some fundamental concepts for linear programing will be elaborated. Finally, various geometries have been considered in the conic section.

The course will help students in learning basic concepts, theories, and applications like calculating areas, finding velocities and accelerations.

It includes the following major topics:

- Functions, Limit and Continuity
- Derivative and its Applications
- Integration and its applications.
- Linear programming
- Conic section

Recommended Books

Calculus, by Thomas Finney, 11th edition, 2005
Calculus, by Howard Anton , 10th edition, 2012
Calculus with Analytical Geometry, by Earl W. Swokowski, 2nd Edition, 1979

7. Detail of Courses for Bachelor of Science in Mathematics (AI / Data Science / Economics)

7.1 Detail of Courses for Bachelor of Science in Mathematics (AI)

Semester-V

Course Code: DATS-3503 **Title:** Data Science with Fundamentals **Credit Hours:** 03

Course Outline: Introduction: Overview, Datafication, Data Science Process, Statistical Inference, Statistical Modeling, Exploratory Data Analysis, Basic Machine Learning Algorithms: Linear Regression, k-Nearest Neighbors (k-NN), k-means, Naive Bayes; Feature Generation & Feature Selection; Dimensionality Reduction: Singular Value Decomposition, Principal Component Analysis; Mining Social-Network Graphs; Data Visualization; Data Science and Ethical Issues: Discussions on privacy, security, ethics, Next-generation data scientists.

Texts and Reference Books

1. An Introduction to Data Science, Jeffrey S. Saltz and Jeffrey M. Stanton, SAGE Publications, 2017.
2. Data Science for Business with R, Jeffrey S. Saltz and Jeffrey M. Stanton, SAGE Publications, 2021.
3. Foundations of data science, Blum, A., Hopcroft, J., and Kannan, R., Vorabversion eines Lehrbuchs, 2019.

Semester-VI

Course Code: AI-3605 **Title:** Artificial Neural Networks **Credit Hours:** 03

Course Outline: Nodes of a Neural Network, Layers of Neural Networks, Supervised Learning of a Neural Network, Training of a Single Layer Neural Networks, Generalized Delta Rule, SGD, Batch and Mini Batch, Stochastic Gradient Descent, Implementations of these Methods, Limitations of Single Layer Neural Networks, Training of Multi-Layer Neural Network, Back Propagation Algorithm, Cost Function and Learning Rule, Cross Entropy Function, Neural Network and Classification, Binary Classification, Multiclass Classification.

Texts and Reference Books

1. Phil Kim, MATLAB Deep Learning, Apress (2017).

Semester-VII

Course Code: AI-4719 **Title:** Digital Logic Design **Credit Hours:** 03

Course Outline: Digital Systems. Binary Numbers. Number Base Conversions. Octal and Hexadecimal Numbers. Complements. Signed Numbers. Binary Codes. Basic Definitions. Axiomatic Definition of Boolean algebra. Basic Theorems and Properties of Boolean Algebra, Boolean Functions. Canonical and Standard Forms. Other Logic Operations. Digital Logic Gates. Integrated Circuits, The K-Map Method. Four-Variable Map. Product of Sums and Sum of Products simplifications. Introduction to Five-Variable Map. Quine-McCluskey minimization technique (Tabulation). Don't-Care Conditions. NAND and NOR Implementation. Other Two-Level Implementations Combinational Circuits. Analysis Procedure. Design Procedure. Binary Adder-Subtractor. Decimal Adder. ALU Design using Combinational Circuits. Binary Multiplier. Magnitude Comparator. Decoders. Encoders. Multiplexers Sequential Circuits. Latches and Flip-flops. Analysis of Clocked Sequential Circuits. Mealy and Moore FSM. State Reduction and Assignment. Design of clocked sequential circuits. Registers. Shift Registers. Ripple Counters. Synchronous Counters. Other Counters

Texts and Reference Books

1. Digital Fundamentals (Eleventh Edition) by Floyd
2. Logic and Computer Design Fundamentals (Fourth Edition) by M. Morris Mano and Charles R. Kime
3. Fundamentals of Logic Design (Sixth Edition) by Charles H. Roth Jr
4. Digital Systems: Principles and Applications (Tenth Edition) by TocciWidmer

Semester-VIII

Course Code: AI-4818 **Title:** Introduction to Artificial Intelligence **Credit Hours:** 03

Course Outline: This course gives a broad overview of the fundamental theories and techniques of Artificial Intelligence. Topics include: Overview of Artificial Intelligence; Agents & Environments; Problem-Solving; Adversarial Search; Constraint Satisfaction Problems; Knowledge Representation & Reasoning; Uncertainty; and Automated Planning.

Texts and Reference Books

1. Koller and Friedman. Probabilistic Graphical Models.
2. Sutton and Barto. Reinforcement Learning: An Introduction.
3. Hastie, Tibshirani, and Friedman. The elements of statistical learning.
4. Tsang. Foundations of constraint satisfaction.

Course Code: AI-4819 **Title:** Programming for Artificial Intelligence **Credit Hours:** 2+1

Course Outline: Basics of linear algebra, Probability models, including normal and binomial distributions, Sampling and inference and predictive techniques, Measures of central tendency and dispersion to summarize data, Modify small programs for data manipulation, Principles of data visualization, visualization solutions to real data, Write programs to load, manipulate, visualize and store data, AI Programming Tools and Libraries (scientific computing library, visualization library, data manipulation and analysis library, and machine learning library.), Trade-offs involved in design-choices, Using AI libraries for data loading, processing, manipulation and visualization, Model selection, customization and Evaluations and performance metrics, Analysis and interpretation of results, Guidelines by social, professional and ethical issues, Self-directed study, Emerging Trends and Future Directions in AI.

Texts and Reference Books

1. "Python Cookbook", David Beazley, Brian K. Jones, 3rd Edition, O'Reilly, 2013. 2.
2. "Artificial Intelligence with Python", Prateek Joshi, Packt Publishing, 2017. 3.
3. "Hands-on Machine Learning with Scikit-Learn and TensorFlow", Aurélien Géron, O'Reilly, 2017.

7.2 Detail of Courses for Bachelor of Science in Mathematics (Data Science)

Semester-V

Course Code: DATS-3503 **Title:** Data Science with Fundamentals **Credit Hours:** 03

Course Outline: Introduction: Overview, Datafication, Data Science Process, Statistical Inference, Statistical Modeling, Exploratory Data Analysis, Basic Machine Learning Algorithms: Linear Regression, k-Nearest Neighbors (k-NN), k-means, Naive Bayes; Feature Generation & Feature Selection; Dimensionality Reduction: Singular Value Decomposition, Principal Component Analysis; Mining Social-Network Graphs; Data Visualization; Data Science and Ethical Issues: Discussions on privacy, security, ethics, Next-generation data scientists.

Texts and Reference Books

1. An Introduction to Data Science, Jeffrey S. Saltz and Jeffrey M. Stanton, SAGE Publications, 2017.
2. Data Science for Business with R, Jeffrey S. Saltz and Jeffrey M. Stanton, SAGE Publications, 2021.
3. Foundations of data science, Blum, A., Hopcroft, J., and Kannan, R., Vorabversion eines Lehrbuchs, 2019.

Semester-VI

Course Code: DATS-3605 **Title:** Regression Model and Analysis **Credit Hours:** 03

Course Outline: General linear model and its assumptions, Least-squares estimators, MLE, Least squares estimators, tests of hypothesis, tests of significance of a single and complete regression, tests of significance of subset of coefficients. Significance tests and confidence intervals. Test of linearity of regression. Use of extraneous information in linear regression model. Residual analysis, Detection and study of outliers. Polynomial regression, orthogonal polynomial, orthogonal regression analysis. Specification of models.

Texts and Reference Books

1. Draper, N.R. and Smith, H. (2004)." *Applied Regression Analysis",* John Wiley. New York.
2. Baltagi, B. H. (1999). "Econometrics", 2nd Edition, Springer Varlog.
3. Gujrati, D. (1998). "Econometrics", John Wiley, New York.
4. Wonnacott, T.H. and Wonnacott R.J. (1998). "Econometrics", John Wiley, New -York.
5. Johnston, J. and Di. Nardo, J., (1997). "Econometric *Method",* 4th Edition, McGraw Hill, New York.
6. Ryan, P. T. (1996) "Modern *Regression Methods",* John Wiley and sons Inc. New York.
7. Montgomery, D.C., and Peck E.A. (1992)." Introduction *to linear Regression Analysis",* 2nd Edition, John Wiley and sons Inc. New York.

Semester-VII

Course Code: DATS-4719 **Title:** Platform and Architecture for Data Science **Credit Hours:** 03

Course Contents: This course introduces standards and principles for data architecting and platform for data scientists. Topics Include; Data Architecture; Data Infrastructure; Data Life Cycle; End-State Architecture; Data Vault; Data Science Platforms; and Modern Platforms for Data Science.

Texts and Reference Books

1. Data Architecture: A Primer for the Data Scientist: A Primer for the Data Scientist, William Inmon, Daniel Linstedt & Mary Levins, Academic Press, 2019.
2. Data Science Solutions on Azure: Tools and Techniques Using Databricks and MLOps, Julian Soh & Priyanshi Singh, Apress, 2020.
3. Data Science on AWS: Implementing End-to-End, Continuous AI and Machine Learning Pipelines, Chris Fregly & Antje Barth, O'Reilly, 2021.

Course Code: DATS-4720 **Course Title:** Big Data Analytics **Credit Hours:** 2+1

Course Contents: The course will cover the following topics: Importing Datasets: Understanding the Data, Python packages for Data Science, Importing and Exporting Data in Python, Basics of Analyzing Data in Python; Data Wrangling: Pre-processing Data in Python, Dealing with Missing Values in Python, Data Formatting in Python, Data Normalization, Binning, Turning Categorical Variables into Quantitative Variables; Exploratory Data Analysis; Correlation; ANOVA; Model Development: Linear Regression & Multiple Linear Regression, Model Evaluation using Visualization; Polynomial Regression & Pipelines; Measures for In- Sample Evaluation, Prediction & Decision Making; and Model Evaluation: Model Evaluation & Refinement.

Texts and Reference Books

1. Python Data Analytics: The Beginner's Real-World Crash Course, Booth, T., Independently published, 2019.
2. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython, McKinney, W., O'Reilly Media, 2017.

Course Code: 4721 **Title:** Exploratory Data Analysis & Visualization ` **Credit Hours:** 03

Course Contents: Introduction to Exploratory Data Analysis(EDA); Dimensionality Reduction: Linear and Non Linear Methods, Model-Based Clustering, Smoothing Scatterplots; Graphical Methods for EDA: Visualizing Clusters, Distribution Shapes, Multivariate Visualization, Data Representation in Visualization Applications, Visualization Pipeline, Fundamental Techniques for Scalar Visualization, Vector Visualization Techniques, Tensor Visualization Techniques; Domain Modeling Techniques; Scientific Visualization and Signal/Image Processing; Information Visualization Techniques.

Texts and Reference Books

1. Exploratory Data Analysis with R, Roger D. Peng, Lulo, 2019.
2. Data Visualization - Principles and Practice, Alexandru C. Telea, CRC Press, 2018.
3. Exploratory Data Analysis with MATLAB, Wendy L. Martinez, Angel R. Martinez, Wendy L. Martinez, Angel Martinez, Jeffrey Solka, CRC Press,2017.
4. Interactive Graphics for Data Analysis: Principles and Examples, Martin Theus, Simon Urbanek, Taylor & Francis, 2017.

Semester-VIII

Course Code: DATS-4818 **Title:** Statistical Packages & Data Analysis (SPSS, R & Python) **Credit Hours:** 03

Course Outline: Descriptive vs. Inferential Statistics: Understanding the difference between summarizing data (descriptive) and drawing conclusions about populations, Data Types and Measurement Scales, Measures of Central Tendency, Measures of Dispersion, Data Visualization, Probability, Sampling Methods, Statistical Analysis Techniques Descriptive Statistics: Calculating and interpreting summary statistics for various datasets. Inferential Statistics, Correlation and Regression, Analysis of Variance (ANOVA), Non-parametric Tests, Data Cleaning and Preparation, Statistical Software and Programming, SPSS (Statistical Package for the Social Sciences): Learning to use SPSS for data entry, analysis, and reporting. R Programming: Understanding R syntax and using it for statistical analysis and data visualization. Python for Data Analysis: Using Python libraries like Pandas, NumPy, and SciPy for data manipulation and analysis. Data Visualization Tools, Applications and Case Studies: Real-world examples: Applying statistical techniques to solve problems in various fields (e.g., business, healthcare, social sciences). Case studies: Analyzing datasets and drawing conclusions based on statistical findings. Ethical considerations.

Texts and Reference Books

1. Cox, D. R., Hinckley D.V. and Nielsen O.E.B. (1996). "Time *Series Models - In Econometrics, finances and other fields";* Chapman & Hall, London.
2. Chatfield, C. (1996). "The *Analysis of Time Series: An Introduction",* Chapman and Hall, London.
3. Andy, P, West M. and Harrison, P. J. (1994). "Applied *Bayesian Forecasting and Time Series*

Course Code: DATS-4819 **Title:** Time Series Analysis **Credit Hours:** 03

Course Outline: Stochastic Process, Stationary Time-Series, Exponential smoothing techniques, auto-correlation and auto-covariance, estimates functions and standard error of the auto-correlation function (ACF) and PACF, Periodogram, spectral density functions, comparison with ACF, Linear stationary models: Auto regressive, Moving Average and mixed models, Non-stationary models, general ARIMA notation and models, minimum mean square forecasting. ARIMA Seasonal Models.

Texts and Reference Books

4. Cox, D. R., Hinckley D.V. and Nielsen O.E.B. (1996). "Time *Series Models - In Econometrics, finances and other fields";* Chapman & Hall, London.
5. Chatfield, C. (1996). "The *Analysis of Time Series: An Introduction",* Chapman and Hall, London.
6. Andy, P, West M. and Harrison, P. J. (1994). "Applied *Bayesian Forecasting and Time Series*

7.3. Detail of Courses for Bachelor of Science in Mathematics (Economics)

Semester-V

Course Code: ECON-3503 **Title:** Principles of Economics **Credit Hours:** 03

Course Outline: Introduction to Economics: Fundamental Concepts, Definition and scope of economics, Positive vs. normative economics, Economic methodology, Economic Models and Mathematics, Mathematical modeling in economics, Functions and equations in economic analysis, Graphs and economic relationships, Scarcity, Choice, and Opportunity Cost, Production Possibility Frontier (PPF), Economic efficiency, Comparative advantage and specialization, Supply and Demand Analysis, Demand Analysis, Individual and market demand, Determinants of demand, Movement along vs. shifts in demand curve, Supply Analysis, Individual and market supply, Determinants of supply, Movement along vs. shifts in supply curve, Market Equilibrium , Equilibrium price and quantity, Surplus and shortage, Price controls and their effects, Elasticity Concepts, Price elasticity of demand, Income elasticity, Cross-price elasticity, Price elasticity of supply, Consumer Theory, Consumer Preferences, Utility concept, Cardinal vs. ordinal utility, Indifference curves, Utility Maximization , Marginal utility analysis, Law of diminishing marginal consumer equilibrium, Budget Constraints , Budget line and its properties, Income and substitution effects, Consumer surplus, Production Theory, Production Concepts ,Factors of production, Production functions, Short-run vs. long-run, Cost Analysis , Fixed and variable costs, Average and marginal costs, Long-run cost curves, Economies and diseconomies of scale, Profit Maximization, Revenue concepts, Profit maximization conditions, Break-even analysis, Market Structures - Perfect Competition and Monopoly, Oligopoly and Strategic Behavior, Factor Markets, Market Failures and Government Intervention, National Income Accounting, Aggregate Supply and Demand, Money and Banking, Monetary Policy, Fiscal Policy, Inflation and Unemployment, International Trade, Integration and Review.

Texts and Reference Books

1. Mankiw, N. G. (2023). *Principles of economics* (10th ed.). Cengage Learning.
2. Acemoglu, D., Laibson, D., & List, J. A. (2023). *Economics* (3rd ed.). Pearson.
3. Supplementary Readings
4. Frank, R. H., Bernanke, B. S., & Antonovics, K. (2022). *Principles of economics* (8th ed.). McGraw-Hill Education.
5. Varian, H. R. (2020). *Intermediate microeconomics: A modern approach* (9th ed.). W. W. Norton & Company.
6. Blanchard, O. (2021). *Macroeconomics* (8th ed.). Pearson.

Semester-VI

Course Code: ECON-3605 **Title:** Econometrics and Big data **Credit Hours:** 03

Course Outline: Introduction to Econometrics and Big Data, Econometric Foundations, Statistical Software Introduction, Data Management Fundamentals, Probability and Statistical Review, Probability Concepts, Statistical Inference, Large Sample Theory, Linear Algebra for Econometrics, Data Management and Processing, Simple Linear Regression, Multiple Regression Analysis, Model Specification Issues, Violation of Assumptions, Time Series Analysis, Panel Data Analysis, Machine Learning in Econometrics, Big Data Analytics, Deep Learning Applications, Text Analysis and NLP, Advanced Topics.

Texts and Reference Books

1. Wooldridge, J. M. (2024). *Introductory econometrics: A modern approach* (8th ed.). Cengage Learning.
2. Bruce, P., Bruce, A., & Gedeck, P. (2023). *Practical statistics for data scientists* (3rd ed.). O'Reilly Media.
3. Supplementary Readings
4. Angrist, J. D., & Pischke, J. S. (2023). *Mostly harmless econometrics* (2nd ed.). Princeton University Press.
5. VanderPlas, J. (2023). *Python data science handbook* (2nd ed.). O'Reilly Media.
6. Wickham, H., & Grolemund, G. (2023). *R for data science* (2nd ed.). O'Reilly Media.

Semester-VII

Course Code: ECON- 4719 **Title:** Computational Economics **Credit Hours:** 2+1

Course Outline: Introduction to Computational Economics, Numerical Methods Fundamentals, Linear Systems and Matrix Methods, Optimization Techniques, Consumer Theory and Market Models, Production and Cost Analysis, Dynamic Programming in Economic, Game Theory and Strategic Behavior, Monte Carlo Methods, Agent-Based Modeling, Machine Learning in Economics, Time Series Analysis, General Equilibrium Models, Parallel Computing in Economics, Advanced Applications.

Texts and Reference Books

1. Miranda, M. J., & Fackler, P. L. (2023). *Computational methods in economics* (2nd ed.). MIT Press.
2. Judd, K. L. (2023). *Numerical methods in economics* (2nd ed.). MIT Press.
3. Supplementary Readings
4. Kendrick, D. A., Mercado, P. R., & Amman, H. M. (2023). *Computational economics* (2nd ed.). Princeton University Press.
5. Stachurski, J. (2023). *Economic dynamics: Theory and computation*. MIT Press.

Course Code: ECON-4720 **Title:** Principles of Microeconomics **Credit Hours:** 03

Course Outline: The Themes of Microeconomics, Scarcity and Economics, what is a Market? Real versus Nominal Prices, Why Study Microeconomics? Cardinal Approach/Utility Analysis: Marginal Utility, Law of Diminishing Marginal Utility, Law of Equi-Marginal Utility, consumer equilibrium. Ordinal Approach of Consumer Behavior: Indifference Curves, Features of Indifference Curves, Budget Line, Consumer Equilibrium. Comparative Statics, The Market Mechanism: Demand and Supply, factors effecting the market forces, Changes in Market Equilibrium. Price Elasticity of Demand, Price Elasticity of Supply, Point versus Arc Elasticities, Computing Elasticities, Price Elasticity and Total Expenditure, Cross-Price Elasticity of Demand, Income Elasticity of Demand. Consumer Surplus and producer surplus, price effect, Income effect, and Substitution Effect, The Technology of Production, Production with one Variable Input (Labor), Production with two Variables, Inputs, Returns to Scale, Measuring Cost: Which Costs Matter? Costs in the Short Run, Costs in the Long Run, Long Run versus Short Run Cost Curves. Average, total, marginal cost curves. Measuring revenue: total, average, and marginal revenue. Introduction to markets – Perfect competition, monopoly, monopolistic competition, oligopoly. Difference in revenue between perfect competition and other market types. Profit Maximization, derivation of supply curve under perfect competition. Introduction to factor markets

Texts and Reference Books

1. McConnell, C., & Bruce, S. (2006). Principles of Economics (17th ed.). McGraw-Hill.
2. Fuller, N. (1997). Principles of Microeconomics. UK: Tudor Business Publisher.

Course Code: ECON-4721 **Title:** Principles of Macroeconomics **Credit Hours:** 03

Course Outline: The economy in aggregate, Complexities of the world of business, Scope of macroeconomics, Brief account of the development of macro-economic after the World War-II, Concept of business cycles: Boom and Depression, Concepts of Inflation and Unemployment, Price Indices and Inflation, the simple macroeconomic models, Lead and Lagged variables, Exogenous and Endogenous variables and their functional relationships, Macro-models as abstraction from the real economy. Ingredients of the classical model: The Says Law of Market, The Quantity theory of money, The marginal productivity theory, Equilibrium in the goods and money market, A critical appraisal of classical model, classical dichotomy. Definition and concept of national income, Computation of national income: Product, Income and Expenditure approaches, Circular flow of income, Nominal versus Real income, Per capita income and the standard of living. The circular flow of National Income, GDP and GNP, Measurement of GNP: Expenditure (demand), Product (supply) and Income (factor rewards) approach, Value added at factor cost and market prices, Personal and disposable income, Per capita income, GNP as measure of welfare, Injections into and Leakages from the economy: Saving and Investment, Exports and Imports, Domestic Absorption, Nominal and Real income, The GDP deflator, Problems in computation of national income, The underground economy. Money and Banking, Public Finance and Taxation, International Trade.

Texts and Reference Books

1. Mankiw, G–Principles of Economics- Latest Edition- South- West Publishers.
2. McConnell, Campbell & Stanley Brue, and Sean Flynn, Macroeconomics, Latest Edition. (McGraw-Hill Economics)

Semester-VIII

Course Code: ECON-4818 **Title:** Dynamic Economic Modeling **Credit Hours:** 03

Course Outline: Introduction to Dynamic Economic Modeling, Mathematical Foundations for Dynamic Models, Solving and Analyzing Basic Dynamic Models, Dynamic Models in Macroeconomics, Intertemporal Choice and Consumption Models, Investment and Capital Accumulation, Introduction to Stochastic Dynamic Models, Dynamic Optimization and Policy Analysis, Computational Methods and Tools, Case Studies and Applications, Review and Final Assessment

Texts and Reference Books

1. "Recursive Macroeconomic Theory" by George Evans and Seppo Honkapohja
2. "Dynamic Economics" by Jerome Adda and Russell Cooper
3. Mathematics for Economists" by Carl P. Simon and Lawrence Blume

Course Code: ECON-4819 **Title:** Intermediate Microeconomics **Credit Hours:** 03

Course Outline: Consumer Theory, Goods classifications, Price Effects, Technology, Cost and Revenue, Profit under perfect and imperfect markets, Monopoly, Monopoly Behavior, Factors Market.

Texts and Reference Books

1. Varian, H. R. (2009). Intermediate Microeconomics: A Modern Approach (8th ed.). W.W. Norton & Company.
2. Nicholson, W. (2000). Intermediate microeconomics and its applications. Dryden Press: New York.
3. Maddala, G. S. (2004), Microeconomics: theory & applications. Tata McGraw-Hill Education: New York.

Course Code: ECON-4820 **Title:** Intermediate Macroeconomics **Credit Hours:** 03

Course Outline: Introduction, Theories of Consumption, Saving and Investment, The Demand for and Supply of Money, Determination of National Income, Aggregate Supply and the Labor Market, Inflation and Unemployment.

Texts and Reference Books

1. Shapiro, Edward – Macroeconomic Analysis- Latest Edition–Harcourt Brace Inc.
2. Froyen, Richard–Macroeconomics: Theories and Policies–Latest Edition–Macmillan
3. Mankiw, Gregory - Macroeconomics –Latest Edition, Worth Publishers, NY.
4. Blanchard, Oliver – Macroeconomics –Latest Edition - Prentice Hall International.
5. Dornbusch & Fisher – Macroeconomics- Latest Edition- McGraw Hill Inc.

8. Admission Criteria for Associate Degree in Mathematics (ADS 2 Year Program)

Sr. No.	Content	Proposed	Remarks
1	F.Sc.	Intermediate with Mathematics	
		DAE	
3	Intermediate or Equivalent	Intermediate with Science / General Science	Such students will be offered non-credit two courses of Mathematics during first year of the degree program.
2	Marks Requirement	45% marks in academic career	

9. Scheme of Studies for Associate Degree in Mathematics

Sr. No	Content	Description
1	Awarding Institute/Body	Mirpur University of Science and Technology (MUST)
2	Teaching Institute	Department of Mathematics, Mirpur University of Science and Technology (MUST), and affiliated colleges
3	Nomenclature	Associate Degree in Mathematics
4	Starting Time for Program	Fall/Spring semester of each academic year
5	Duration of the Program	4-6 Semesters
6	Entrance Requirements	Intermediate or equivalent degree with science (Min 45% marks)
		No 3rd Division in Matric and Intermediate
		Entry Test conducted by the University with the following breakup: Mathematics: 30 %, English: 10%, two other subjects which the candidate have studied in intermediate with 30% weightage for each.
7	Merit Formula	Merit shall be determined on 20% of SSC, 50% of Intermediate and 30% of Entry Test marks.
8	Total Credit Hours	Course Work: 70 Credit Hours
9	Exit Provisions	Exiting from with an Associate Degree: Students enrolled in the undergraduate/equivalent degree program shall be allowed to exit from the program with an Associate Degree provided that the following requirements are met: 1) The student must have completed minimum of 60 credit hours in at least four (04) semesters of the undergraduate/equivalent degree program including general education courses comprised of 30 credit hours. 2) The minimum CGPA is maintained at 2.5 / 4.00. 3) The name of the subject field on the degree shall be the Associate Degree in Mathematics.

10. Structure of Associate Degree in Mathematics

Sr. No.	Category	No. of Courses	Credit Hours	Remarks
01	General Education Cluster	13	32	
02	Allied Courses	02	06	
03	Major Courses	10	30	
04	Holy Quran	02	02	
Total Credit Hours		26	70	

10.1 Layout/Framework

Category	Course Title	Credit Hours	Total Credit Hours
Holy Quran	Understanding of Holy Quran-I	0-1	01
	Understanding of Holy Quran-II	0-1	01
General Education Cluster	Natural Science	03	32
	Ideology & Constitution of Pakistan	02	
	Arts and Humanities	02	
	Social Science*	02	
	Functional English	03	
	Expository Writing	03	
	Quantitative Reasoning I	03	
	Quantitative Reasoning II	03	
	Islamic Studies	02	
	Pakistan Studies	02	
	Application of information and communication technologies	03	
	Entrepreneurship	02	
	Civics and Community Engagement	02	
Interdisciplinary / Allied Courses	Statistics & Probability	03	06
	Introduction to Programing	03	
Major Courses	Calculus-I	03	30
	Calculus-II	03	
	Discrete Mathematics	03	
	Calculus-III	03	
	Elementary Differential Equations	03	
	Linear Algebra	03	
	Ordinary Differential Equations	03	
	Data Structure and Algorithms	03	
	Numerical Methods	03	
	Abstract Algebra	03	
Total Credit Hours of the Program			70

10.2 Semester-Wise Breakdown Associate Degree in Mathematics

1st Year

Semester-I

Course Code	Course Title	Category	Lec. Hrs.	Lab. Hrs.	Credit Hrs.
MATH-1101	Calculus-I	Major	3	0	3
MATH-1102	Introduction to Programing	Interdisciplinary	2	1	3
ENG-1107	Functional English	General Education	3	0	3
---------	Natural Science*	General Education	3	0	3
QTR- 1124	Quantitative Reasoning I	General Education	3	0	3
ICT-1126	Application of information and communication technologies	General Education	2	1	3
	*Natural Science				
*PHY-1118	The Fundamentals of Physics				
Total Credit Hours					**18**

Semester-II

---------	Arts and Humanities*	General Education	2	0	2
MATH-1201	Calculus-II	Major	3	0	3
MATH-1202	Discrete Mathematics	Major	3	0	3
ENG-1207	Expository Writing	General Education	3	0	3
PS-1217	Pakistan Studies	General Education	2	0	2
QTR-1224	Quantitative Reasoning II	General Education	3	0	3
UHQ-1230	Understanding of Holy Quran-I	General Education	0	1	1
	*Arts and Humanities				
*ARA-1201	Arabic				
Total Credit Hours					**17**

2nd Year

Semester-III

MATH-2301	Calculus-III	Major	3	0	3
MATH-2302	Linear Algebra	Major	3	0	3
MATH-2303	Elementary Differential Equations	Major	3	0	3
MATH-2304	Statistics & Probability	Interdisciplinary	3	0	3
ICP-2305	Ideology & Constitution of Pakistan	General Education	2	0	2
ISL-2312	Islamic Studies (Ethics for non-Muslim students)	General Education	2	0	2
---------	Social Science*	General Education	2	0	2
	*List of Social Science Courses				
PSY-2405	Educational Psychology	Social Science	2	0	2
OB-2406	Organizational Behavior	Social Science	2	0	2
EC-2307	Introduction to Environmental Sciences	Social Science	2	0	2
MATH-2308	Business Mathematics	Social Science	2	0	2
HRM-2309	HR Management	Social Science	2	0	2
IR-2310	International Relations	Social Science	2	0	2
LAW-2311	Introduction to Law	Social Science	2	0	2
SOC-2321	Sociology	Social Science	2	0	2
Total Credit Hours					**18**

Semester-IV

MATH-2401	Abstract Algebra	Major	3	0	3
MATH-2402	Numerical Methods	Major	3	0	3
DAT-2403	Data Structures & Algorithms	Major	3	0	3
MATH-2404	Ordinary Differential Equation	Major	3	0	3

ETRE-2408	Entrepreneurship	General Education	2	0	2
CCE-2425	Civic and Community Engagement	General Education	2	0	2
UHQ-2430	Understanding of Holy Quran-II	General Education	1	0	1
Total Credit Hours					**17**

11. Admission Criteria for Bachelor of Science in Mathematics Lateral Entry

Sr. No.	Content	Proposed	Remarks
1	Marks Requirement	45% marks in academic career	
2	BS Program or Equivalent (3 or 4-Years)	Must have passed courses of Mathematics having 400 marks	Such students may be allowed for admission in BS 5th Semester and will be offered deficiency courses during first two years (4-Semsters) of the degree program. Furthermore, the students of BS Mathematics who got admission during Fall 2023 and Fall 2024 are allowed to offer deficiency courses till the end of their degree programs. Note: The council recommended that the matter may be presented at faculty and academic council for admission in any Department of the FNAS.
3	ADS Program		

12. Scheme of Studies for Bachelor of Science in Mathematics Lateral Entry

Sr. No	Content	Description
1	Awarding Institute/Body	Mirpur University of Science and Technology (MUST)
2	Teaching Institute	Department of Mathematics, Mirpur University of Science and Technology (MUST), and affiliated colleges
3	Nomenclature	Bachelor of Science in Mathematics Lateral Entry
4	Starting Time for Program	Fall/Spring semester of each academic year
5	Duration of the Program	4-6 Semesters
6	Entrance Requirements	ADS / BS Degree or Equivalent (3 or 4-Years) with science (Min 45% marks)
		No 3rd Division in academic career
		Entry Test conducted by the University with the following breakup: Mathematics: 30 %, English: 10%, two other subjects which the candidate have studied in ADS / BS Program or Equivalent (3 or 4-Years) with 30% weightage for each.
7	Merit Formula	Merit shall be determined on 10% of Matric, 15% of Intermediate, 40% of ADS / BS Program or Equivalent (3 or 4-Years), 35% of Entry Test marks.
8	Total Credit Hours	Course Work: The Total Credit Hours should meet the requirement of the degree program: 63.
		Capstone/ Project (Compulsory): 0-3 Credit Hours
		Internship (Compulsory): 0-3 Credit Hours

13. Structure of Bachelor of Science in Mathematics Lateral Entry

Sr. No.	Category	No. of Courses	Credit Hours	Remarks
01	General Education Cluster	5	15	
02	Major Courses	14	42	
03	Internship	01	03	
04	Capstone Project	01	03	
Total Credit Hours		**21**	**63**	

13.1 Layout/Framework

Category	Course Title	Credit Hours	Total Credit Hours
Field Experience	Internship / Field Experience	03	03
Project	Capstone Project	03	03
General Education Cluster	Introduction to Mechanics	03	15
	Advanced Programming	03	
	Introduction to Machine Learning	03	
	Introduction to Classical Mechanics	03	
	Scientific Writing and Research Methods	03	
Major Courses	Real Analysis-I	03	42
	Partial Differential Equations	03	
	Topology	03	
	Real Analysis-II	03	
	Complex Analysis	03	
	Differential Geometry	03	
	Optimization Theory	03	
	Elective-I (Semester-II)	03	
	Elective-II (Semester-III)	03	
	Elective-III (Semester-III)	03	
	Elective-IV (Semester-III)	03	
	Elective-V (Semester-IV)	03	
	Elective-VI (Semester-IV)	03	
	Elective-VII (Semester-IV)	03	
Total Credit Hours of the Program			63

13.2 Semester-Wise Breakdown

1st Year

Semester-I

MATH-3501	Real Analysis-I	Major	3	0	3
MATH-3502	Topology	Major	3	0	3
MATH-3503	Partial Differential Equations	Major	3	0	3
MATH-3504	Advanced Programming	Interdisciplinary	2	1	3
MATH-3505	Introduction to Mechanics	Interdisciplinary	3	0	3
Total Credit Hours					**15**

Semester-II

MATH-3601	Real Analysis-II	Major	3	0	3
MATH-3602	Complex Analysis	Major	3	0	3
MATH-3603	Introduction to Machine Learning	Interdisciplinary	2	1	3
MATH-3504	Introduction to Classical Mechanics	Interdisciplinary	3	0	3
---------	Elective-I*	Major	3	0	3
	*List of Elective Courses				
MATH-3605	Vector and Tensor Analysis	Major	3	0	3
AI-3605	Artificial Neural Networks	Major	2	1	3
DATS-3605	Regression Model and Analysis	Major	3	0	3
ECON-3605	Econometrics and Big data	Major	2	1	3
Total Credit Hours					**15**

2nd Year

Semester-III

MATH-4701	Internship*	Internship	3	0	3
MATH-4702	Scientific Writing and Research Methods	Interdisciplinary	3	0	3
MATH-4703	Differential Geometry	Major	3	0	3
---------	Elective-II*	Major	3	0	3
---------	Elective-III*	Major	3	0	3
---------	Elective-IV*	Major	3	0	3
	*List of Elective Courses				
MATH-4704	Functional Analysis	Major	3	0	3
MATH-4705	Fluid Mechanics-I	Major	3	0	3
MATH-4706	Numerical Methods II	Major	3	0	3
MATH-4707	Mathematical Physics	Major	3	0	3
MATH-4708	Number Theory and Metric Spaces	Major	3	0	3
MATH-4709	Measure Theory	Major	3	0	3
MATH-4710	Discrete Structures	Major	3	0	3
MATH-4711	Special Functions	Major	3	0	3
MATH-4712	Quantum Mechanics-I	Major	3	0	3
MATH-4713	Ring Theory	Major	3	0	3
MATH-4714	Analytical Dynamics	Major	3	0	3
MATH-4715	Approximation Theory	Major	3	0	3
MATH-4716	Differential Geometry-II	Major	3	0	3
MATH-4717	Electromagnetic Theory-I	Major	3	0	3
MATH-4718	Introduction to Univalent Functions	Major	3	0	3
AI-4719	Digital Logic Design	Major	2	1	3
DATS-4719	Data Science with Fundamentals	Major	3	0	3
DATS-4720	Platform and Architecture for Data Science	Major	3	0	3
DATS-4721	Big Data Analytics	Major	2	1	3

DATS-4722	Exploratory Data Analysis and Visualization	Major	3	0	3
ECON-4719	Principles of Economics	Major	3	0	3
ECON-4720	Computational Economics	Major	2	1	3
ECON-4721	Principles of Microeconomics	Major	3	0	3
ECON-4722	Principles of Macroeconomics	Major	3	0	3
Total Credit Hours					**18**
	Semester-IV				
MATH-4801	Capstone Project	Capstone	0	3	3
MATH-4802	Optimization Theory	Major	3	0	3
---------	Elective-V	Major	3	0	3
---------	Elective-VI	Major	3	0	3
---------	Elective-VII	Major	3	0	3
	*List of Elective Courses				
MATH-4803	Integral Equations	Major	3	0	3
MATH-4804	Fluid Mechanics-II	Major	3	0	3
MATH-4805	Dynamical Systems	Major	3	0	3
MATH-4806	Mathematical Modeling	Major	3	0	3
MATH-4807	Mathematical Systems Theory	Major	3	0	3
MATH-4808	Algebraic Topology	Major	3	0	3
MATH-4809	Special Functions	Major	3	0	3
MATH-4810	Quantum Mechanics-II	Major	3	0	3
MATH-4811	Introduction to Combinatorics	Major	3	0	3
MATH-4812	Variational Inequalities	Major	3	0	3
MATH-4813	Theory of Elasticity	Major	3	0	3
MATH-4814	Special Theory of Relativity	Major	3	0	3
MATH-4815	Fixed point Theory	Major	3	0	3
MATH-4816	Mathematical Statistics II	Major	3	0	3
MATH-4817	Fractional Calculus	Major	3	0	3
AI-4818	Introduction to Artificial Intelligence	Major	3	0	3
AI-4819	Programming for Artificial Intelligence	Major	2	1	3
DATS-4818	Statistical Packages & Data Analysis (SPSS, R & Python)	Major	2	1	3
DATS-4819	Time Series Analysis	Major	3	0	3
ECON-4818	Dynamic Economic Modeling	Major	3	0	3
ECON-4819	Intermediate Microeconomics	Major	3	0	3
ECON-4820	Intermediate Macroeconomics	Major	3	0	3
Total Credit Hours					**15**
Total Credit Hours of the Program					**63**

* The internship will be registered during 3rd or 4th semester according to the approved policy of the University.

14. Admission Criteria for MPhil in Mathematics

Sr. No.	Content	Requirement	Remarks
1	Mathematics		
		UGAT (Mathematics) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 50%	
2	Intra-disciplinary	BS / MSc or Equivalent Degree in Science (Physics, Statistics, CS, IT)	Such students may be allowed for admission in MS Program and will be offered deficiency courses during first year of the degree program with 6 to 9 Credit Hours.
		UGAT (Mathematics) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 50%	

15. Scheme of Studies for MPhil in Mathematics: General Breakup

Sr. No	Content	Description
1	Awarding Institute/Body	Mirpur University of Science and Technology (MUST)
2	Teaching Institute	Department of Mathematics, Mirpur University of Science and Technology (MUST), and affiliated colleges
3	Nomenclature	MPhil in Mathematics
4	Starting Time for Program	Fall/Spring semester of each academic year
5	Duration of the Program	4-8 Semesters
6	Entrance Requirements	BS or equivalent degree with science (Min 45% marks)
		No 3rd Division in Matric and Intermediate
		Mathematics: UGAT (Mathematics) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 50%. Intra-disciplinary: UGAT (Mathematics) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 50%
7	Merit Formula	Merit formulas are the following: For M.Sc: 15% of Intermediate, 20% of B.Sc, 20% of M.Sc, 35% of Entry Test marks, and 10% of interview conducted by the department. For BS**:** 15% of Intermediate, 40% of BS, 35% of Entry Test marks, and 10% of interview conducted by the department.
8	Total Credit Hours	Course Work: 26 Credit Hours
		Seminar (Compulsory): 1 Credit Hour
		Thesis (Compulsory): 6 Credit Hours

15.1 Program Educational Objectives (PEOs)

After graduation, our students will be equipped not only with advanced mathematical tools but will also acquire skill set needed to apply mathematics towards engineering problems. Moreover, our graduates will be able to:

i. Collaborate with engineers, scientists and other professionals from industry and academia on research/projects.

ii. Promote the culture of interdisciplinary novel research and produce fundamental & applied quality research in Pakistan

iii. Contribute through publishing fundamental research in the emerging areas of science and engineering, like, systems and control, computational fluid dynamics, mathematical modelling, and complex analysis etc.

15.2 Program Learning Outcomes (PLOs)

The curriculum for MS program is so designed that the students undertaking research in this department will have a chance to learn not only the fundamental courses of mathematics but also advanced courses related to their area of specialization and interest. Fundamental and emerging specializations in the domain of mathematics, like systems and control, computational and theoretical fluid dynamics, advanced complex analysis, mathematical modelling of biological systems, and applied and theoretical statistics etc., will be offered as area of research for graduate students at this department. The mathematics department is also providing support to other engineering and sciences departments of MUST, so upon successful completion of the courses taught by mathematics faculty, students will be able to:

PLO-01: Apply knowledge of mathematics, science, and engineering fundamentals to the solution of complex problems involved in different areas of engineering and sciences.

PLO-02: Identify, formulate, search literature, and analyze mathematical models governing laws of physics and other engineering sciences.

PLO-03: Design solution strategy for mathematical models arising in aerospace engineering, electrical engineering, mechanical engineering, and other science and engineering disciplines.

PLO-04: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling the physical phenomena with an understanding of the limitations.

PLO-05: Communicate effectively on mathematical activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive instructions effectively.

PLO-06: Apply ethical principles and exhibit commitment to professional ethics, responsibilities and norms of the profession.

15.3 Scope of the Program

The mathematical experts are in demand across all kind of industries, the world over. The curriculum of MS Mathematics is so designed that students in this department will have a chance to learn not only the fundamental courses of mathematics but also advanced courses and tools related to the emerging areas of applied mathematics like systems and control, mathematical modelling, computational fluid dynamics, complex analysis, statistics, etc. Some of the career opportunities for our graduates are listed in the following.

a). Teaching at school, college, or higher level
b). R&D and strategic organizations like PAEC, NESCOM, SUPARCO, KRL, etc.
c). Banking sector, trading, and stock exchange businesses
d). Higher studies in national and international universities and institutes
e). Armed forces, civil services, oil and gas sector, etc.

16. Modification in The Scheme of Study for MPhil in Mathematics

16.1 Structure of MPhil in Mathematics

Course Code	Description	Credit Hours
01	Minimum Credit Hours	33
02	Minimum Course Work Required	24
03	Core Courses	12
04	Elective Courses	12
05	Understanding of Holy Quran-I	0-1
06	Understanding of Holy Quran-II	0-1
07	Seminar	01
08	Thesis	0-6
Total Credit Hours		33

Program	Previous Courses	Course type	Proposed Amendment / New Offering
MS in Mathematics	A list of elective courses is given. A student will have to complete 24 Credit Hours (8-courses).	Core Courses	A list of elective courses is given. A student will have to complete 12 Credit Hours (4-courses).
		Elective Courses	A list of elective courses is given. A student will have to complete 12 Credit Hours (4-courses).
		General Courses	Two course of Understanding of Holy Quran will be offered with 02 credit hours during first year

16.2 List of Courses for MPhil in Mathematics Program

A. Compulsory Requirements

Course Code	Course Title	Category	Credit Hours
UHQ-796	Understanding of Holy Quran-I	General Education	0-1
UHQ-797	Understanding of Holy Quran-II	General Education	0-1
MATH-798	Seminar	Mandatory	01
MATH-799	Thesis	Mandatory	0-6

In the following, a list of core courses is given. A student will have to complete 12 credit hours (4 core courses) of his/her course work from these courses.

First Year (Semester I)			
Course Code	**Course Title**	**Category**	**Credit Hours**
UHQ-796	Understanding of Holy Quran-I	General Education	0-1
---------	Core - I*	Core Courses	
---------	Core - II*	Core Courses	
---------	Core - III*	Core Courses	
---------	Core - IV*	Core Courses	
*List of Core Courses			
MATH-701	Advanced Optimization Theory	Core Course	03
MATH-702	Advanced Complex Analysis	Core Course	03
MATH-703	Advanced Partial Differential Equations	Core Course	03
MATH-704	Advanced Mathematical Modelling	Elective Course	03
MATH-705	Finite Element Methods	Core Course	03
MATH-706	Deep Neural Networking and Artificial Intelligence	Core Course	2-1

A. Elective Courses (12 credit hours)

In the following, a list of elective courses is given. A student will have to complete 12 credit hours of his/her course work from these courses.

First Year (Semester II)			
Course Code	**Course Title**	**Category**	**Credit Hrs.**
UHQ-797	Understanding of Holy Quran-II	General Education	0-1
---------	Elective - I*	Elective	03
---------	Elective - II*	Elective	03
---------	Elective - III*	Elective	03
---------	Elective - IV*	Elective	03
*List of Elective Courses			
MATH-707	Advanced Numerical Analysis	Core Course	03
MATH-708	Finite Difference Methods	Elective Course	03
MATH-709	Non-Newtonian Fluid Mechanics	Elective Course	03
MATH-710	Advanced Integral Equations	Core Course	03
MATH-711	Advanced Mathematical Physics	Elective Course	03
MATH-712	Numerical Methods for Differential Equations	Elective Course	03
MATH-713	Advances in Discrete Mathematics and Applications	Elective Course	03
MATH-714	Geometric Functions Theory	Elective Course	03
MATH-715	Mathematical Techniques for Boundary Value Problems	Elective Course	03
MATH-716	Optimal Control	Elective Course	03
MATH-717	Fundamentals of the Theory of Fluids	Elective Course	03
MATH-718	Group Methods for Differential Equations	Elective Course	03
MATH-719	Approximation Theory	Elective Course	03
MATH-720	Complex Analysis of Several Variables	Elective Course	03
MATH-721	Advanced Analytical Dynamics	Elective Course	03
MATH-722	Introduction to Robotics	Elective Course	03
MATH-723	Stochastic Differential Equations	Elective Course	03
MATH-724	Multivariate Analysis	Elective Course	03

MATH-725	Time Series	Elective Course	03
MATH-726	Advanced Functional Analysis	Elective Course	03
MATH-727	Variational Inequalities	Elective Course	03
MATH-728	Graph Theory	Elective Course	03
MATH-729	Lie Algebra	Elective Course	03
MATH-730	Convex Analysis	Elective Course	03
MATH-731	Advanced Topology	Elective Course	03
MATH-732	Advanced Abstract Algebra	Elective Course	03
MATH-733	Mathematical Ecology	Elective Course	03
MATH-734	Biomathematics	Elective Course	03
MATH-735	Advances in Discrete Mathematics and Applications	Elective Course	03
MATH-736	Graph Theory	Elective Course	03
MATH-737	Lie Algebra	Elective Course	03
MATH-738	Fuzzy Algebra	Elective Course	03

Remark: The Departmental Council recommends to include additional 1 Credit hour each for Understanding of Holy Quran I & II in First and Second Semester respectively.

17. Courses for MPhil in Mathematics Program

Course Code: MATH-701 Title: Advanced Optimization Theory Credit Hrs: 03

Course Outline: Intro to mathematical optimization, objective of constraint functions, basic optimization concepts, mathematical prerequisites, convexity, gradient vectors, Hessian matrix, global and local minima, saddle points, optimality conductions, general structure for line search method, Wolf conditions, Goldstein conditions, convergence of line search method, convergence of steepest decent method, Newton method, Quasi Newton method, Newton method with Hessian approximation, line search algorithm for Wolf conditions, conjugate gradient method, Trust Region Method and Cauchy point, Newton point, Dogleg method.

Texts and Reference Books

1. L. Elsgolts, *DEs and the Calculus of Variations,* Mir Publishers Moscow, 1970.
2. B. S. Gotfried and J. Weisman, *Introduction to Optimization Theory,* Prentice Hall, Englewood Cliffs, NJ, USA, 1973.
3. D. G. Luenberger, *Introduction to Linear and Non-Linear Programming,* Addision Wesley, Reading, Ma, USA, 1973.
4. D. A. Pierre, *Optimization Theory with Applications,* Dover Publications, 1986.

Course Code: MATH-702 Title: Advanced Complex Analysis Credit Hrs: 03

An Overview of the Theory of a Compl, ex Variable, Argument Principle, Rouche's Theorem, Conformal Mapping, Harwitz Theorems, Cauchy's Theorem on Partial Fraction Expansions, Inverse and Implicit Functions, Riemann Mapping Theorem, Univalent Functions, Basic Properties of Harmonic, Positive Harmonic and Subharminic Functions, Poisson Integral Formula, Mittag-Leffler and Weierstrass Theorems, Infinite Products and Weierstrass Factorisation Theorem, Analytic Continuation, Special Functions Including Gamma Function, Riemann Zeta Function, Prime Number Theorem, Elliptic Functions

Texts and Reference Books

1. L. V. Ahlfors, *Complex Analysis*, M. G. Hill, 1979.
2. R.V. Churchill and J.W. Brown, *Complex Variables and Applications*, 5th Edition, M. Graw Hill, 1989.
3. J. B. Conway, *Functions of one Complex Variable*, Springer, 1979.
4. E. Hill, *Analytic Function Theory*, Vol. I and II, Chelsea Publishing Company, New York, 1974.

Course Code: MATH-703 Title: Advanced Partial Differential Equations Credit Hrs: 03

Course Outline: Cauchy's Problems for Linear Second Order Equation in N- Independent Variables, Cauchy Kowalewski Theorem, Characteristic Surface, Adjoint Operations, Bicharacteristics, Spherical and Cylindrical Waves, Heat Equations, Wave, Laplace and Diffusion Equations in Spherical and Cylindrical Polar Coordinates, Maximum-Minimum Principle, Non-Homogeneous Partial Differential Equations.

Texts and Reference Books

1. C. B. Chester, *Techniques in Partial Differential Equations*, McGraw Hill Book Company, 1971.
2. R. Dennemyer, *Introduction to Partial Differential Equations and Boundary Value Problems*, McGraw Hill Book Company, 1968.
3. H. F. Weinberger, *A First Course in Partial Differential Equations: with Complex Variables and Transform Methods*, Dover Publications, 1995.
4. E. C. Zachmanoglou and D. W. Thoe, *Introduction to Partial Differential Equations with applications,* Dover Publications, 1987.

Course Code: MATH-704 Title: Advanced Mathematical Modeling Credit Hrs: 03

Course Outline: Modeling through Differential Equations, Mathematical modeling through Ordinary Differential Equations, Mathematical modeling through system of Ordinary Differential equations of first order, Excursive of some modeling projects to demonstrate the variety of the require equations to formulate essential, control theory as modeling tool, Parameter estimation as optimization problem, Sensitivity analysis, Parameter estimation, Situation giving rise to Partial Differential Equations, Modeling through Delay differential and Differential–Difference equations

Texts and Reference Books

1. Edwards, D. and Hamson, Mathematical modeling Skills, Macmillan Press Ltd, 1996.
2. Giordano, F.R., Weir, M.D. and Fox, W.P., A First Course in Mathematical modeling , Thomson Brooks/Cole, 2003.
3. J.N.Kapur, Mathematical modeling , New Age international (P) Limited, 2015.
4. M. M. Meerschaert, Mathematical modeling, 4th Edition, Academic Press, 2013.

Course Code: MATH-705 Title: Finite Element Methods Credit Hrs: 03

Course Outline: Finite Element Methods: General Approach, The Galarkin Method in One and More Dimensions and Application, Error Bound on the Galarkin Method and Application, The Method of Collocation, Error Bounds on the Collocation Method and Application, Comparison of Efficiency of the Finite Difference and Finite Element Method, Application to Solution of Linear and Non-Linear Partial Differential Equations Appearing in Physical Problems

Texts and Reference Books

1. S. D. Burnett, Finite Element Analysis from Concept to Applications, Addison Wesley, 1987.
2. G. S. Desai, Elementary Finite Element Method, Prentice Hall, 1988.
3. G. Strang and G. Fix, Analysis of Finite Element Method, Prentice Hall, New Jersey, 1973.
4. J. N. Reddy, Introduction to the Finite Element Method, 3rd Edition, MHI, 2006.

Course Code: MATH-706 Title: Deep Neural Networking and Artificial Intelligence Credit Hours: 02+01

Course Outline: Nodes of a Neural Network, Layers of Neural Networks, Supervised Learning of a Neural Network, Training of a Single Layer Neural Networks, Generalized Delta Rule, SGD, Batch and Mini Batch, Stochastic Gradient Descent, Implementations of these Methods, Limitations of Single Layer Neural Networks, Training of Multi-Layer Neural Network, Back Propagation Algorithm, Cost Function and Learning Rule, Cross Entropy Function, Neural Network and Classification, Binary Classification, Multiclass Classification. Conventional Neural Networking.

Texts and Reference Books

1. Phil Kim, MATLAB Deep Learning, Apress (2017).

Course Code: MATH-707 Title: Advanced Numerical Analysis Credit Hrs: 03

Course Outline: Numerical Differentiation, Richardson's Extrapolation, Elements of Numerical Integration, Composite Numerical Integration, Romberg Integration, Adaptive Quadrature Methods, Gaussian Quadrature, Multiple Integrals, Improper Integrals

Discrete Least Squares Approximation, Orthogonal Polynomials and Least Squares Approximation, Chebyshev Polynomials and Economization of Power Series, Rational Function and Trigonometric Polynomial Approximations, Fast Fourier Transforms Linear Algebra and Eigenvalues, The Power Method, Householder's Method

Fixed Points for Functions of Several Variables, Newton's Method, Quasi-Newton Methods, Steepest Descent Techniques, Homotopy and Continuation Methods

The Linear Shooting Method, The Shooting Method for Nonlinear Problems, Finite-Difference Methods for Linear Problems, Finite-Difference Methods for Nonlinear Problems, The Rayleigh-Ritz Method

Elliptic Partial Differential Equations, Parabolic Partial Differential Equations, Hyperbolic Partial Differential Equations, An Introduction to the Finite-Element Method

Text and Reference Books

1. R. L. Burden and 1. D. Faires*, Numerical Analysis,* 9th Edition, PWS Publishing Company, 2011.
2. K.E. Atkinson*, An Introduction to Numerical Analysis*, 2nd Edition, John Wiley and Sons, New York, 1989.
3. U. Ascher, R. Matteij and R. Russell, *Numerical Solution of BVPs for ODEs*, Prentice Hall, 1988.
4. M. S. Allen, I. Herrea and George F., *Numerical Modeling in Science and Engineering*, Wiley-Interscience, 99 edition, 1988.

Course Code: MATH-708 Title: Finite Difference Methods Credit Hours: 03

Course Outline: Introduction to Finite Difference, Convergence, IVPs, IBVPs, Consistency, Stability, Lax Theorem, Gerschgorin Circle theorem, Parabolic Equations and different explicit and implicit methods, One and Two dimensional, ADI, Non-homogeneous ADI, Hyperbolic Equations and different explicit and implicit methods, Periodic boundary Conditions, Systems of PDEs, Dispersion and Dissipation.

Texts and Reference Books

1. Numerical Partial Differential Equations, by Thomas.
2. Numerical Methods for solving PDEs by Pinder.

Course Code: MATH-709 Title: Non-Newtonian Fluid Mechanics Credit Hrs: 03

Course Outline: Classification of Non-Newtonian Fluids, Rheological Formulates (Time–Independent Fluids, Thyrotrophic Fluids and Viscoelastic Fluids), Variable Viscosity Fluids. Cross Viscosity Fluids, The Deformation Rate, The Rivlin-Ericksen Fluid, Basic Equation of Memories in Rheological Models. The Linear Viscoelastic Liquid, Couette Flow, Poiseuille Flows, The Current Semi-Infinite Field. Axial Oscillatory Tube Flow, Angular Oscillatory Motion, Periodic Transients, Basic Equations in Boundary Layer Theory, Orders of Magnitude, Truncated Solutions for Viscoelastic Flow, Similarity Solutions. Turbulent Boundary Layers, Stability Analysis.

Texts and Reference Books

1. G. Astarita and M. G.*Principles of Non-Newtonian Fluid mechanics*McGraw-Hill 1974.
2. R. B. Bird, R. C. Armstrong and O. Hassager, *Dynamic of Polymeric liquids*,Vol. 1 and II, John Wiley and Sons, New York, 1987.
3. W. F. Robert and A. T. McDonald, *Introduction to Fluid Mechanics,* John Wiley and Sons, 1995.
4. W. R. Schowalter, *Mechanics of Non-Newtonian Fluids,* Pergamon Press, New York, 1978.

Course Code: MATH-710 Title: Advanced Integral Equations Credit Hrs: 03

Course Outline: Existence Theorem, Integral Equations with L2 Kernal, Applications to Partial differential equations, Integral Transforms, Wiener-Hopt Techniques.

Texts and Reference Books

1. H. H. Stadl, Integral Equactions,John Wiley and Sons, 1973.
2. I. Stakgold, Boundary Value Problems of Mathematical Physics, Macmillan, New York, 1968.
3. F. G. Tricomi, Integral Equations, Inter science, 1957.
4. J. J. Abdul, Introduction to Integral Equations with Applications, Marcel Dekker Inc. New York, 1985.

Course Code: MATH-711 Title: Advanced Mathematical Physics Credit Hrs: 03

Course Outline: Nonlinear ordinary differential equations, Linear partial differential equations, classification, initial and boundary values problems, Fourier analysis, Heat equation, Wave equation, Laplace equation etc. Integral equations, classification, d,Alembert solutions, Initial boundary value problems, semi-infinite string with a fixed end, equations with non-homogeneous boundary conditions, vibration of finite string with fixed ends, non-homogeneous wave equations, Method of separation of variables, vibration of a circular membrane: symmetric case, vibration of a circular membrane: general case, non-homogeneous problems, time independent boundary conditions, method of eigen function expansion, Method of eigenfunction using Green's formula, forced vibrating membranes and resonance, methods of Green's function.

Text and Reference Books

1. G. Stephenson and P. M. Radmore, *Advanced Mathematical Methods for Engineeering and Science Students,* Cambridge University Press, 2006.
2. K. T. Tang, *Mathematical Methods for Engineers and Scientists,* Volumes I, II & III, Springer, 2007.
3. M. Stone and P. Goldbart, *Mathematics for Physics*, Academic Press, 2005.
4. S.I. Hayek*, Advanced Mathematical Methods in Science and Engineering*, 2010.

Course Code: MATH-712 Title: Numerical Methods for Differential Equations Credit Hours: 03

Course Outline: Interpolation, Lagrange interpolation, Error, Multiple elements, Two point Difference formulas, Weighted Residual Methods, finite Volume method, Examples, Galerkin Method for First order Equations, Galerkin Method for second order Equations, Finite Difference Interpretation of second order Galerkin Method, Collocation method, Initial boundary value problem, Finite difference methods in two space, Finite element methods in two space, Finite volume in two space, Initial BVPs.

Texts and Reference Books

1. Numerical Partial Differential Equations, by Thomas.
2. Numerical Methods for solving PDEs by Pinder.

Course Code: MATH-713 Title: Advances in Discrete Mathematics and Applications Credit Hours: 03

Course Outlines: Introduction, Definitions of stability and linearized stability, Semi-cycle analysis, Full limiting sequences and Convergence theorems, Lyness equation, Todd equation, the generalized Lozi equation, the Gingerbreadman equation and the Riccati difference equation, analysis of semi-cycle of some special type of equations, Period-2 solutions, Global asymptotic stability of period-2 solutions, Existence of unbounded solutions and Boundedness of solutions, on the systems of rational difference equations

Text and Reference Books:

1. M. R. S. Kulenovic*, Dynamics of Second Order Rational Difference Equations: With Open Problems and Conjectures*, Chapman and Hall/CRC, 2005.
2. E. Camouzis, G. Ladas, *Dynamics of Third-Order Rational Difference Equations with Open Problems and Conjectures*, Chapman and Hall/CRC, 2007.
3. M. H. Education, *Advanced Mathematical Concepts*, 6th Edition, McGraw-Hill Education, 2003.
4. K. Abidi and J. X. Xu, *Advanced Discrete-Time Control: Designs and Applications*, 5th Edition, Springer, 2015.

Course Code: MATH-714 Title: Geometric Functions Theory Credit Hrs: 03

Course Outline: Holomorphic Functions and their Convergence, Metric Spaces and Fixed Point Principles, Schwarz-Pick Lemma and Automorphisms, Boundary Behavior of Holomorphic Self-Mappings and Fixed Points and Fixed Point Free Holomorphic Self-Mappings, The Denjoy-Wolff Theorem, Commuting Family of Holomorphic Mappings, Hyperbolic Geometry and Fixed Points, The Poincare Metric and its Compatibility with Convexity, Infinitesimal Poincare Metric and Geodesics, Fixed Points of Non-expansive Mappings

One-Parameter Continuous Semigroup of Holomorphic and Nonexpansive Self-Mappings, Infinitesimal Generator, Nonlinear Resolvent and the Exponential Formula, Monotonicity w.r.t the Hyperbolic Metric, Flow Invariance Conditions, The Berkson-Porta Parametric Representation of Semi-Complete Vector Fields, Asymptotic Behavior of Continuous Flows, Stationary Points of a Flow, Null Points of Complete Vector Fields, Embedding of Discrete Time Group and Rates of Convergence of a Flow with an Interior Stationary Point, A Rate of Convergence in Poincare Metric, Continuous Version of the Julia-Wolff-Caratheodory Theorem, Lower Bounds for Monotone Functions, Asymptotic behavior of Continuous Flows, Dynamical Approach to Starlike and Spirallike Functions

Texts and Reference Books

1. D. Shoket, *Semigroups in Geometric Function Theory*, Kluwer Academic Publishers, 2001.
2. S. G. Krantz, *Geometric Function Theory: Explorations in Complex Analysis*, 2006th Edition, Birkhäuser, 2005.
3. G. Kohr, G. Graham and I. Graham, *Geometric Function Theory in One and Higher Dimensions*, 1st Edition, CRC Press, 2003.
4. L. V. Ahlfors, *Conformal Invariants: Topics in Geometric Function Theory,* McGraw-Hill Inc.,US, 1973.

Course Code: MATH-715 Title: Mathematical Techniques for BVPs Credit Hrs: 03

Course Outline: Green's Function Method, Perturbation Method: Regular and Singular Perturbation Techniques with Application, Variational Methods, Wiener-Hopf Techniques with Applications to Diffraction Problems.

Texts and Reference Books

1. R. Mitra and S. W. Lee, *Analytical Techniques in the Theory of Guided Waves,* Macmillan, 1971.
2. E. J. Hinch, *Perturbation Methods,* Cambridge University Press , 1991.
3. B. Noble, *Methods Based on the Wiener Hopf Techniques for the Solution of Partial Differential Equations,* 2nd Edition, American Mathematical Society, 1988.
4. I. Stakgold, *Boundary Value Problems of Mathematical Physics,* Society for Industrial and Applied Mathematics, 1987.

Course Code: MATH-716 Title: Optimal Control Credit Hrs: 03

Course Outline: Calculus of Variation: Principle of calculus of variation, Euler Equation in Calculus of variation, some important theoretical results of calculus of variation and mathematical examples

Optimal Control and the Minimum Principle: Application of calculus of variation in optimal control, simplest problem in the Calculus of variation, Necessary condition for optimality, Lagrange multipliers, and Hamiltonian equations, The minimum principle, solution of Zermelo's problem, Linear quadratic cost problem with finite and infinite horizon: theory and examples,

Optimal Control Theory and Dynamic Programming: Dynamic programming in discrete time, Principle of optimality and Bellman's equation, linear quadratic cost problem with finite and infinite horizon in the dynamic programming perspective: theory and examples,

Differential Games: Introduction, continuous time differential games, intro to Nash and Stackleberg equilibrium solutions concepts, solutions of Nash differential games: theory and examples

Texts and Reference Books

1. D. Liberzon, *Calculus of Variations and Optimal Control Theory: A Concise Introduction*, Princeton University Press, 2012
2. G. Meisma, *Lecture Notes on Optimal Control*, University of Twente, Enschede, The Netherlands, 2013.
3. D. E. Krik, *Optimal Control Theory: An Introduction,* Dover Publications, 2004.
4. R. F. Stengel, *Optimal Control,* Dover Publications, 1994.

Course Code: MATH-717 Title: Fundamentals of the Theory of Fluids. Credit Hrs: 03

Course Outline: Euler's Equations of Motion, Viscosity, Navier-Stokes Equations and Exact Solutions, Dynamical Similarity and Reynolds Number, Energy Equation, Boundary Layer Concept and Governing Equations, Magnetohydrodynamics (MHD) Equations, Fluid Drifts, Stability and Equilibrium Problems, Introduction to Turbulent Flow.

Texts and Reference Books

1. G. Astarita and G. Merrucci, *Principles of Non-Newtonian Fluid mechanics,* M. Graw Hill, 1974.
2. R. B. Bird, R. C. Armstrong and O. Hassager, *Dynamic of Polymeric liquids,* Vol. I, 2nd Edition, John Wiley and Sons, New York, 1987.
3. J. Harris, *Rheology and Non-Newtonian Flow,* Longman Inc., New York, 1977.
4. Schowalter, *Mechanics of Non-Newtonian Fluids,* Pergamon Press, New York, 1978.

Course Code: MATH-718 Title: Group Methods for Differential Equations Credit Hrs: 03

Course Outline: Basic Concept of Groups of Transformation, Parameter Lie Group of Transformation (LGT), Infinitesimal Transformation (I.T), Infinitesimal Generators, Lie's First Fundamental Theorem, Invariance, Canonical Coordinates, Elongations, Multi-Parameter Lie Group of Transformation (MLGT), Lie Algebra, Solvable Lie Algebra, Lie's Second and Third Fundamental Theorems.

Invariance of ODE's Under (LGT) and (MLGT), Mapping Solutions to Other Solutions From Invariance of an ODE and PDE, Determining Equations (I.T) of and N^{th} Order ODE and System of PDE's, Determination of N^{th} Order ODE Invariant Under a Given Group, Reduction of Order by Canonical Coordinates and Differential Invariants, Invariant Solutions of ODE's and PDE's Separatices and Envelops Neother's Theorem and Lie-Backlund Symmetries, Potential Symmetries, Mapping of Differential Equations

Texts and Reference Books

1. G. W. Bluman and S. Kumei, *Symmetries and Differential Equations,* Springer-Verlag, New York, 1989.
2. J. M. Hill *Differential Equations and Group Methods,* CRC Press, Inc. New York, 1992.
3. M. A. Armstrong, *Groups and Symmetry* , 2nd Edition, Springer, 1997.
4. M. S. Gockenbach, *Partial Differential Equations: Analytical and Numerical Methods,* 2nd Edition, Society for Industrial and Applied Mathematics, 2010.

Course Code: MATH-719 Title: Approximation Theory. Credit Hrs: 03

Course Outline: Best Approximation in Metric and Normed Spaces, Least Square Approximation, Rational Approximation, Haar Condition and Best Approximation in Function Spaces, Interpolation, Stone-Weierstrass Theorem for Scalar and Vector-Valued Functions, Spline Approximation.

Texts and Reference Books

1. E. W. Cheney, *Introduction to Approximation Theory*, M. Graw Hill, New York, 1966.
2. I. Singer, *Best Approximation in Normed Linear Spaces by Elements of Linear Subspaces*, Springer Verlag, 1970.
3. J. R. Rice, *The Approximation of Functions, Vol. I, II,* Addison Wesley, 1969.
4. R. B. Holmes, *A Course on Optimization and Best Approximation, Lecture Notes,* Springer Verlag, 1971.

Course Code: MATH-720 Title: Complex Analysis of Several Variables Credit Hrs: 03

Course Outline: Holomorphic Functions: Review of One Variable Theory, Real and Complex Differentiability, Power Series, Complex Differentiable Functions, Cauchy Inequalities, The Maximum Principles.

Extension of Analytical Functions: Hartogs Figures, Hortogs Theorems, Domains of Holomorphy, Holomorphic Convexity, Theorem of Cartan Thullen.

Levi-Convexity: The Levi Forms, Geometric Interpretation of its Signature, E. E. Levi's Theorem, Connections with Khlerian Geometry, Elementary Properties of Plurisubharmonic Functions.

Introduction to Cohomology: Definition and Example of Complex Manifolds, The D Ð Б Operators, The Poincare Lemma and the Dolbeaut Lemma, The Cousin Problems, Introduction to Sheaf Theory.

Texts and Reference Books

1. J. Morrow and K. Kodaria, *Complex Manifolds,* Holt, Rinehart and Winston, New York, 1971.
2. L. Hormander, An *Introduction to Complex Analysis in Several Variables,* D. V. Nostarnad, New York, 1966.
3. H. Grauert and K. Fritsch, *Several Complex Variables,* Springer Verlag, 1976.
4. M. Field, *Several Variables and Complex Manifolds,* Cambridge University Press, 1982.

Course Code: MATH-721 Title: Advanced Analytical Dynamics Credit Hrs: 03

Course Outline: Equations of Dynamic and its Various Forms, Equations of Langrange and Euler, Jacobi's Elliptic Functions and the Quantitative and Quantitative Solutions of the Problem of the Euler and Poisson, the Problems of Langrange and Poisson, Dynamical System, Equations of Hamilton and Appell, Hamilton–Jacobi Theorem, Separable System, Holder's Variational Principle and its Consequences. Group of Continuous Transformations and Poincare's Equations, System with one Degree of Freedom, Singular Points, Cyclic Characteristics of System With N-Degree of Freedom, Ergodic Theorem, Metric Indecompossability, Stability of Motion, Periodic Orbits.

Texts and Reference Books

1. H. Baruh, *Analytical Dynamics,* Heinmann, 1st Edition, WCB/McGraw-Hill, 1998.
2. E. T. Whittaker, *A treastise on Dynamic of Rigid Bodies and Particles,* At the University Press, 1927.
3. V. D. Sapio, *Advanced Analytical Dynamics: Theory and Applications,* 1st Edition, Cambridge University Press, 2017.
4. L. Meirovitch, *Methods of analytical dynamics*, McGraw-Hill , 1970.

Course Code: MATH-722 Title: Introduction to Robotics Credit Hrs: 03

Course Outline: Fundamental Concepts: Introduction to Robot (Fundamental notions and Definitions), Jacobians: Transformations and Jacobians, Manipulator. Kinematics: Kinematics (Forward and Inverse) of manipulator, Manipulator Dynamics, Trajectory Generation, Manipulator Mechanism, Manipulator Design. Linear Control: Linear Control of Minipulator, Non-linear Control of Manipulator, Forced Control of Manipulator, Multivariable Control: Multivariable control, Feedback linearization, Variable structure and Adaptive Control.

Texts and Reference Books

1. J. J. Craig, *Introduction to Robotics*, Addison-Wesley Publishing Company, 1999.
2. Mark, W. Sponge and M. Vidyasagar*, Robot Dynamics Control*, John Wiley and Sons, 2004.
3. Gene Franklin, J. David Powell *Feed-back Control of Dynamic Systems*, A. E. N. Addison-Wesley Publishing Company , 1989.
4. S. M. Shinners, *Modern Control System Theory and Applications*, Addison-Wesley Publishing Company, 1987.
5. John, J. Craig, *Adaptive Control of Mechanical Manipulators*, Addison-Wesley Publishing Company, 1997.

Course Code: MATH-723 Title: Stochastic Differential Equations Credit Hrs: 03

Course Outline: Brief Introduction to Diffusion Processes and How They Arise as Natural Approximations to Certain Discrete Processes, Review of Some Basic Facts about Brownian Motion and Martingales, ITO Stochastic Integrals Construction and Martingale Properties, ITO's Formula, Integration by Parts, Comparison with Stieltjes Integrals and Ordinary Calculus, Stochastic Differential Equations, Existence and Uniqueness of Solutions, Markov Property, Generators, Martingale Problem Characterization of Weak Solutions, Diffusion Processes, Dynkin's Formula, Calculations of Expectations and Probabilities, Converting to the Natural Scale, Stationary Distributions, Examples from Biology: Wright-Fisher Diffusions, Branching Diffusions

Texts and Reference Books

1. K.L. Chung and R. J. Williams, *Introduction to stochastic integration*, Second Ed., Probability and its Applications, Birkhauser Boston Inc., MA, 1990.
2. S. Karlin and H. Taylor, *A Second Course in Stochastic Processes*, 1st Edition, Academic Press, 1981.
3. F. C. Klebaner, *Introduction to Stochastic Calculus with Applications*, 3rd Edition, Imperial College Press, 2012.
4. D. Richard, *Stochastic calculus: A practical introduction*, 1st Edition, CRC Press, 1992.

Course Code: MATH-724 Title: Multivariate Analysis Credit Hrs: 03

Course Outline: Introduction: Some Multivariate Problems and Techniques, The Data Matrix, Multivariate Normal Distribution Theory: Characterization and Properties, Linear Forms, The Wishart Distribution, The Hotelling T^2 Distribution, Maximum Likelihood Estimation and Other Techniques, Principal Component Analysis: Definition and Properties of Principal Components, Testing Hypothesis about Principal Components, Correspondence Analysis, Discarding of Variables, Principal Component Analysis in Regression. Factor Analysis: The Factor Model, Relationship between Factor Analysis and Principal Component Analysis. Canonical Correlation Analysis: Dummy Variable and Qualitative Data, Qualitative and Quantitative Data. Discriminant Analysis.

Texts and Reference Books

1. M. Kshirsagar, *Multivariate Analysis,* M. Dekker, New York, 1972.
2. K. V. Mardia, J. T. Kent and J. M. Bibby, *Multivariate Analysis,* Academic Press, London, 1982.
3. A. C. Rencher and W. F. Christenson, *Methods of Multivariate Analysis,* 3rd Edition*,* Wiley, 2012.
4. K. V. Mardia, J. T. Kent and J. M. Biby, *Multivariate Analysis,* 1st Edition, 1980.

Course Code: MATH-725 Title: Time Series Credit Hrs: 03

Course Outline: Methods of decomposing time-series into its component parts and measuring their effects. Stationary stochastic processes and their properties in the time domain. Frequency domain- Cyclical trend, spectral representation of a stochastic process. Properties of ARMA process and linear filters. Multivariate spectral analysis. Estimation of ARMA models. Model building and forecasting. Practicals based on the above topics

Texts and Reference Books

1. A. C. Harvey*, Time Series Models*, Philip Allan Publishers,1981.
2. I. G. Zurbenko, *The Spectral Analysis of Time Series*, Elsevier Science Publishers B.V.,Amsterdam, 1986.
3. E. J. Hannan*, Time Series Analysis*, Methuen, London, 1960.
4. M. G. Kendall, *Time-Series*, Griffin, London, 1973.

Course Code: MATH-726 Title: Advanced Functional Analysis Credit Hrs: 03

Course Outline: Normed Linear Spaces, Bounded Linear Transformation, Finite Dimensional Normed Linear Spaces, Some Dual Spaces, The Hahn Banach Theorem, The Algebra of Bounded Linear Operators, Baire's Theorem, The Principle of Uniform Boundedness, The Open Mapping Theorem, The Closed Graph Theorem, Hilbert Spaces, Spectral Theory in Hilbert Spaces, Hermitian Symmetric Forms, Orthogonality Self Adjoint Bounded Linear Operator, Spectrum of Bounded Linear Operators, Self Adjoint Bounded Linear Operators, Positive Operators, The Spectral Theorem

Texts and Reference Books

1. L. Brown, *Elements of Functional Analysis*, Von Nostrand and Renihold Company, 1970.
2. E. Kreyszig, *Introduction to Functional Analysis with Applications*, John Wiley and Sons, New York, 1989.
3. A. Majeed, *Elements of Topological and Functional Analysis*, Ilmi Kitab Khana, 1994.
4. J. T. Oden, *Applied Functional Analysis*, Prentice Hall Inc, 1979.
5. A. E. Taylor, *Introduction to Functional Analysis*, John Wiley and Sons, New York

Course Code: MATH-727 Title: Variational Inequalities Credit Hrs: 03

Course Outline: Variational Inequalities in Fixed Points, The Characterization of the Projection onto a Convex Set, A First Theorem about Variational Inequalities, Some Problems about Variational Inequalities, Variational Inequalities in Hilbert Space, The Obstacle Problem, Variational Inequalities for Monotone Operators, A Variational Inequality with Mixed Boundary Conditions, Penalization

Texts and Reference Books

1. C. Baiocchi and A. Capelo, *Variational and Quasivariational Inequalities, Applications to Free Boundary Problems*, John Wiley and Sons, New York, 1984.
2. G. Isac, *Complementarity Problems and Variational Inequalities*, Springer-Verlag, 2006.
3. D. Kinderlehrer and G. Stampacchia, *An Introduction to Variational Inequalities and Their Applications*, Academic Press, New York, 1980.
4. M. A. Noor, *Principles of Variational Inequalities,* Lambert Academic Publishing, Saarbrucken, Germany, 2009.

Course Code: MATH-728 Title: Graph Theory Credit Hrs: 03

Course Outline: Undirected Graphs, Geometric Graphs, Abstract Graphs, Isomorphism, Edge Progressions Chains and Circuits, Rank and Nullity, Degrees, Trees, Bipartite Graphs, Unicursal Graphs, Hamiltonian Graphs. Directed Graphs, Arc Progressions, Paths Progression and Cycle Progression

Partition and Distances in Graphs, Edge Partitions, Arc Partitions, Hamiltonian Chains and Circuits, Vertex Partitions, Radius and Diameter, Minimal Length Problem, Foundation of Electrical Network Theory, Matrix Representation, The Incidence Matrix, The Circuit Matrix, The Cut-Set Matrix, The Vertex or Adjacency Matrix, The Path Matrix, Network Flows, Network Flow Problems.

Texts and Reference Books

1. J. A. Bondy and U. S. R. Murty, *Graph Theory*, Springer Verlag, York, 2008.
2. B. W. Douglas, *Introduction to Graph Theory*, Prentice Hall, 2001.
3. G. Jonathan and Y. Jay, *Graph Theory and its Applications*, CRC Press, London 1999.
4. R. J. Wilson, *Introduction to Graph Theory*, Prentice Hall Wesley, 1996.

Course Code: MATH-729 Title: Lie Algebra Credit Hrs: 03

Course Outline: Definitions and Example of Lie Algebras, Ideals and Quotients, Simple, Solvable and Nilpotent Lie Algebras, Radial of a Lie Algebra, Semi-simple Lie Algebra, Engel's Nil Potency Criterion, Lie's and Cartan Theorems, Jordan-Chevalley Decomposition, Killing Forms, Criterion for Semisimplecity, Product of Lie Algebra, Classification of Lie Algebra up to Four Dimension, Application of Lie Algebras.

Texts and Reference Books

1. J. E. Humphreya, *Introduction to the Algebra and Representation Theory,* S. Verlag, 1972.
2. N. Jacobson, *Lie Algebra*, Intersience, New York, 1983.
3. J. Lapowsky and G.W. Macculum, *Elementary Lie Algebra Theory,* Yale University, 1974.
4. W. Jr. Miller, *Symmetry Groups and Their Groups,* Academic Press, 1972.
5. O. Neill, *Semi-Riemannian Geometry,* Academic Press, 1983.

Course Code: MATH-730 Title: Convex Analysis Credit Hrs: 03

Course Outline: Affine Sets, Convex Sets and Cones, The Algebra of Convex Sets, Convex Functions, Functional Operations, Relative Interiors of Convex Sets, Closures of Convex Functions, Recession Cones and Unboundedness, Some Closedness Criteria, Continuity of Convex Functions, Separation Theorems, Conjugates of Convex Functions, Support Functions, Polars of Convex Sets, Polars of Convex Functions, Linear Inequalities, Directional Derivatives and Subgradients, Differential Continuity and Monotonicity, Differentiability of Convex Functions, The Legendre Transformation, The Minimum of a Convex Function, Ordinary Convex Programs and Lagrange

Texts and Reference Books

1. G. G. M. Ilyaev and V. M. Tikhomirov, *Convex Analysis*: *Theory and Applications*, AMS, 2003.
2. R. T. Rockafellar, *Convex Analysis*, Princeton University Press, 1997.
3. J. V. Tiel, *Convex Analysis: An Introductory Text*, Wiley, 1984.
4. J. B. H. Urruty and C. Lemarechal, *Fundamentals of Convex Analysis*, Springer Verlag, 2001.

Course Code: MATH-731 Title: Advanced Topology Credit Hrs: 03

Course Outline: Convergence: Sequence and Nets, Filterbase in Space, Convergence, Properties of Filterbases, Closure in Terms of Filterbase, Continuity, Convergence in Cartesian Products, Adequacy of Sequences, Maximal Filterbase
Compactness: Compact Spaces, Special Properties of Compact, Countable Compactness, Compactness in Metric Spaces, Perfect Maps, Local Compactness, O-Compact Spaces, Compactification, K-Space, Baire Space Category
Function Spaces: The Compact Open Topology, Continuity of Composition, The Evaluation Map, Cartesian Products, Application to Identification Topologies, Basis for Z^y, Compact Subsets of Z^y Sequential Convergence in the C-Topology, Metric Topologies, Relation to the C-Topologies, Point-Wise Convergence, Comparison of Topologies in Z^y
The Spaces C(Y): Continuity of the Algebraic Operations, Algebras in C(Y; C), Stone-Weierstrass Theorem, The Metric Space C(Y), Embedding of Y in C(Y), The Ring C(Y).
The Complete Spaces: Cauchy Sequences, Complete Metrics and Complete Spaces, Cauchy Filterbases, Total Boundedness, Baire's Theorem for Complete Metric Spaces, Extension of Uniformly Continues Maps, Fixed Point Theorem for Complete Spaces, Complete Subspaces of Complete Spaces, Complete Gauge Structure.

Texts and Reference Books

1. J. Dugundji, *Topology,* Allyn and Bascon, Boston, 1966.
2. J. L. Kelley, *General Topology,* Ishi Press, 2008.
3. J. R. Munkress, *Topology A First Course,* Prentice Inc. Englewood Cliffis, New Jessy, 2nd Edition, 2005.
4. S. Davis, *Topology,* 1st Edition, McGraw-Hill Math, 2004.

Course Code: MATH-732 Title: Advanced Abstract Algebra Credit Hrs: 03

Course Outline: Endomorphism and Automorphism of Groups, Simple Groups (Definition and Examples), Direct Product of Groups, Sylow Groups and Sylow Theorems, Normal Series of a Group, Refinement Theorem, Composition Series and Jordan Holder Theorem, Solvable and Nilpotent Groups, Finitely Generated Abelian Groups.

Texts and Reference Books

1. P. M. Cohn, *Algebra*, Vol. I & II, John Wiley & Sons,
2. S. Lang, *Algebra*, Springer Verlag, 2002.
3. D.S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, Wiley, 2003.
4. J. A. Gallian, Contemporary abstract algebra, D.C. Heath, 1986.

Course Code: MATH-733 Title: Mathematical Ecology Credit Hrs: 3

Course Outlines: Key models in Behavioral Ecology, Diet-choice and foraging, Evolutionarily Stable Strategies, Search and Predation, Stochastic models and statistics, Probability background and important distributions, Some applications to search and foraging, Bayesian methods, Host-parasitoid models, Nicholson-Bailey and extensions, Evolutionary models and stochastic dynamic programming, Disease models and Fishery models (may be included based on participant interest and available time), Basic SIR and extensions, Evolution of virulence, Vectors and disease, Fisheries bio-economic models, Stochastic population models, Sample paths and stochastic differential equations, General stochastic diffusion processes, Extinction time in density independent case, Extinction time in density-dependent case, Designing a model Cellular automata and IBMs, Formulating and implementing a model

Text and Reference Books:

1. Allen, L. J. S., *An Introduction to Stochastic Processes with Applications to Biology*. Pearson. Upper Saddle River, NJ, USA, 2003.
2. Allen, L. J. S., *An Introduction to Mathematical Biology*. Pearson. Upper Saddle River, NJ, USA, 2007.
3. Allman, E. S. and J. Rhodes*., Mathematical Models in Biology*: An Introduction. Cambridge University Press, 2004.
4. Brauer, F. and C. Castillo-Chavez*., Mathematical Models in Population Biology and Epidemiology*, Springer, NY, 2001.

Course Code: MATH- 734 Biomathematics Credit Hrs: 3

Course Outlines: Biological applications of difference and differential equations, Biological applications of nonlinear differential equations, Biological applications of graph theory.

Text and Reference Books:

1. Linda J. S. Allen, *An introduction to Mathematical Biology*, Pesrson, 2007.
2. J. Smith, *Mathematical ideas in biology*, Cambridge Press, Cambridge, 1968.
3. S. I. Rubinow, *An introduction to Mathematical Biology*, 1st edition, Dover Publications, 2003.
4. B. P. ingalls, *Mathematical Modeling in Systems Biology,* 1st edition, The MIT Press, 2013.

Course Code: MATH-735 Advances in Discrete Mathematics and Applications Credit Hrs: 3

Course Outlines: Introduction, Definitions of stability and linearized stability, Semi-cycle analysis, Full limiting sequences and Convergence theorems, Lyness equation, Todd equation, the generalized Lozi equation, the Gingerbreadman equation and the Riccati difference equation, analysis of semi-cycle of some special type of equations, Period-2 solutions, Global asymptotic stability of period-2 solutions, Existence of unbounded solutions and Boundedness of solutions, on the systems of rational difference equations

Text and Reference Books:

1. M. R. S. Kulenovic, *Dynamics of Second Order Rational Difference Equations: With Open Problems and Conjectures*, Chapman and Hall/CRC, 2005.
2. E. Camouzis, G. Ladas, *Dynamics of Third-Order Rational Difference Equations with Open Problems and Conjectures*, Chapman and Hall/CRC, 2007.
3. M. H. Education, *Advanced Mathematical Concepts*, 6th Edition, McGraw-Hill Education, 2003.
4. K. Abidi and J. X. Xu, *Advanced Discrete-Time Control: Designs and Applications*, 5th Edition, Springer, 2015.

Course Code: MATH-736 Title: Graph Theory Credit Hrs: 03

Course Outline: Undirected Graphs, Geometric Graphs, Abstract Graphs, Isomorphism, Edge Progressions Chains and Circuits, Rank and Nullity, Degrees, Trees, Bipartite Graphs, Unicursal Graphs, Hamiltonian Graphs. Directed Graphs, Arc Progressions, Paths Progression and Cycle Progression

Partition and Distances in Graphs, Edge Partitions, Arc Partitions, Hamiltonian Chains and Circuits, Vertex Partitions, Radius and Diameter, Minimal Length Problem, Foundation of Electrical Network Theory, Matrix Representation, The Incidence Matrix, The Circuit Matrix, The Cut-Set Matrix, The Vertex or Adjacency Matrix, The Path Matrix, Network Flows, Network Flow Problems.

Text and Reference Books

5. J. A. Bondy and U. S. R. Murty, *Graph Theory*, Springer Verlag, York, 2008.
6. B. W. Douglas, *Introduction to Graph Theory*, Prentice Hall, 2001.
7. G. Jonathan and Y. Jay, *Graph Theory and its Applications*, CRC Press, London 1999.
8. R. J. Wilson, *Introduction to Graph Theory,* Prentice Hall Wesley, 1996.

Course Code: MATH-737 Title: Lie Algebra Credit Hrs: 03

Course Outline: Definitions and Example of Lie Algebras, Ideals and Quotients, Simple, Solvable and Nilpotent Lie Algebras, Radial of a Lie Algebra, Semi-simple Lie Algebra, Engel's Nil Potency Criterion, Lie's and Cartan Theorems, Jordan-Chevalley Decomposition, Killing Forms, Criterion for Semisimplecity, Product of Lie Algebra, Classification of Lie Algebra up to Four Dimension, Application of Lie Algebras.

Text and Reference Books

1. J. E. Humphreya, *Introduction to the Algebra and Representation Theory*, S. Verlag, 1972.
2. N. Jacobson, *Lie Algebr*a, Intersience, New York, 1983.
3. J. Lapowsky and G.W. Macculum, *Elementary Lie Algebra Theory*, Yale University, 1974.
4. O. Neill, *Semi-Riemannian Geometry*, Academic Press, 1983.

Course Code: MATH-738 Title: Fuzzy Algebra Credit Hrs: 03

Course Outline: Introduction, The Concept of Fuzziness Examples, Mathematical Modeling, Operations of fuzzy sets, Fuzziness asuncertainty. Algebra of Fuzzy Sets: Boolean Algebra and lattices, Equivalence relations and partions, Composing mappings, Alpha-cuts, Images of alpha-level sets, Operations on fuzzy sets. Fuzzy Relations: Definition and examples, Binary Fuzzy relations Operations on Fuzzy relations, fuzzy partitions. Fuzzy Semigroups: Fuzzy ideals of semigroups, Fuzzy quasi-ideals, Fuzzy bi-ideals of Semigroups, Characterization of different classes of semigroups by the properties of their fuzzy ideals fuzzy quasi-ideals and fuzzy bi-ideals. Fuzzy Rings: Fuzzy ideals of rings, Prime, semiprime fuzzy ideals, Characterization of rings using the properties of fuzzy ideals

Text and Reference Books

1. Hung T. Nguyen and A First course in Fuzzy Logic, Chapman and Hall/CRC Elbert A. Walker 1999.
2. M. Ganesh, Introduction to Fuzzy Sets and Fuzzy Logic, Prentice-Hall of India, 2006.
3. John N. Mordeson and Fuzzy Commutative algebra, World Scientific, 1998.D.S. Malik,
4. John N. Mordeson, Fuzzy Semigroups, Springer-Verlage, 2003. D.S. Malik and Nobuki Kuroki

17. Admission Criteria for PhD in Mathematics

Sr. No.	Content	Requirement	Remarks
1	Mathematics	MPhil or MS or Equivalent Degree in Mathematics / Physics / Statistics / Computer Science / Information Technology with CGPA 3.0 or above (for semester system degree) or 1st division (for annual system).	
		UGAT (General) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 60%.	
2	Intra-disciplinary	MPhil / MS or Equivalent Degree in Science (Physics, Statistics, CS, IT)	Such students may be allowed for admission in PhD Program and will be offered deficiency courses during first year of the degree program with 6 to 9 Credit Hours.
		UGAT (General) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 60%.	

18. Scheme of Studies for PhD in Mathematics: General Breakup

Sr. No	Content	Description
1	Awarding Institute/Body	Mirpur University of Science and Technology (MUST)
2	Teaching Institute	Department of Mathematics, Mirpur University of Science and Technology (MUST), and affiliated colleges
3	Nomenclature	PhD in Mathematics
4	Starting Time for Program	Fall/Spring semester of each academic year
5	Duration of the Program	3-8 Years
6	Entrance Requirements	MPhil or MS or Equivalent Degree in Mathematics / Physics / Statistics / Computer Science / Information Technology with CGPA 3.0 or above (for semester system degree) or 1st division (for annual system).
		No D-grade in academic career
		Mathematics: UGAT (General) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 60%. Intra-disciplinary: UGAT (General) by MUST / HAT General by ETC / GRE General with minimum cumulative score of 60%.
7	Merit Formula	Merit formulas are the following: For M.Sc: 15% of Intermediate, 20% of B.Sc, 20% of M.Sc, 25% of M.Phil / MS marks, 5% Publications, and 15% of interview conducted by the department. For BS: 15% of Intermediate, 40% of BS, 25% of M.Phil marks, 5% Publications, and 15% of interview conducted by the Department.
8	Total Credit Hours	Course Work: 20 Credit Hours
		Seminar I (Compulsory): 1 Credit Hour
		Seminar II (Compulsory): 1 Credit Hour
		Comprehensive Examination (Written and Oral): P/F
		Thesis (Compulsory): 50 Credit Hours

19. Modification in The Scheme of Study for PhD in Mathematics

19.1 Structure of PhD in Mathematics

Course Code	Description	Credit Hours
01	Minimum Credit Hours	31
02	Elective Courses	18
03	Understanding of Holy Quran-I	0-1
04	Understanding of Holy Quran-II	0-1
05	Seminar I	01
06	Seminar II	01
07	Thesis	0-50
Total		72

19.2 List of Courses for PhD in Mathematics Program

a. Compulsory Requirements

Course Code	Course Title	Category	Credit Hours
UHQ-894	Understanding of Holy Quran-I	General Education	0-1
UHQ-895	Understanding of Holy Quran-II	General Education	0-1
MATH-896	Comprehensive Examination (Written & Oral)	Mandatory	P/F
MATH-897	Seminar-I	Mandatory	01
MATH-898	Seminar-II	Mandatory	01
MATH-899	Thesis	Mandatory	09

b. Elective Courses (18 credit hours)

In the following, a list of elective courses is given. A student will have to complete 12 credit hours of his/her course work from these courses.

Semester I			
Course Code	**Course Title**	**Category**	**Credit Hrs.**
MATH-801	Mathematical Analysis	Elective Course	03
MATH-802	Riemanian Geometry	Elective Course	03
MATH-803	Mathematical Techniques	Elective Course	03
MATH-804	Advanced Abstract Algebra	Elective Course	03
MATH-805	Finite Element Methods	Elective Course	03
MATH-806	Advanced Partial Differential Equations	Elective Course	3
MATH-807	Advanced Functional Analysis	Elective Course	03
MATH-808	Variational Inequalities	Elective Course	03
MATH-809	Convex Analysis	Elective Course	03
MATH-810	Parameter Estimation and Sensitivity Analysis	Elective Course	03
MATH-811	Semigroups in Geometric Functions Theory	Elective Course	03
MATH-812	Differential Subordination Theory and Applications	Elective Course	03
MATH-813	Conformal Mappings	Elective Course	03
MATH-814	Perturbation Methods	Elective Course	03
MATH-815	Electro-dynamics	Elective Course	03
MATH-816	Magneto-hydro-dynamics	Elective Course	03
MATH-817	Fundamentals of Turbulence	Elective Course	03
MATH-818	Lie Group Analysis of Differential Equations	Elective Course	03
MATH-819	Selected Topics in Applied Mathematics	Elective Course	03

MATH-820	Selected Topics in Pure Mathematics	Elective Course	03
MATH-821	Numerical Solutions of PDEs	Elective Course	03
MATH-822	Design Methods for Control Systems	Elective Course	03
MATH-823	Optimal State Estimation	Elective Course	03
MATH-824	Linear Matrix Inequalities	Elective Course	03
MATH-825	Stochastic Differential Equations	Elective Course	03
MATH-826	Fixed Point Theory and Applications	Elective Course	03
MATH-827	Integral Inequalities	Elective Course	03
MATH-828	Banach Algebras	Elective Course	03
MATH-829	Harmonic Functions Theory	Elective Course	03
MATH-830	Cosmology	Elective Course	03
MATH-831	Bifurcation and Chaos	Elective Course	03
MATH-832	Nonlinear Systems and Control	Elective Course	03

19.3 Courses for PHD in Mathematics Program

Course Code: MATH-801 **Title:** Advanced Mathematical Analysis **Credit Hrs:** 03

Course Outline: Introduction to Fourier analysis: Lebesgue measure, Fubini Theorem, Convolutions, Introduction to the Fourier Transform, **Introduction to Function spaces:** Introduction to Sobolev spaces and distributions, Foundations of Harmonic analysis and theory of maximal operators, Lebesgue points, **Introduction to Geometric measure theory:** Hausdorff metric, Hausdorff measure, Fractals, Hausdorff dimensions, Box dimension,

Text and Reference Books:

1. E. B. Davis, *Spectral Theory and Differential Operators,* Graduate text, Cambridge University Press, 1995.
2. E. H. Lieb and M. Loss, *Analysis, Graduate Studies in Mathematics*, Volume 14, AMS, 1997.
3. V. Maziya and S. Poborchi, *Differntial Functions on bad domains,* World Scientific, 1997.
4. Steven R. L., *Analysis: With an Introduction to Proof*, 4th edition, Pearson, 2004.

Course Code: MATH-802 **Title:** Riemanian Geometry **Credit Hrs:** 03

Course Outline: Definition and examples of manifolds. Differential maps. Submanifolds. Tangents. Coordinate vector fields. Tangent spaces. Dual spaces. Multilinear functions. Algebra of tensors. Vector fields. Tensor fields. Integral curves. Flows. Lie derivatives. Brackets. Differential forms. Introduction to integration theory on manifolds. Riemannian and semi Riemannian metrics. Flat spaces. Affine connection. Parallel translations. Covariant differentiation of tensor fields. Curvature and Torsion tensors. Connection of a semi-Riemannian tensor. Killing equation and Killing vector fields. Geodesics. Conformal transformations and the Weyl tensor.

Text and Reference Books:

5. M. P. do Carmo, Riemannian Geometry, Birkhauser, Boston, 1992.
6. D. Langwitz, Differential and Riemannian Geometry, Academic Press, 1970.
7. R. L. Bishop and S. I. Goldberg, Tensor Nalysis and Manifolds, Dover Publication, Inc., 1980.
8. M. Berger , A Panoramic View of Riemannian Geometry, Springer, 2007.

Course Code: MATH-803 **Title:** Mathematical Techniques **Credit Hrs:** 03

Course Outline: Green's function method with applications to wave-propagation. Solution of algebraic equations by perturbation methods. Evaluation of integrals by expansion of integrands. Laplace methods. The method of stationary phase. The methods of steepest descent. Solution of the linear damped oscillator equation by perturbation methods. The WKB approximation. Variational problems with variable end points. Corner conditions. Sufficient conditions for minimum. The Ritz method and its applications. A survey of transform techniques. Wiener-Hopf technique with applications to diffraction problems.

Text and Reference Books:

1. A. Nayfeh, *Perturbation Methods,* John Wiley & Sons, Inc., 1973.
2. I. Stakgold, *Boundary Value Problems of Mathematical Physics,* Volume I & II, The MacMillan Company, 1970.
3. B. Boble, *Methods Based on the Wiener-Hopf Technique for the Solution of Partial Differential Equations,* Pergamon Press, 1958.
4. J. Jordan and P. Smith*, Mathematical Techniques: An Introduction for the Engineering, Physical, and Mathematical Sciences*, Oxford University Press, 2008.

Course Code: MAT-804 **Title:** Advanced Abstract Algebra **Credit Hrs:** 03

Course Outline: Endomorphism and Automorphism of Groups, Simple Groups (Definition and Examples), Direct Product of Groups, Sylow Groups and Sylow Theorems, Normal Series of a Group, Refinement Theorem, Composition Series and Jordan Holder Theorem, Solvable and Nilpotent Groups, Finitely Generated Abelian Groups.

Text and Reference Books

1. P. M. Cohn*, Algebra*, Vol. I & II, John Wiley & Sons,
2. S. Lang*, Algebra*, Springer Verlag, 2002.
3. D.S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, Wiley, 2003.
4. J. A. Gallian*, Contemporary abstract algebra*, D.C. Heath, 1986.

Course Code: MATH-805 **Title:** Finite Element Methods **Credit Hrs:** 03

Course Outline: Finite Element Methods: General Approach, The Galarkin Method in One and More Dimensions and Application, Error Bound on the Galarkin Method and Application, The Method of Collocation, Error Bounds on the Collocation Method and Application, Comparison of Efficiency of the Finite Difference and Finite Element Method, Application to Solution of Linear and Non-Linear Partial Differential Equations Appearing in Physical Problems

Text and Reference Books

1. S. D. Burnett, Finite Element Analysis from Concept to Applications, Addison Wesley, 1987.
2. G. S. Desai*, Elementary Finite Element Metho*d, Prentice Hall, 1988.
3. G. Strang and G. Fix, *Analysis of Finite Element Method*, Prentice Hall, New Jersey, 1973.
4. J. N. Reddy*, Introduction to the Finite Element Method*, 3rd Edition, MHI, 2006.

Course Code: MATH-806 **Title:** Advanced Functional Analysis **Credit Hrs:** 03

Course Outline: Normed Linear Spaces, Bounded Linear Transformation, Finite Dimensional Normed Linear Spaces, Some Dual Spaces, The Hahn Banach Theorem, The Algebra of Bounded Linear Operators, Baire's Theorem, The Principle of Uniform Boundedness, The Open Mapping Theorem, The Closed Graph Theorem, Hilbert Spaces, Spectral Theory in Hilbert Spaces, Hermitian Symmetric Forms, Orthogonality Self Adjoint Bounded Linear Operator, Spectrum of Bounded Linear Operators, Self Adjoint Bounded Linear Operators, Positive Operators, The Spectral Theorem

Text and Reference Books

1. L. Brown, *Elements of Functional Analysis***,** Von Nostrand and Renihold Company, 1970.
2. E. Kreyszig, *Introduction to Functional Analysis with Applications***,** John Wiley and Sons, New York, 1989.
3. A. Majeed, *Elements of Topological and Functional* Analysis, Ilmi Kitab Khana, 1994.
4. J. T. Oden, *Applied Functional Analysis*, Prentice Hall Inc, 1979.

Course Code: MATH-807 **Title:** Advanced Partial Differential Equations **Credit Hrs:** 03

Course Outline: Cauchy's Problems for Linear Second Order Equation in N- Independent Variables, Cauchy Kowalewski Theorem, Characteristic Surface, Adjoint Operations, Bicharacteristics, Spherical and Cylindrical Waves, Heat Equations, Wave, Laplace and Diffusion Equations in Spherical and Cylindrical Polar Coordinates, Maximum-Minimum Principle, Non-Homogeneous Partial Differential Equations.

Text and Reference Books

1. C. B. Chester, *Techniques in Partial Differential Equations*, McGraw Hill Book Company, 1971.
2. R. Dennemyer*, Introduction to Partial Differential Equations and Boundary Value Problems,* McGraw Hill Book Company, 1968.

3. H. F. Weinberger, *A First Course in Partial Differential Equations: with Complex Variables and Transform Methods*, Dover Publications, 1995.
4. E. C. Zachmanoglou and D. W. Thoe, *Introduction to Partial Differential Equations with applications*, Dover Publications, 1987.

Course Code: MATH-808 **Title:** Variational Inequalities **Credit Hrs:** 03

Course Outline: Variational Inequalities in Fixed Points, The Characterization of the Projection onto a Convex Set, A First Theorem about Variational Inequalities, Some Problems about Variational Inequalities, Variational Inequalities in Hilbert Space, The Obstacle Problem, Variational Inequalities for Monotone Operators, A Variational Inequality with Mixed Boundary Conditions, Penalization

Text and Reference Books

1. C. Baiocchi and A. Capelo, *Variational and Quasivariational Inequalities*, Applications to Free Boundary Problems, John Wiley and Sons, New York, 1984.
2. G. Isac, *Complementarity Problems and Variational Inequalities*, Springer-Verlag, 2006.
3. D. Kinderlehrer and G. Stampacchia, *An Introduction to Variational Inequalities and TheirApplications*,Academic Press, New York, 1980.
4. M. A. Noor, *Principles of Variational Inequalities,* Lambert Academic Publishing, Saarbrucken, Germany, 2009.

Course Code: MATH-809 **Title:** Convex Analysis **Credit Hrs:** 03

Course Outline: Affine Sets, Convex Sets and Cones, The Algebra of Convex Sets, Convex Functions, Functional Operations, Relative Interiors of Convex Sets, Closures of Convex Functions, Recession Cones and Unboundedness, Some Closedness Criteria, Continuity of Convex Functions, Separation Theorems, Conjugates of Convex Functions, Support Functions, Polars of Convex Sets, Polars of Convex Functions, Linear Inequalities, Directional Derivatives and Subgradients, Differential Continuity and Monotonicity, Differentiability of Convex Functions, The Legendre Transformation, The Minimum of a Convex Function, Ordinary Convex Programs and Lagrange

Text and Reference Books

1. G. G. M. Ilyaev and V. M. Tikhomirov, *Convex Analysis: Theory and Applications*, AMS, 2003.
2. R. T. Rockafellar, *Convex Analysis,* Princeton University Press, 1997.
3. J. V. Tiel, *Convex Analysis: An Introductory Text, Wiley, 1984.*
4. J. B. H. Urruty and C. Lemarechal, *Fundamentals of Convex Analysis*, Springer Verlag, 2001.

Code: MATH-810 **Title:** Parameter Estimation and Sensitivity Analysis **Credit Hrs:** 03

Course Outline:

Some Basic Notions from Probability Theory, Probability spaces, random variables and distribution functions, Expected value and variance, Normally distributed random variables, Some simple examples, Parameter Estimation, Problem formulation, First order necessary condition, Second order conditions, The expected value for the least squares estimator,

The variance-covariance matrix for the least squares estimator Sensitivity Analysis, definition ,classical sensitivity, Sensitivity equations, fisher information matrix.

Text and Reference Books

1. J. N. Kapur, *Mathematical Modelling*, New Age International, 01-jan-1988.
2. Sandip Banerjee, *Mathematical Modelling*, CRC press, 07-Feb-2014.
3. J. Berry and J. Stephen, Mathematical Modelling, PLC Great Britian 1995.
4. E. A. Bender, *Mathematical Modelling*, 1st Edition, Dover Publications, 2000.

Course Code: MATH-811 **Title:** Semigroups in Geometric Functions Theory **Credit Hrs:** 03

Course Outline: Holomorphic Functions and their Convergence, Metric Spaces and Fixed Point Principles, Schwarz-Pick Lemma and Automorphisms, Boundary Behavior of Holomorphic Self-Mappings and Fixed Points and Fixed Point Free Holomorphic Self-Mappings, The Denjoy-Wolff Theorem,

Commuting Family of Holomorphic Mappings, Hyperbolic Geometry and Fixed Points, The Poincare Metric and its Compatibility with Convexity, Infinitesimal Poincare Metric and Geodesics, Fixed Points of Non-expansive Mappings

One-Parameter Continuous Semigroup of Holomorphic and Nonexpansive Self-Mappings, Infinitesimal Generator, Nonlinear Resolvent and the Exponential Formula, Monotonicity w.r.t the Hyperbolic Metric, Flow Invariance Conditions, The Berkson-Porta Parametric Representation of Semi-Complete Vector Fields, Asymptotic Behavior of Continuous Flows, Stationary Points of a Flow, Null Points of Complete Vector Fields, Embedding of Discrete Time Group and Rates of Convergence of a Flow with an Interior Stationary Point, A Rate of Convergence in Poincare Metric, Continuous Version of the Julia-Wolff-Caratheodory Theorem, Lower Bounds for Monotone Functions, Asymptotic behavior of Continuous Flows, Dynamical Approach to Starlike and Spirallike Functions

Text and Reference Books

1. Shoket*, Semigroups in Geometric Function Theory*, Kluwer Academic Publishers, 2001.
2. S. G. Krantz*, Geometric Function Theory: Explorations in Complex Analysis*, 2006th Edition, Birkhäuser, 2005.
3. G. Kohr, G. Graham and I. Graham, *Geometric Function Theory in One and Higher Dimensions*, 1st Edition, CRC Press, 2003.
4. L. V. Ahlfors*, Conformal Invariants: Topics in Geometric Function Theory*, McGraw-Hill Inc., US, 1973.

Course Code: MATH-812 **Title:** Differential Subordination Theory and Applications **Credit Hrs:** 03

Course Outline: History, Definitions and Some Results, Integral Operators, Introduction to the Theory of Second-Order Differential Subordinations, Applications of First-Order Differential Subordinations, First-Order Linear Differential Subordinations, Briot-Bouquet Differential Subordinations and its Applications in Univalent Functions, Generalized Briot-Bouquet Differential Subordinations, Analytic Integral Operators between Classes of Functions, Subordination-Preserving Integral Operators, Applications of Second-Order Differential Subordinations, Second-Order Linear Differential Subordinations, Operators Preserving Functions with Positive Real Part and Bounded Functions, Averaging Integral Operators, The Schwarzian and Starlikeness, Special Differential Subordinations, Higher Order Differential Subordinations, Introduction to Differential Subordinations of Several Complex Variables

Text and Reference Books

1. P. L. Duren, *Univalent Functions*, Grundlehren der Math. Wissenchaften, Springer-Verlag, New York-Berlin, 1983.
2. S.S. Miller and P.T. Mocanu, *Differential Subordination Theory and Applications*, Marcel Dekker, Inc., New York, Basel, 2000.
3. E. D. Rainville, *Special Functions*, Brett Macmillan Compnay, 1960.
4. 5. C. Viola, *Special Functions*, 1st Edition, Springer, 2016.

Course Code: MATH-813 **Title:** Conformal Mappings **Credit Hrs:** 03

Course Outline: Conformal Mappings on Simply-connected Domains: Mapping Properties of Analytic Functions, The Linear Transformations, The Schwarz Lemma, The Symmetry Principle, The Schwarz-Christoffel Formula, Domains Bounded by Circular Arcs, The Kernel Functions, Conformal Mappings of Nearly Circular Domains

Mapping Properties of Special Functions: Rational Functions of Second Degree, Exponential and Trigonometric Functions, Elliptic Functions, Domains Bounded by Arcs of Confocal Conics, The Schwarzian δ-Functions, the Elliptic Modular Functions

Conformal Mappings on Multiply-Connected Domains: Conanical Domains and their Characterizations by Extremal Problems, Green's Function and the Dirichlet Problems, Area Problems, The Kernel Functions and the Orthonormal Sets

Text and Reference Books

1. L. Bieberbach, *Conformal Mappings*, Chelsea Publishing Company, 1964.
2. Z. Nehri, *Conformal Mappings*, Dover Publications, 1975.
3. I. I. Gikhman and A.V. Skorokhod, *Theory of Random Processes*, N. Moskow, 1973.
4. R. Schinzinger and P. A. A. Laura*, Conformal Mappings*, Dover Publications, 2003.

Course Code: MATH-814 **Title:** Perturbation Methods **Credit Hrs:** 03

Course Outline: Approximate Solution of Linear Differential Equations, Approximate Solution of Nonlinear Differential Equations, Singular Perturbation Theory Perturbation Methods for Linear Eigen Value Problems, Asymptotic Matching Boundary Layer Theory, Mathematical Structure of Boundary Layers, Inner, Outer, And Intermediate Limits Higher-Order Boundary, Layer Theory Distinguished Limits and Boundary Layers Validity of the WKB Approximation Patched Asymptotic Approximations, WKB Solution of Inhomogeneous Linear Quations, Matched Asymptotic Approximation, Solution of the One-Turning-Point Problem.

Text and Reference Books

1. A. H. Nayfeh, *Perturbation Meth*ods, 1st Edition, Wiley-VCH, 2000.
2. E. J. Hinch*, Perturbation Methods*, Cambridge University Press, 1991.
3. A. H. Nayfeh and D. T. Mook, *Nonlinear Oscillations*, Wiley-VCH, 1995,
4. A. H. Nayfeh, *Introduction to Perturbation Techniques*, 1st Edition, Wiley-VCH, 1993.

Course Code: MATH-815 **Title:** Electro-dynamics **Credit Hrs:** 03

Course Outline: Maxwell's Equations, Electrodynamics Wave Equations, Boundary Conditions, Wave in Conducting and Non-Conducting Media, Reflection and Polarization, Energy Density and Energy Flux, Lorntz Formula, Wave Guides and Cavity Resonators, Spherical and Cylindrical Waves, Inhomogeneous Wave Equations, Retarded Potentials, Lenard-Wiechart Potentials, Fields of Uniformly Moving Point Charge, Radiation From a Group of Moving Charges, Field of Oscillating Dipole, Field of an Accelerated Point Charge.

Text and Reference Books

1. D. Corson and P. Lorrain, *Introduction to Electromagnetic Fields and Waves*, Freeman, 1962.
2. J. D. Jacson, *Classical Electromagnetic*, 3rd Edition, Wiley, 1998.
3. K. Panofsky and M. Philips*, Classical Electricity and Magnetism*, Addison Wesley, 1962.
4. I. R. Retiz and F. J. Malford, *Foundation of Electromagnetic Theory*, Addison Wesley, 1969.

Course Code: MATH-816 **Title:** Magneto-hydro-dynamics **Credit Hrs:** 03

Course Outline: Basic Equations: Equations of Electrodynamics, Equations of Fluid Dynamics, Ohm's Law Equations of Magneto Hydrodynamics.

Motion of an Incompressible Fluid: Motion of a Viscous Electrically Conducting Fluid with Linear Current Flow, Steady State Motion along a Magnetic Field, Wave Motion of an Ideal Fluid

Small Amplitude MHD Waves: Magneto-Sonic Waves, Alfven's Waves, Damping and Excitations of MHD Waves, Characteristic Lines and Surfaces.

Simple Wave and Shock Wave in Magneto Hydrodynamics, Stability and Structure of Shock Waves in Relativistic Magneto Hydrodynamics, Stability and Structure of Shock Waves, Discontinuities in Various Quantities, Piston Problem, Oblique Shock Waves.

Text and Reference Books

1. A. Etal, *Plasma Electrodynamics*, Pergamon Press, 1975.
2. H. Alfven*, Cosmical Electrodynamics*, Create Space Independent Publishing Platform, 1950.
3. J. E. Anderson, *Magneto hydrodynamics*, Shock Waves, M. I. T. Press, Cambridge, 1963.
4. T. G. Cowling*, Magnetohydrodynamics*, Intersience Publishers, 1963.

Course Code: MATH-817 **Title:** Fundamentals of Turbulence **Credit Hrs:** 03

Course Outline: Introduction to turbulence, various types of turbulent flows, transition to turbulence from laminar flow. Navier-Stokes equations and turbulence. Statistical Tools: Statistical moments and

correlations, probabilities and averaging, space and time scales of turbulence. Kolmogorov's Theory of turbulence, Intermittency.

Text and Reference Books:

1. Marcel Lesieur, *Turbulence in Fluids*, 4th edition, Springer, 2008.
2. J. Mathieu and J. Scott, *An Introduction to Turbulent Flow*, 1st edition, Cambridge University Press, 2000.
3. A. Tsinober, *An Informal Conceptual Introduction to Turbulent Flows*, 2nd edition, Springer, 2009.
4. P. A. Durbin and B. A. P. Reif, *Statistical Theory and Modeling for Turbulent Flows*, 2nd edition, John Wiley and Sons, Ltd., 2011.

Course Code: MATH-818 **Title:** Lie Group Analysis of Differential Equations **Credit Hrs:** 03

Course Outline: Brief introduction to Lie group analysis of differential equations, preliminaries: heuristic approach in examples, finite differences and transformation groups in space of discrete variables, invariance of finite difference models, invariance difference models of ordinary differential equations, invariance difference models of partial differential equations, combined mathematical models and some generalizations, Lagrangian formalism for difference equations, Hamiltonian formalism for difference equations, symmetries and first integrals, discrete representation of ordinary differential equations with symmetries.

Text and Reference Books:

1. P.J Olver, *Application of Lie groups to Differential Equations*, Springer, New York, 1986.
2. S. Goldberge, *Introduction to Difference Equations*, John Wiley & Sons, New York, 1965.
3. V. Dorodnitsyn, *Applications of Lie Groups to Difference Equations*, CRC press, America, 2011.
4. A. Cohen, An introduction to the Lie theory of one-parameter groups, Ulan Press, 2012.
5. S. Elaydi, , *Introduction to Difference Equations,* 3rd edition, Springer, 2005.

Course Code: MATH-819 **Title:** Selected Topics in Applied Mathematics C**redits:** 3

Course Outline: Course out lines of this course will be determined by the concerned teacher as per requirement of a student in connection with his/her research.

Course Code: MATH-820 **Title:** Selected Topics in Pure Mathematics **Credit Hrs:** 03

Course Outline: Course out lines of this course will be determined by the concerned teacher as per requirement of a student in connection with his/her research.

Course Code: MATH-821 **Title:** Numerical Solutions of PDEs **Credit Hrs:** 03

Course Outline: Preliminaries, Classification of PDEs, Canonical Forms and Well-Posed Problems, Behavior of Solutions, Characteristics, Introduction to Finite Difference Methods
Basics of Finite Difference Approximations: Derivation of Finite Difference Approximations, Consistency, Stability, and Convergence for Difference Approximations, Lax Theorem, Matrix and Fourier Stability Analysis, Parabolic Equations: Explicit and Implicit Methods for the Heat Equation, Direction Splitting and ADI Schemes, Convection-Diffusion Equations
Hyperbolic Equations: Finite Difference Methods for the Wave Equation and High-Order Methods, First-Order Non-Linear Equations, Quasi-Linear and Conservation Forms, Characteristics, Shock Waves and Contact Discontinuities, Elliptic Equations: Dirichlet and Neumann Problems, Solvability, Direct vs. Iterative Methods of Solution

Text and Reference Books

1. R. J. LeVeque*, Finite Difference Methods for ODEs and PFEs*, SIAM, Philadelphia, 2007.

2. K. Morton and D. Mayers, *Numerical Solution of PDEs*, Cambridge University Press, 1994.
3. J. W. Thomas, *Numerical PDEs, Finite Difference Methods*, Springer-Verlag, 1995.
4. J. W. Thomas*, Numerical PDEs: Conservation Laws and Elliptic Equations*, Springer-Verlag, 1999.

Course Code: MATH-822 **Title:** Design Methods for Control Systems **Credit Hrs:** 03

Course Outline:

Introduction to Feedback Control Theory: Basic feedback theory, closed loop stability, stability robustness, frequency response design goals, loop shaping, limits of performance,

Classical Control System Design: Steady state error behavior, integral control, frequency response plots, classical control system design, lead, lag, and lag-lead compensation, the root locus approach to parameter selection, quantitative feedback theory,

Multivariable Control System Design: Poles and zeros of multivariable systems, MIMO structural requirements and design methods,

LQ, LQG, and H_2 Control System Design: LQ theory, LQG theory, H_2 optimization, feedback system design by H_2 optimization, examples and applications

Uncertainty Models and Robustness: parameter robustness analysis, the basic perturbation model, the small gain theorem, stability robustness of feedback systems, structured singular value robustness analysis, combined performance and stability robustness,

$H_\infty -$ optimization and μ-synthesis: The mixed sensitivity problem, the standard H_∞ problem, suboptimal solutions and examples, state space solutions of standard H_∞ problem, optimal solutions to the H_∞ problem, integral control and high frequency roll-off, μ-synthesis with applications,

Text and Reference Books:

1. O. H. Bosgra, H. Kwakernaak, and G. Meinsma, *Lecture Notes on Design Methods for Systems and Control*, Dutch Institute of Systems and Control, 2006 .
2. B. Friedland, Control System Design: *An Introduction to State-Space Methods*, Dover Publications, 2005.
3. J. Distifano, A. R. Stubberud and L. J. Williams, *Schaum's Outline of Feedback and Control Systems*, 2nd Edition, McGraw-Hill Education, 2013.
4. R. F. Stengel*, Optimal Control*, Dover Publications, 1994.

Course Code: MATH-823 **Title**: Optimal State Estimation **Credit Hrs:** 03

Course Outline: Least squares estimation, Wiener filtering, propagation of states and covariances for discrete and continuous time systems, the discrete and continuous time Kalman filters, the H-infinity filters, the extended and unscented Kalman filters.

Text and Reference Books

1. D. Simon, *Optimal State Estimation*, John Wiley & Sons, Inc, 2006.
2. J. L. Crassidis and J. L. Junkins*, Optimal Estimation of Dynamic Systems*, 2nd Edition, Chapman and Hall, 2011.
3. B. M. Mohan and S. K. Kar*, Continuous Time Dynamical Systems:* State Estimation and Optimal Control with Orthogonal Functions, CRC Press, 2012.
4. R. F. Stengel*, Optimal State Estimation,* Dover Publications, 1994.

Code: MATH-824 **Title:** Linear Matrix Inequalities **Credit Hrs:** 03

Course Outline: Basic Concepts: Convex Optimization and LMIs, Dissipative Dynamical Systems: Storage functions and quadratic supply rates, Kalman-Yakubovich-Popov Lemma, The Positive Real Lemma, and Bounded Real Lemma, interconnected dissipative systems,

Stability and Nominal Performance: Review of Lyapunov stability,Generalized stability regions for LTI systems, the generalized plane concept, Quadratic, H-infinity, and H2 nominal performances,

Control Synthesis: Analysis to synthesis – a general procedure, Performance Specifications: H-infinity design, positive real design, H2 problem, State feedback problems, Discrete Time Systems,
Systems with Parametric Uncertainty: Affine parameter dependent systems, polytopic parameter dependent systems, Robust stability for autonomous systems: quadratic stability, quadratic stability of affine and polytopic models, parameter dependent Lyapunov functions,

Text and Reference Books

1. C. Scherer and S. Weiland, *Linear Matrix Inequalities in Control*, Dutch Institute of Systems and Control, 2006.
2. S. Boyd, L. E. Ghaoui, E. Feron and E. Balakrishnan*, Linear Matrix Inequalities in System & Control Theory, Society for Industrial & Applied,* 1994.
3. R. Bhatia*, Matrix Analysis*, 1997 Edition, Springer, 1996.
4. F. Zhang, *Matrix Theory*, 2nd Edition, Springer, 2011.

Course Code: MATH-825 **Title:** Stochastic Differential Equations **Credit Hrs:** 03

Course Outline: Brief Introduction to Diffusion Processes and How They Arise as Natural Approximations to Certain Discrete Processes, Review of Some Basic Facts about Brownian Motion and Martingales, ITO Stochastic Integrals Construction and Martingale Properties, ITO's Formula, Integration by Parts, Comparison with Stieltjes Integrals and Ordinary Calculus, Stochastic Differential Equations, Existence and Uniqueness of Solutions, Markov Property, Generators, Martingale Problem Characterization of Weak Solutions, Diffusion Processes, Dynkin's Formula, Calculations of Expectations and Probabilities, Converting to the Natural Scale, Stationary Distributions, Examples from Biology: Wright-Fisher Diffusions, Branching Diffusions

Text and Reference Books

1. K.L. Chung and R. J. Williams, *Introduction to stochastic integration*, Second Ed., Probability and its Applications, Birkhauser Boston Inc., MA, 1990.
2. S. Karlin and H. Taylor,*A Second Course in Stochastic Processes*, 1st Edition, Academic Press, 1981.
3. F. C. Klebaner*, Introduction to Stochastic Calculus with Applications*, 3rd Edition, Imperial College Press, 2012.
4. D. Richard*, Stochastic calculus: A practical introduction*, 1st Edition, CRC Press, 1992.

Course Code: MATH-826 **Title:** Fixed Point Theory and Applications **Credit Hrs:** 03

Course Outline: Lipschitzian, Contraction, Contractive and Non-Expansive Mappings, Banach's Contraction Principal with Application to Differential and Integral Equations, Brouwer's Fixed Point Theorem with Applications, Schauder's Fixed Point Theorem with Applications, Uniformly Convex and Strictly Convex Spaces, Properties of Non-Expansive Mappings, Extension's of Banach's Contraction Principal

Text and Reference Books

1. A. Granas and J. Dugundji*, Fixed Point Theory*, 2003 Edition, Springer, 2003.
2. R. P. Agarwal, D. O. Regan and D. R. Sahu*, Fixed Point Theory for Lipschitzian-type mappings with applications,* Springer-Verlag, USA.
3. R. P. Agarwal*, Fixed Point Theory and Applications*, Cambridge University Press, 2006.
4. V. I. Istratescu, *Fixed Point Theory: (Mathematics and Its Applications), 1st edition, 2001.*

Course Code: MATH-827 **Title:** Integral Inequalities **Credit Hrs:** 03

Course Outline: Some Quadrature Rules and Their Applications Ostrowski Inequality in L_1 And L_p-and L~ Spaces and Applications Gruss Inequality, Its Variant and Applications Ostrowski – Gruss Inequalities, Their Consequences and Applications Perturbed Results for Ostrowski and Ostrowski-Gruss Type

Inequalities for Convex Functions, Hadmard, Sinequality, Hadmard,S Inequality for Convex Functions and Applications.

Text and Reference Books

1. S. Dragomir and T. M. Rassias*, Ostrowski Type Inequalities and Applications in Numerical Integration*, 2002 Edition, Springer, 2002.
2. G. A. Anastassiou*, Advanced Inequalities*, World Scientific Publishing Company, Singapore. 2011.
3. D. D. Bainov and P.S. Simeonov, *Integral Inequalities and Applications*, 1st Edition, Springer, 1992.
4. D. S. Mitrinovic, J. Picarcic and A.M Fink, *Inequalities Involving Functions and Their Integrals and Derivatives*, 1991 Edition, Springer, 1991.

Course Code: MATH-828 **Title**: Banach Algebras **Credit Hrs:** 03

Course Outline: Banach Algebra: Ideals, Homeomorphisms, Quotient Algebra, Wiener's Lemma, Gelfand's Theory of Commutative Banach Algebras: The Notions of Gelfand's Topology, Radicals Gelfand's Transforms.
Basic Properties of Spectra, Gelfand-Mazur Theorem and Symbolic Calculus of A-Valued Functions, Normed Rings, Gelfand-Naimark Theorem.

Text and Reference Books

1. M.A. Naimark*, Normed Algebras***,** Wolters Noordhoff Publishing Groningen, Netherlands, 1972.
2. C. E. Rickart, *Banach Algebras***,** D Van Nostrand Company Inc. NewYorK , 1960.
3. W. Rudin, *Functional Analysis***,** McGraw Hill, Inc, New York, 1989.
4. W. Zelazko*, Banach Algebras***,** American Elsevier Publishing Company Inc, New York, 1973.

Code: MATH-829 **Title:** Harmonic Functions Theory **Credit Hrs:** 03

Course Outline: Definition and Examples, Invariance Properties, The Mean-Value Property, The Maximum Principle, The Poisson Kernel, The Dirichlet Problem, Converse of the Mean-Value Property, Real Analyticity and Homogeneous Expansions, Bounded Harmonic Functions Related Properties, Positive Harmonic Functions Related Properties, The Kelvin Transforms, Harmonic Polynomials, Harmonic Hardy Spaces, Harmonic Functions on Half-Spaces, Harmonic Bergman Spaces, The Decomposition Theorem, Annular Regions, The Dirichlet Problem and Boundary Behavior

Text and Reference Books

1. S. Axler, P. Bourdon, W. Ramey, *Harmonic Function Theory*,2n Edition, Springer, 2001.
2. S. Bergman*,The Kernel Function and Conformal Mapping*, American Mathematical Society, 1950
3. L. L. Helms, *Introduction to Potential Theory,* Wiley-Inter science, 1969.
4. O. D. Kellogg, *Foundations of Potential Theory,* Springer, 1929.

Course Code: MATH-830 **Title:** Cosmology **Credit Hrs:** 03

Course Outline: Review of Relativity, Historical Background, Astronomy, Astrophysics, Cosmology, The Cosmological Principle and its Strong Form, The Einstein and Desitter Universe Models, Measurement of Comic Distance, The Hubble Law and the Friedmann Models, Steady State Models, The Hot Big Bang Models, The Inicrowave Background, Discussion of Significance of a Start of Time, Fundamentals of High Energy Physic, The Chronology and Composition of the Universe, Non-Brayonic Dark Matter, Problems of the Standard Model of Cosmology, Bianch Space-Times, Mixmaster Models, Inflationary Cosmology, Further Development of Inflationary Models, Kaluza-Klein Cosmologies, Review of Material.

Text and Reference Books

1. L. F. Abbott and S. Y. Pi, *Inflationary Cosmology*, World Scientific, 1986.
2. E.W. Kolb and M. S. Turner *The Early Universe*, Addison Wesley, 1990.
3. P. J. E. Peebles, *Principles of Physical, Princeton University Press*, 1993.

4. Ryan M. P. Jr. and Shepley*, Homogeneous Relativistic Cosmologies*, Princeton University Press, 1975.

Course Code: MATH-831 Bifurcation and Chaos Credit Hrs: 3
Course Outlines: Modeling with Nonlinear Systems of ODEs, Stability and Bifurcation Theory, The Hopf bifurcation and limit cycles, Lyapunnov exponents, Periodic and quasi periodic behavior Homoclinic & Heteroclinic Orbits and Mel'nikov Theory, Stability, Bifurcation and Chaos in I-dimensional Maps. Period doubling, Feigenbaum's Approach to Chaos, Properties of Chaos. The Lorenz Equations
Text and Reference Books:

1. S. Strogatz, *Nonlinear Dynamics, and Chaos: With Applications* to *Physics, Biology, Chemistry and Engineering*, 2nd Edition, Westview Press, 2014.
2. P. Glendinning, *Stability, Instability and Chaos*, 1st edition, Cambridge University Press, 1994.
3. R. Hillborn, *Nonlinear Dynamics and Chaos,* 2nd edition, Oxford University Press, 2001.
4. J. Ohtsubu, Stability, Instability and Chaos, 3rd edition, Springer, 2012.

Course Code: MATH-832 **Title:** Nonlinear Systems and Control **Credit Hrs:** 03
Course Outline:
Analysis techniques for nonlinear systems: phase portraits and their symmetries, singular points, phase plan analysis of linear and nonlinear systems, existence of limit cycles,
Fundamentals of Lyapunov Theory: Nonlinear systems and equilibrium points, concept of stability, linearization and local stability, Lyapunov's direct method and stability analysis, Krasovskii and variable gradient methods, performance analysis, control design based on Lyapunov's direct method
Advanced Stability Analysis: Stability of non-autonomous systems, Linearization and Lyapunov's direct methods for nonlinear autonomous systems, Asymptotic properties of functions and their derivatives, Barbalat Lemma, positive real and strictly positive real transfer functions, Kalman-Yakubovich lemma, passivity of linear systems,
Describing Function Analysis: Fundamentals of describing function analysis, common nonlinearities in control systems and their describing functions, Nyquist criterion and its extensions, existence and stability of limit cycles, reliability of describing function analysis,
Nonlinear Control Systems Design: Feedback Linearization: Canonical form, Lie derivatives and Lie brackets, diffeomorphism and state transformations, the Frobenius theorem, input-state and input-output linearization of SISO systems, the normal forms and zero dynamics, local and global asymptotic stabilizations, tracking control and inverse dynamics, feedback linearization of multi-input systems,
Adaptive Control: Basic concepts in Adaptive Control, Adaptive control of first order systems, Adaptive control of linear systems of relative degree 1 and higher with full state-feedback and output feedback, Adaptive Control of nonlinear systems, robustness of adaptive control systems,

Text and Reference Books

1. H. K. Khalil*, Nonlinear Control*, Prentice Hall, 2002.
2. Slotine and Li, *Applied Nonlinear Control*, Prentice Hall, 1991.
3. A. Isidori, *Nonlinear Control Systems*, 3rd Edition, Springer, 1995.
4. B. Friedland*, Control System Design: An Introduction to State-Space Methods*, Dover Publications, 2005

20. List of Examiners for MPhil / PhD in Mathematics Programs
20.1 National Examiners

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   Professor, Department of Mathematics, University of the Punjab Quaid-i-Azam Campus,
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    Associate Professor, Department of Mathematics, University of Sargodha (UOS), Sargodha
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    Associate Professor, Department of Mathematics, CUI, Sahiwal
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31. Dr. Azad Hussain
    Associate Professor (Tenured), Department of Mathematics, University of Gujrat, Punjab
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    Associate Professor, Department of Mathematics, UAJ&K Muzaffarabad
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    Associate Professor, Department of Mathematics, GCU, Lahore
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