School of Engineering

Applied Science Cluster

4 - Year B.Sc. (Hons.) Mathematics/ B.Sc. (Hons.) Mathematics with Research

Specialization: Data Science / Computational Mathematics

Programme Handbook

2023-2027

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Contents

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1.0 Abbreviations

Cat	-	Category
Cr	-	Credits (*A credit is equivalent to one lecture hour/ one hour of tutorial/ two hours of Laboratory)*
L	-	Lecture
T	-	Tutorial
P	-	Practical
ENGG	-	Engineering Sciences (including General, Core)
HUM	-	Humanities (including Languages, Social Sciences, and others)
SCI	-	Basic Sciences (including Mathematics)
PRJ	-	Project Work (including Seminars, Dissertation, and Internships)
PE	-	Program Elective (includes Specialization courses)
TC	-	Total Credits

AES	-	Aerospace Engineering
AIE	-	Computer Science and Engineering-Artificial Intelligence
BIO	-	Biology
CCE	-	Computer Science and Communication Engineering
CHE	-	Chemical Engineering
CHY	-	Chemistry
CSE	-	Computer Science and Engineering
CVL	-	Civil Engineering
CUL	-	Cultural Education
EAC	-	Electronics and Computer Engineering
ECE	-	Electronics and Communication Engineering
EEE	-	Electrical and Electronics Engineering
ELC	-	Electrical and Computer Engineering
MAT	-	Mathematics
MEE	-	Mechanical Engineering
PHY	-	Physics
UE	-	University Elective (includes Signatory, Exploratory and Open Electives)

2.0 Dean Message

The vision of UPES is to deliver a high-quality education to the community of aspiring students. UPES offers affordable and interactive learning solutions for students from the undergraduate section to the Ph.D. programme. It works collaboratively with the student community to ensure that they acquire globally relevant education in order to realize their cherished goals in life.

The vision of Applied Science Cluster (ASC) is to attain global recognition as a hub of excellence for both learning and research in diverse areas of Applied Sciences. It has three departments: Department of Chemistry, Physics, Mathematics, It offers UG, PG, and Ph.D. programmes that are designed to be outcome-based and industry-focused. Curriculum has been carefully created by experienced faculty members in consultation with various renowned Universities. It complements theoretical learning with practical application and ensures industry exposure. The programmes are also designed to train students in interdisciplinary thinking and effective communication skills. This contributes to student’s employability and guarantees a smooth transition from academia to work.

ASC has well qualified, experienced and dedicated faculty with exceptional research profiles and vision. Its areas of research interest and expertise cover a broad range from basic to modern sciences. Students are encouraged to pursue internships with organizations involved in research and development. They are also expected to execute a well-defined project in order to cultivate and enhance essential skills like critical thinking and problem solving.

The cluster, with all of its amenities and pleasant ambiance, assures striving young minds of an all-round academic and personality development. I am sure the journey of students at UPES will be enlightening, encouraging and rewarding. My best wishes to our incoming graduates. We are eager and proud to help you in your academic and professional journeys.

3.0 Vision and Mission of the University:

Vision of UPES

To be an Institution of Global standing for developing professionally competent talent contributing to nation building.

Mission of UPES

- Develop industry-focused professionals with an international outlook.
- Foster effective outcome-based education system to continually improve teaching-learning and research.
- Inculcate integrative thought process among students to instill lifelong learning.
- Create global knowledge eco-system through training, research & development and consultancy.
- Practice and promote high standards of professional ethics and develop harmonious relationship with environment and society.

4.0 Vision and Mission of the School

Vision of School

To be a forerunner in engineering education by delivering excellent engineering graduates fortified with sound knowledge and integrity, by performing cutting-edge research and by innovating new technologies to benefit the nation and the world at large.

Mission of School

- To develop industry focused engineers with expertise in the areas of oil and gas, energy, infrastructure, transportation, electronics, automotive design and aviation.
- To sustain a strong focus on delivering excellent engineering and science education by providing an exposure to the concurrent research and industry trends and by employing innovative pedagogy tools/ techniques.
- To promote research, technology incubation and entrepreneurship to address the most pressing needs of our society and nation.

- To maintain a professional and ethical environment conducive to the intellectual growth of faculty and students, fostering communication, dialogue and sharing of ideas.
- To strengthen our linkages with academic institutes worldwide, industry and alumni network for evolving our programs towards better student outcomes.

5.0 About the Cluster

Applied Science Cluster (ASC) will offer programs designed under the guidelines prescribed by UGC and in a wide-range consultation with Industrial experts, to incorporate the latest trends thus keeping the syllabus abreast of the latest developments in the field of Science. The Applied Science Cluster offers a diverse array of UG, PG, and Ph.D. degree programs in disciplines including Physics, Chemistry, and Mathematics. The curriculum for the UG and PG programs has been designed so as to provide students with the necessary background in basic sciences as well as analytical skills to enable them to pursue higher studies in emerging research areas of science and thereby empower them to become industry-ready. The major focus of the school will be on producing high-quality research output in the form of publications, patents, and the execution of externally funded research and consultancy projects.

6.0 Programme Overview

The B. Sc. (Hons.) Mathematics by Research program offered by UPES School of Advanced Engineering is a comprehensive 4-year course falling under the Applied Science Cluster. It provides students with a flexible and dynamic curriculum, aligned with the NEP 2020 framework, enabling them to customize their education according to their individual interests and career aspirations. The program is divided into 8 semesters, and each semester encompasses courses worth a maximum of 20 credits. One of the key highlights of this program is the provision of multiple exit and entry options. After completing 40 credits in a year, students have the option to exit with a certificate in the respective discipline. Similarly, after earning 80 credits in two years, students can choose to take an exit with a diploma. Furthermore, those who accumulate 120 credits in three years are eligible to receive a UG degree in the given discipline. The program culminates in the fourth year, where students have the opportunity to earn either a B. Sc. (Hons.) or B. Sc. (Hons.) by Research, depending on their preferences and choices. Those opting for B. Sc. (Hons.) will undertake advanced domain-specific courses, while students pursuing B. Sc. (Hons.) by Research will engage in extensive research and defend their thesis in front of a panel comprising experts from their area of research.

As part of the program, students will also have the option to specialize in Data Science & Computational Mathematics through electives and additional courses. In the final year, students will undergo research-specific courses to prepare for their dissertations. Moreover, the program allows for lateral entry, adhering to the NEP 2020 regulations, which enables students to join the course at a later stage if they have prior qualifying credits. An additional benefit is that after completing the 4-year UG degree, students can directly pursue a PhD with coursework both in India and abroad, opening up further avenues for advanced research and academic pursuits.

7.0 Programme Educational Objectives

PEO-1: To train students to appreciate mathematical and computational skills to clear various competitive examinations including civil services, and JAM.

PEO-2: To provide knowledge of highest standards in Mathematics so that the students are able to utilize significant opportunities in various service sectors such as banks, government offices and higher studies in leading universities and institutions.

PEO-3: To engage students in life-long learning and guide them to continuously explore, learn and adapt new skills that will help them in their higher education and career prospects.

PEO-4: To encourage students to be committed towards ethical practices and development of the society.

8.0 Programme Outcome and Programme Specific Outcomes

Programme Outcome

PO1 Science Knowledge: Explain the theoretical, conceptual, computational and experimental knowledge of science & mathematics to the solution of scientific problems.

PO2 Problem Analysis and Solution: Formulate and analyze scientific approach for solving real-life problems that meet the specified needs with appropriate consideration for the broader understanding of subject.

PO3 Data Analysis and Interpretation: Demonstrate, analyze & interpret the scientific data to provide the appropriate solution of the problem.

PO4 Modern Tool Usage: Select and apply appropriate techniques/tools effectively including graphical techniques, IT tools, reports and presentations within the scientific environment.

PO5 Environment and Sustainability: Understand the impact of the scientific solutions in societal and environmental contexts, demonstrate the knowledge of, and need for sustainable development.

PO6 Teamwork and Ethics: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings by applying the ethical principles.

PO7 Communication: Demonstrate professional attitude with effective communication that support and enhance individual/team performance.

PO8 Technical Project Handling: Demonstrate knowledge of science & mathematics and its various principles and apply them to handle projects in multidisciplinary environments.

PO9 Life-long Learning: Recognize the need to engage in lifelong learning through continuing education and research.

PO10 Research: Investigate experimental, computational or theoretical research problems from science & mathematics domains independently.

Programme Specific Outcomes

PSO 1: Understand the mathematical concepts in the field of algebra, analysis, computational techniques, optimization, differential equations, etc.

PSO 2: Able to acquire critical thinking and effective reasoning skills for establishing mathematical results and to provide a knowledge base for advanced study or research in Mathematics.

PSO 3: Execute new ideas in the field of research and development using principles of Mathematics learned through activities such as expert lecturers, workshops, seminars, and field projects.

9.0 Academic Integrity Policy

a. University Integrity Policy

b. Course integrity policy

10.0 Overview of Credit Allocation/ Credit Break up

Category-wise Credit distribution

Category	Number of Credits
Major Core (MC)	BSc (H) Mathematics:80
	BSc (H) by Research: 74
Major Elective (ME)	16
Signature courses (SC)*	
Life Skill Courses (LSC)*	14
Exploratory Courses (EC)*/Minor	32
Humanities (HUM)	7
Projects (PRJ)	BSc (H) mathematics: 11
	BSc Mathematics by Research :17
Mandatory Non-Credit Courses	0
Total	160

* Electives

- Major core subjects include those subjects that are mandatory to all similar programmes and program specific courses. To be eligible for the degree, students must successfully finish each of the courses.
- Major elective courses provide the students the opportunity to study courses that are more complex and specialized, in their field of specialization.

Major Core	**Total number of Credits (BSc (H) Mathematics: 80 Credits**				
Course Code	**Course Title**	**L**	**T**	**P**	**TC**
MATH1044	Differential Calculus	3	2	0	4
MATH1057	Linear Algebra I	3	1	0	4
CSEG1023	Computational Techniques	2	0	0	2
MATH1062	Real Analysis I	3	1	0	4
MATH1063	Linear Algebra II	3	1	0	4
MATH1064	Analytical Geometry	3	1	0	4
MATH2048	Ordinary Differential Equations	3	0	2	4
MATH2055	Real Analysis II	3	1	0	4
MATH2056	Integral Calculus	3	0	2	4
MATH2054	Partial Differential Equations	3	0	2	4
MATH2057	Complex Analysis	3	1	0	4
MECH2073	Mechanics	3	1	0	4
MATH3061	Probability and Statistics	3	1	0	4
MATH3063	Abstract Algebra	3	1	0	4
MATH3017	Mathematical Modelling	3	0	2	4
MATH3062	Numerical Analysis	3	0	2	4
MATH3064	Linear Programming	3	1	0	4
MATH4011	Advanced Numerical Techniques	2	0	2	3
MATH4012	Discrete Mathematics	3	0	0	3
ASRM4001	Research Methodology & Ethics	2	0	0	2
MATH4022	Integral Equation & Calculus of Variation	3	0	0	3
MATH4023	Topology	3	0	0	3
				Total Credits	80

Major Core	Total number of Credits (BSc Mathematics by Research): 72 Credits				
Course Code	**Course Title**	**L**	**T**	**P**	**TC**
MATH1044	Differential Calculus	3	2	0	4
MATH1057	Linear Algebra I	3	1	0	4
CSEG1023	Computational Techniques	2	0	0	2
MATH1062	Real Analysis I	3	1	0	4
MATH1063	Linear Algebra II	3	1	0	4
MATH1064	Analytical Geometry	3	1	0	4
MATH2048	Ordinary Differential Equations	3	0	2	4
MATH2055	Real Analysis II	3	1	0	4
MATH2056	Integral Calculus	3	0	2	4
MATH2054	Partial Differential Equations	3	0	2	4
MATH2057	Complex Analysis	3	1	0	4
MECH2073	Mechanics	3	1	0	4
MATH3061	Probability and Statistics	3	1	0	4
MATH3063	Abstract Algebra	3	1	0	4
MATH3017	Mathematical Modelling	3	0	2	4
MATH3062	Numerical Analysis	3	0	2	4
MATH3064	Linear Programming	3	1	0	4
MATH4011	Advanced Numerical Techniques	2	0	2	3
MATH4012	Discrete Mathematics	3	0	0	3
ASRM4001	Research Methodology & Ethics	2	0	0	2
		Total Credits			**72**

Humanities (HUM)	Total Number of Credits: 7 Credits				
Course Code	**Course Title**	**L**	**T**	**P**	**TC**
SSEN0101	Environment Sustainability & Climate Change	2	0	0	2
SSEN0102	Environmental Sustainability & Climate Change (Living Lab)	0	0	4	2
LSPS1001	Constitution and Indian Polity	2	0	0	2
ASSC3001	Scientific Communication	1	0	0	1
				Total Credits	**7**

Projects (PRJ)	Total Number of Credits (BSc (H) Mathematics):11 Credit Total Number of Credits (BSc Mathematics by Research):17 Credits				
Course Code	**Course Title**	**L**	**T**	**P**	**TC**
SIIB3102	Summer Internship	0	0	10	5
DSIT4102	Dissertation: BSc (H) Mathematics	0	0	12	6
	Dissertation: BSc Mathematics by Research	0	0	24	12

Mandatory Non-Credit Courses	Total Number of Credits: 0 Credits				
Course Code	**Course Title**	**L**	**T**	**P**	**TC**
SLLS2001	Social Internship	0	0	0	0
				Total Credits	**0**

Major Electives

Course Code	Course Title	L	T	P	TC
	Skill Enhancement Course I (Elective)	2	0	0	2
	Skill Enhancement Course II (Elective)	2	0	0	2
	Elective I (Specialization)	4	0	0	4
	Elective II (Specialization)	4	0	0	4
	Elective III (Specialization)	4	0	0	4
				Total Credits	**16**

Mandatory Minor Courses- 32 Credits*			
Course Code	**Course Name**	**credit**	**Prerequisite**
MATH1057	Linear Algebra I	4	NA
MATH1030	Calculus	4	NA
MATH2048	Ordinary Differential Equations	4	NA
MATH2054	Partial Differential Equations	4	NA
MATH3061	Probability and Statistics	4	NA
MATH3062	Numerical Analysis	4	NA
MATH4013	Discrete Mathematics	4	NA
MATH4019	Integral Eq.& Calculus of Variations	4	NA
	Total Credits	**32**	
*If a student has completed 'n' number of equivalent credits among the above three courses, as a part of major curriculum then 'n' number of credits should be taken extra from the optional courses			

School for Life Courses- 14 Credits*			
Course Code	**Course Name**	**credit**	**Prerequisite**
SLSG0102	Critical Thinking	2	NA
SLLS0101	Living Conversations	2	NA
SLLS0201	Design Thinking	2	NA
SLLS0202	Working with Data	2	NA
SLLS0103	Leadership & Teamwork	2	NA
	Technologies of Future/Meta 101	2	NA
SLSG0205	Start your own start-up	2	NA
	Total Credits	**14**	

11.0 Programme Structure

The term "Program Structure" refers to a list of courses (Core, Elective, and Open Elective) that make up an academic program, describing the syllabus, credits, hours of instruction, assessment and examination systems, minimum number of credits necessary for program graduation, etc.

Sample: BSc (H) Mathematics & BSc Mathematics by Research

Semester I:

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
MC	MATH1044	Differential Calculus	3	2	0	4	
MC	MATH1057	Linear Algebra I	3	1	0	4	
ME		Minor-I	4	0	0	4	
HUM	SSEN0101	Environment Sustainability & Climate Change	2	0	0	2	
LSC	SLSG0102	Critical Thinking	2	0	0	2	
MC	CSEG1023	Computational Techniques	2	0	0	2	
						Semester Credits: 18	

Semester II:

Cat	Course Code	Course Title	L	T	P	TC	prerequisites
MC	MATH1061	Real Analysis I	3	1	0	4	
MC	MATH1062	Linear Algebra II	3	1	0	4	Linear Algebra I (MATH1057)
MC	MATH1064	Analytical Geometry	3	1	0	4	
ME		Minor-II	4	0	0	4	
HUM	SSEN0102	Environment Sustainability & Climate Change (Living Lab)	0	0	4	2	
LSC	SLLS0101	Living Conversations	2	0	0	2	
HUM	LSPS1001	Constitution and Indian Politics	2	0	0	2	
						Semester Credits: 22	

Semester III:

Cat	Course Code	Course Title	L	T	P	TC	prerequisites
MC	MATH2048	Ordinary Differential Equation	3	0	2	4	
MC	MATH2055	Real Analysis II	3	1	0	4	Real Analysis I (MATH1061)
MC	MATH2056	Integral Calculus	3	0	2	4	
ME		Skill Enhancement Course I (Elective)	2	0	0	2	
ME		Minor-III	4	0	0	4	
LSC	SLLS0201	Design Thinking	2	0	0	2	
	SLLS2001	Social Internship	0	0	0	0	
						Semester Credits: 20	

Semester IV:

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
MC	MATH2054	Partial Differential Equations	3	0	2	4	
MC	MATH2057	Complex Analysis	3	1	0	4	Analytical Geometry (MATH1064)
ME	MECH2073	Mechanics	3	1	0	4	
ME		Skill Enhancement Course II (Elective)	2	0	0	2	
ME		Minor-IV	4	0	0	4	
LSC	SLLS0202	Working with Data	2	0	0	2	
Semester Credits: 20							

Semester V:

Cat	Course Code	Course Title	L	T	P	TC	prerequisites
MC	MATH3061	Probability and Statistics	3	1	0	4	
MC	MATH3063	Abstract Algebra	3	1	0	4	
ME		Minor-V	4	0	0	4	
LSC	SLLS0103	Leadership & Teamwork	2	0	0	2	
		Technologies of Future/Meta 101	2	0	0	2	
PRJ	SIIB3102	Summer Internship	0	0	10	5	
HUM		Scientific Communication	1	0	0	1	
Semester Credits: 22							

Semester VI:

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
MC	MATH3017	Mathematical Modelling	3	0	2	4	
MC	MATH3062	Numerical Analysis	3	0	2	4	
MC	MATH3064	Linear Programming	3	1	0	4	
ME		Minor-VI	4	0	0	4	
LSC	SLSG0205	Start your own start-up	2	0	0	2	
Semester Credits: 18							

Semester VII:

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
MC	MATH4011	Advanced Numerical Techniques	2	0	2	3	Numerical Analysis (MATH3062)
MC	MATH4012	Discrete Mathematics	3	0	0	3	
ME		Elective I	3	1	0	4	
ME		Elective II	3	1	0	4	
ME		Minor-VII	4	0	0	4	
MC	ASRM4001	Research Methodology & Ethics	2	0	0	2	
Semester Credits: 20							

Semester VIII (B.Sc. (Hons.) :

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
PRJ	DIST4102	Dissertation	0	0	12	6	
ME		Elective III	3	1	0	4	
MC	MATH4022	Integral Equation & Calculus of Variation	3	0	0	3	
MC	MATH4023	Topology	3	0	0	3	
ME		Minor-VIII	3	1	0	4	
		Total	12	4	12	20	
						Semester Credits: 20	

Semester VIII (B.Sc. (Hons.) by Research):

Cat	Course Code	Course Title	L	T	P	TC	Prerequisites
PRJ	DIST4102	Dissertation	0	0	24	12	
ME		Elective III	3	1	0	4	
ME		Minor -VIII	3	1	0	4	
		Total	6	2	24	20	
						Semester Credits: 20	

Specialization Tracks

The students enrolled in B.Sc. Mathematics would have an option to specialize in one the following emerging areas:

1. Data Science
2. Computational Mathematics

The student must complete a minimum of 12 credits in the chosen area of specialization. List of elective courses in specialization tracks

Major Elective 12 Credits (3 Courses)						
Track 1 : Data Science						
Cat	**Course Code**	**Course Title**	**L**	**T**	**P**	**TC**
	MATH4020P	Bayesian Data Analysis	3	1	0	4
	MATH4014P	Time Series and Forecasting Methods	3	1	0	4
	MATH4015P	Multivariate Statistics	3	1	0	4
	MATH4024P	Text Analytics	3	1	0	4
	MATH4017P	Financial Data Analysis	3	1	0	4
Track 2 : Computational Mathematics						
	MATH4016P	Optimization Techniques	3	1	0	4
	MATH4014P	Time Series and Forecasting Methods	3	1	0	4
	MATH4021P	Boolean Algebra & Automata Theory	3	1	0	4
	MATH4025P	Riemann Integration & Series of Functions	3	1	0	4
	MATH4018P	Finite Element Method	3	1	0	4

Mathematics Minor course requirement list

Students from other departments in the university have the option to take a minor degree from the Mathematics stream. The list of course requirements to obtain a Mathematics minor degree is as follows.

Total credit for minor requirement is minimum 32

Mandatory Courses- 32 Credits*			
Course Code	**Course Name**	**credit**	**Prerequisite**
MATH1057	Linear Algebra I	4	NA
MATH1030	Calculus	4	NA
MATH2048	Ordinary Differential Equations	4	NA
MATH2054	Partial Differential Equations	4	NA
MATH3061	Probability and Statistics	4	NA
MATH3062	Numerical Analysis	4	NA
MATH4013	Discrete Mathematics	4	NA
MATH4019	Integral Eq.& Calculus of Variations	4	NA
*If a student has completed 'n' number of equivalent credits among the above three courses, as a part of major curriculum then 'n' number of credits should be taken extra from the optional courses			
Optional Courses- XX Credits**			
**Equivalent courses in the student's major discipline will not be counted towards minor requirement. Apart from these equivalent courses, the student must complete optional course requirement			

12.0 List of Electives

A. Programme Electives

- Specialization (Name of the subjective)

Data Science	**Computational Mathematics**
Bayesian Data Analysis	Optimization Techniques
Time Series and Forecasting Methods	Time Series and Forecasting Methods
Multivariate Statistics	Boolean Algebra & Automata Theory
Text Analytics	Riemann Integration & Series of Functions
Financial Data Analysis	Finite Element Method

- **Minor**

  If all courses from any basket are completed by the student, he/she receives a minor.

Minor Basket
Linear Algebra I
Calculus
Ordinary Differential Equations
Partial Differential Equations
Probability and Statistics
Numerical Analysis
Discrete Mathematics
Integral Eq.& Calculus of Variations

B. University Electives

- Signature Courses- School for Life Courses/ Life Skill Courses

School for Life Courses- 14 Credits*			
Course Code	**Course Name**	**credit**	**Prerequisite**
SLSG0102	Critical Thinking	2	NA
SLLS0101	Living Conversations	2	NA
SLLS0201	Design Thinking	2	NA
SLLS0202	Working with Data	2	NA
SLLS0103	Leadership & Teamwork	2	NA
	Technologies of Future/Meta 101	2	NA
SLSG0205	Start your own start-up	2	NA
	Total Credits	**14**	

- **Exploratory Courses**

  If the student takes up courses from different baskets, that is regarded as an exploratory course.

Physics	AIML
Chemical Science	IOT
Mathematics	Block Chain
Geoscience	Data Science
Disaster Management	Law
Sustainability	Business
Space Engineering	Design
Reclaim Engineering	Health Science
Climate Change	Economics

- **Open Elective**

  Skill Enhancement Courses (SEC) Electives

Operating System: Linux
Introduction to R
Computer Algebra Systems and Related Software
Computer Graphics
Graph Theory
Introduction to MATLAB Programming
Latex and HTML
Introduction to Python

Course Syllabus/ Course Plans

SEMESTER I

Course Code	Course name	L	T	P	C
MATH1044	Differential Calculus	3	0	1	4
Total Units to be Covered: 4	Total Contact Hours: 45+30				
Prerequisite(s):	Elementary Algebra and Elementary Geometry	Syllabus version: 1.0			

Course Objectives

1. To help the students understand the concept of differentiability of functions of one and several variables.
2. To make the students know the computation of extrema of functions.
3. To help the students to obtain series expansion of functions.
4. To make the students understand to trace different curves.
5. To enable the students to apply the concepts of calculus in real life applications.

Course Outcomes

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

CO1. Find higher order derivatives, expand the functions and find the extrema of functions of single variable.
CO2. Determine the asymptotes and trace the curves.
CO3. Solve the partial and total differentiation problems.
CO4. Expand the functions and find the extrema of functions of several variables.

Course Description

Calculus is the most fundamental tool in mathematics and its applications. This course covers calculus of functions of one and several variables. This course is designed in such a way that it enables the students to cope confidently with the mathematics needed in their future subjects. The curriculum aims at developing student's ability to conceptualize and to use mathematics to formulate and solve problems for more advanced mathematical studies.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	1	-	-	-	-	-	1	2	3	1
CO2	3	2	1	1	-	-	-	-	-	-	2	1	-
CO3	3	2	-	-	-	-	-	-	2	2	3	2	1
CO4	3	2	-	-	-	-	-	-	2	2	2	3	1
Average	3	2	1	1	-	-	-	-	2	1.7	2.2	2.2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Calculus of Functions of One Variables-I 10 Lecture Hours

Limit of a function ($\epsilon - \delta$ Definition), Continuity of a function, Properties of continuous functions, Intermediate value theorem, Classification of discontinuities, Differentiability of a function, Rolle's theorem, Mean value theorems and their geometrical interpretations, Applications of mean value theorems, Indeterminate forms, Successive differentiation, Leibnitz theorem, Expansion of functions in Taylor's and Maclaurin's series, Extrema of functions of one variable.

Unit 2: Calculus of Functions of One Variables-II 15 Lecture Hours

Tangents and Normal of cartesian curves, Tangent at origin, Angle of intersection of two curves, Cartesian subtangent and subnormal, Tangents and Normals of polar curves, Angle between radius vector and tangent, Perpendicular from pole to tangent, Polar sub tangent and polar subnormal, Pedal equation of curve (cartesian and polar), Derivative of arc (cartesian and polar formula), Curvature, Radius of curvature; Cartesian, Parametric, Polar and Pedal formula for radius of curvature, Centre and circle of curvature, Asymptotes, Determination of asymptotes for cartesian and polar curves, Regular and Singular points of a curve, Points of inflexion, Multiple points, Double points (Cusp, Node and conjugate points), Curve tracing.

Unit 3: Calculus of Functions of Several Variables-I 12 Lecture Hours

Functions of several variables, level curves and surfaces, limit, continuity and differentiability of functions of two variables, Partial differentiation, Total differential, Directional derivatives, The gradient, Maximal and normal property of the gradient, Tangent plane and normal lines.

Unit 4: Calculus of Functions of Several Variables-II 8 Lecture Hours

Jacobians, Extrema for functions of several variables, Lagrange's method of undetermined multipliers, constrained optimization problems, Expansion of functions.

List of Practical's

Computer Software: Matlab/ Python/ R/ Maple/ Mathematica or any other software tool

Experiment No: 01 Some Standard Functions
Plotting the graphs of different functions such as exponential, logarithmic, trigonometric etc. with an understanding to illustrate the effect of arbitrary constants on the graphs.

Experiment No: 02 Polynomials and Parametric Curves
Plotting the graphs of polynomials of degree 4 and 5, the derivative graph, the second derivative graph and comparing them; sketching parametric curves (eg. Trochoid, cycloid, epicycloids, hypocycloid).

Experiment No: 03 Surfaces
Obtaining surface of revolution of curves.

Experiment No: 04 Conics I and Conics II
Tracing of conics in Cartesian coordinates/ polar coordinates; sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, hyperbolic paraboloid using Cartesian coordinates.

Experiment No: 05 Hyperbolic Functions
Graph of hyperbolic functions.

Experiment No: 06 Extrema of functions
Graphs of local and global extrema for functions of one and several variables.

Experiment No: 07 Directional derivatives
Graphical representation of gradient vectors and directional derivatives

Text Books:

1. T. M. Apostol: Calculus, John Willey and Sons, New York
2. M. Ray: Differential Calculus, Shiva Lal Agarwal and Co., Agra
3. G. B. Thomas., R. L. Finney, Calculus and Analytical Geometry, Pearson, ISBN: 9788177583250.
4. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005, ISBN: 9780387979762
5. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

Reference Books:

1. R. Courant and F. John, Introduction to Calculus and Analysis I, Springer-Verlag, ISBN: 9783642586040.
2. R. Courant and F. John, Introduction to Calculus and Analysis II, Springer-Verlag, ISBN: 9783540665700.
3. H. Anton, I. Bivens and S. Davis, Calculus: Early Transcendentals, John Wiley and Sons, ISBN: 9780470647691.
4. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001.

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH1057	Linear Algebra-I		3	1	0	4
Total Units to be Covered: 3		Total Contact Hours: 45+15				
Prerequisite(s):	Mathematics at 10+2		Syllabus version: 1.0			

Course Objective

1. To make the students acquire the knowledge of matrix algebra and diagonalization.
2. To make the students acquire knowledge of vector spaces and linear transformations.
3. To make the students prove certain isomorphism theorems.

Course Outcomes

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

CO1. Determine the solution of linear system of equations, eigenvalues and eigenvectors of a matrix.

CO2. understand the concept of vector spaces, subspaces, and their dimensions.

CO3. illustrate the concepts of matrix of a linear transformation and similar transformation.

Course Description

Algebra plays a significant role in many areas of mathematics, engineering, and natural sciences. It provides a foundation of important mathematical ideas that will engage students in sound mathematical thinking and reasoning. This course covers the fundamental theory of matrix algebra, vector spaces and linear transformations which is extensively used in the field of approximation theory and numerical methods. This course is designed in such a way that it enables the students to cope confidently with the mathematics needed in their future subjects and the curriculum aims at developing student's ability how to simplify many types of complex problems using fundamental theory of matrix algebra.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	1	-	3	1	-
CO2	3	2	-	-	-	-	-	-	1	-	3	1	-
CO3	3	2	-	-	-	-	-	1	2	-	3	-	-
Average	3	2	-	-	-	-	-	1	1.3	-	3	1	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Matrix Algebra **15 Lecture Hours**

Rank of a matrix, Echelon form, Normal form, Linear independence of vectors, Solution of homogeneous and non-homogeneous system of equations, Characteristic Equation of a matrix, Eigenvalues and eigenvectors, Diagonalization, Powers of matrix.

Unit 2: Vector Spaces **15 Lecture Hours**

Field, Definition of vector space, Span, Linear independence/dependence of vectors, Basis and dimension, Subspaces and their intersection, Sum of subspaces, Direct sum.

Unit 3: Linear Transformation **15 Lecture Hours**

Linear mapping, Matrix as a linear mapping, Kernel and range space, Rank nullity theorem, Solution space of $Ax = 0$, Singular and non-singular mappings, Isomorphisms, Operations with linear mappings, Algebra $A(V)$ of linear operators, Similarity of matrices, Change of basis.

Text Books:

1. G. Strang, Linear Algebra and its Applications, Cengage Learning, ISBN: 9788131501726.
2. S. Lipschutz and M. Lipson, Schaum's Series: Linear Algebra, Tata McGraw-Hill Company Limited, ISBN: 9780070605022.
3. S. H. Friedberg, A. J. Insel and L.E. Spence, Linear Algebra, PHI Learning Private Limited, ISBN: 9788120326064.

Reference Books:

1. David C. Lay, Linear Algebra and its Applications, Pearson Education India, ISBN: 9788177583335.
2. G. Strang, Linear Algebra and its Applications, Cengage Learning, ISBN: 9788131501726.
3. E. G. Goodaire and M. Parmenter, Discrete Mathematics with Graph Theory, Pearson Education, ISBN: 9789353433017.

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
CSEG1023	**Computational Techniques**	2	0	0	2
Total Units to be Covered: 4		**Total Contact Hours: 30**			
Prerequisite(s):	**Fundamentals of Computers**	**Syllabus version: 1.0**			

Course Objectives

1. To demonstrate the fundamentals of Linux OS and to write computer codes using vim editor.
2. To explain the elementary concepts of Python and LATeX.
3. To acquire knowledge of plotting graphs and data analysis using Gnuplot software.

Course Outcomes

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

CO1. Demonstrate the fundamental understanding Linux OS and write computer programs for solving physical problems.

CO2. Compute data and other physical parameters with the aid of Python programming.

CO3. Employ GNUPLOT to visualize data and LATEX to produce high quality scientific documents.

Course Description

In this course, the students will learn basics of Linux OS and use it to write computer codes for solving physical problems. In addition, students will learn Python programming language and use it in solving simple problems. Further the students will learn using LaTeX for scientific word processing and GNUPLOT for visualization and basic data analysis.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	-	3	-	-	1	-	-	-	3	-	2	-
CO2	-	-	2	-	-	1	-	1	-	3	-	2	-
CO3	-	-	3	-	-	1	-	1	2	3	1	-	2
Average	2		2.7			1		1	2	3	1	2	2

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Introduction to LINUX and Scientific Computing 7 Lectures Hours

Basics of LINUX Operating system, Linux Commands, vi and vim editors.

Computer architecture and organization, number systems and arithmetic, floating point representation, underflow & overflow, algorithms, errors in scientific computations.

Unit 2: Programming with Python **11 Lectures Hours**

Introduction, Python literals, Operators, Variables, decision making, loops, logic operators, lists, sorting list, functions, scopes in Python, Tuples and dictionaries, modules and packages, errors and exceptions, Characters and strings, Basic concepts of object programming, Processing files. Numpy and Pandas.

Unit 3: Scientific Word Processing **6 Lecture Hours**

Introduction to LaTeX; preparing a basic LaTeX file, document classes, compiling LaTeX File, LaTeX tags for creating different environments, LaTeX commands and environments, formula and equation representations, preparing figures and tables, preparing bibliography and citation.

Unit 4: Data Analysis & Visualization **6 Lectures Hours**

Introduction to Gnuplot, basic Gnuplot commands for simple plots, plotting data from a file, saving and exporting, multiple data sets per file; understanding data with Gnuplot, data analysis with Gnuplot.

List of Practical's

- To familiarize with Linux OS and vi editor commands
- To learn number systems and their arithmetic
- To understand various floating-point representations
- To write programs in Python using logical statements, control structures
- To write programs in Python using loops & functions
- To understand the use of Arrays and Lists in Python
- To read and write (I/O) external data files in Python
- To apply Pandas in database management systems.
- To write scientific documents using LaTEX
- To learn preparation of bibliography and citation in LaTEX.
- To develop scripts using Gnuplot syntax and produce graphs in .eps, .pdf, .png and .jpg formats
- To use Gnuplot in statistical data analysis using regression
- To learn data smoothening using Gnuplot

Text Books/web resources:

1. A practical guide to Linux, Sobell, Mark G.. Addison-Wesley Longman Publishing Co., Inc., 1997.
2. Introduction to Python Programming, by Gowrishankar S, Veena A, 1st Edition, CRC Press/Taylor & Francis, 2018. ISBN-13: 978-0815394372
3. Programming python, by Mark Lutz, 4th Edition, O'REILLY
4. LaTeX: A Document Preparation System, Leslie Lamport (Second Edition, Addison-Wesley, 1994).
5. Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010)

Reference Books:

1. Your Unix: The Ultimate Guide by Sumitabha Das, McGraw Hill Education, 1st edition (5 June 2001).
2. The complete reference python, by Martin C Brown.

Modes of Evaluation:

Components	**Theory**		
	Assignment	Class test	End-term Project
Weight % (100)	30	20	50

SEMESTER II

Course Code	Course name		L	T	P	C
MATH1061	Classical Mechanics		3	1	0	4
Total Units to be Covered: 3		Total Contact Hours: 45+15				
Prerequisite(s):	Mathematics at 10+2		Syllabus version: 1.0			

Course Objectives

1. To enable the students understand the topology of real line.
2. To enable the students, develop an insight into limit points and isolated points of a set, density of rational numbers.
3. To make the students able to investigate the convergence of various real sequences.
4. To make the students identify uniformly continuous functions using sequential criteria.

Course Outcomes

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

CO1. Understand the topology of real line and set theoretic properties.

CO2. Recognize the convergence of real sequences along with special attention Cauchy's convergence criteria.

CO3. Understand the concept of limit, continuity, uniform continuity and differentiability of functions of one variable.

Course Description

This course is an introduction to Real Analysis. The course develops the basic concepts in a systematic and rigorous manner to formulate and understand mathematical problems in the context of real-valued functions of a real variable. It covers the topology of real line and its basic properties. Real sequences and their usage to check the continuity and differentiability of real functions is also a part of content. The student develops an analytical approach towards the branch of pure mathematics after completion of this course.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	1	1	3	2	1
CO2	3	2	-	-	-	-	-	2	1	-	3	2	-
CO3	3	2	-	-	-	-	-	2	1	-	3	2	-
Average	3	2	-	-	-	-	-	2	1	1	3	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Real Numbers **15 Lecture Hours**

Review of Algebraic and Order Properties of R, δ−neighborhood of a point in R, Countable and uncountable sets in R, Supremum and Infimum, The Completeness Property of R, The Archimedean Property, Density of Rational (and Irrational) numbers in R, Limit points of a set, isolated points, Illustrations of Bolzano-Weierstrass theorem for sets.

Unit 2: Real Sequence **15 Lecture Hours**

Sequences, Bounded sequence, Convergent sequence, Limit of a sequence. Limit Theorems, Monotone Sequences, Monotone Convergence Theorem. Subsequences, Divergence Criteria, Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion.

Unit 3: Functions of Real Variable **15 Lecture Hours**

Limits of functions, Limit theorems, Sequential criterion for limits, Continuity of functions, Sequential criterion for continuity, Continuity theorems, Bolzano's Intermediate value theorem, Uniform continuity, Uniform continuity theorem, Lipschitz function, Continuous extension theorem. Derivative of function, Carathèodary's theorem.

Text Books:
1. R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons India Pvt. Ltd., ISBN: 9788126511099.
2. S. C. Malik and S. Arora, Mathematical Analysis, New Age International Pvt. Ltd. Publishers, ISBN: 9789385923869.

Reference Books:
1. G. G. Bilodeau, P. R. Thie and G.E. Keough, An Introduction to Analysis, Jones & Bartlett Learning, ISBN: 9780763774929.
2. B. S. Thomson, J. B. Bruckner and A. M. Bruckner, Elementary Real Analysis, Createspace Independent Publishers, ISBN: 9781434841612.
3. S. K. Berberian, A First Course in Real Analysis, Springer Verlag, ISBN: 9780387942179.

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH1062	Linear Algebra-Ii		3	1	0	4
Total Units to be Covered: 4		Total Contact Hours: 45+15				
Prerequisite(s):	UG level Physics	Syllabus version: 1.0				

Course Objectives

1. To provide the students with the knowledge of orthogonal diagonalization of symmetric matrices.
2. To make the students learn dual space of vector spaces.
3. To provide the students with the knowledge of inner product spaces and spectral theorem.

Course Outcomes

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

CO1. Investigate the symmetric transformations and their properties in finite dimensional vector space.
CO2. Understand the properties of normal operators and block diagonal matrices.
CO3. Find the dual spaces, transpose of a linear transformation and its matrix in the dual basis.
CO4. Demonstrate the orthogonality of vectors and fundamental inequalities in an inner product space.

Course Description

The course helps the students to cover all the aspects of a Linear algebra course. The first half of the content highlights the importance of canonical forms for a relatively better treatment of linear operators and the use of isomorphism theorems. The fundamental property of the direct sum of a subspace with its orthogonal complement along with the existence of invariant subspaces are main highlights in the second half. This course emphasizes the application of techniques like least squares approximation and minimal solutions to the system of linear equations using linear operators.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	-	-	-	-	-	2	2	3	1	2
CO2	3	2	-	-	-	-	-	-	2	1	3	2	1
CO3	3	2	-	-	-	-	-	2	2	1	2	3	1
CO4	3	2	1	-	-	-	-	1	2	1	3	2	1
Average	3	2	1.5	-	-	-	-	1.5	2	1.25	2.75	2	1.25

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Canonical form **11 Lecture Hours**

Diagonalization of symmetric matrices, Orthogonal diagonalization, Quadratic forms, Minima, maxima and saddle points, Positive definiteness, Nilpotent operator, Jordan canonical form, Rational canonical form, Quotient space.

Unit 2: Operators and Isomorphism **11 Lecture Hours**

Normal operator, Self-adjoint and skew self-adjoint operators and their properties, Block diagonal matrix and its properties. Isomorphism, Isomorphism theorems, Invertibility, Change of coordinate matrix.

Unit 3: Dual spaces and Invariant spaces **11 Lecture Hours**

Dual spaces, Dual basis, Double dual, Transpose of a linear transformation and its matrix representation in the dual basis, Annihilators, Eigen spaces of a linear operator, Diagonalizability, Invariant sub-spaces and Cayley-Hamilton theorem, Minimal polynomial for a linear operator.

Unit 4: Inner product spaces **12 Lecture Hours**

Inner product spaces and norms, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel’s inequality, Adjoint of a linear operator, Least Squares Approximation, Minimal solutions to system of linear equations, Orthogonal projections and Spectral theorem.

Text Books:

1. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971, ISBN: 9780135367971.
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007, ISBN: 9788131501726.

Reference Books:

1. S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005, ISBN: 9781461210702.
2. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999, ISBN: 9788120316287.

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH1064	Analytical Geometry		3	1	0	4
Total Units to be Covered: 3		Total Contact Hours: 45+15				
Prerequisite(s):	Pre-requisites/Exposure Basic Knowledge of Geometry	Syllabus version: 1.0				

Course Objectives

1. To enable the students sketch parabola, ellipse, and hyperbola.
2. To make the students understand the concept of surfaces in 3-space.
3. To provide the students insight into the concept of classification of general equation of degree two.
4. To help the students illustrate geometrical principles of conicoids.

Course Outcomes

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

CO1. Discuss techniques for plotting parabola, ellipse, hyperbola and related problems.

CO2. Describe the geometrical properties of a sphere, cylinder and cone.

CO3. Identify the type of conicoid from the general equation of degree two.

CO4. Determine different associated planes to a given conicoid.

Course Description

Analytical geometry is intensively used in physics and engineerin.. This course initially covers techniques for sketching curves in 2-space like parabola, circle, ellipse and hyperbola. Later, the techniques to classify the surfaces in 3-space become an inherent part of content. Finding intersections of geometric objects adds more dimensions to the analysis. The course not only helps greatly to dwell in the branches like rocketry, space science and spaceflight but also lays foundation of the algebraic, differential, discrete and computational geometry.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	2	2	-
CO2	3	2	-	-	-	-	-	-	-	-	2	2	-
CO3	3	2	-	-	-	-	-	-	-	-	2	2	-
CO4	3	2	-	-	-	-	-	-	-	-	2	2	-
Average	3	2	-	-	-	-	-	-	-	-	2	2	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Analytical Geometry of Two Dimensions **15 Lecture Hours**

Analytical geometry of two dimensions. Transformation of rectangular axes. General equation of second degree and its reduction to normal form. Systems of conics. Polar equation of a conic.

Unit 2: Sphere, Cylinder and Cone **15 Lecture Hours**

System of co-ordinates: Curvilinear coordinates, Spherical and Cylindrical coordinates. The Sphere: Definition and equation of a sphere, Plane section of a sphere, Intersection of two spheres, Intersection of a sphere and a line, Power of a point, tangent plane, Plane of contact, Polar plane, Pole, Angle of Intersection of two spheres, Radical plane, Co-axial system of spheres. Cone and Cylinder: Definition and equation of a cone, Vertex , Guiding curve, Generators, Three mutually perpendicular generators, Intersection of a line with a cone, Tangent line and tangent plane, Reciprocal cone, Right circular cone, Definition and equation of a cylinder, Right circular cylinder, Enveloping cylinder.

Unit 3: Conicoids **15 Lecture Hours**

Conicoids: General equation of second degree, Central conicoids, Tangent plane, Director sphere, Normal, Plane of contact, Polar plane, Conjugate plane and conjugate points.

Text Books:

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. S.L. Loney, The Elements of Coordinate Geometry, McMillan and Company, London.
3. Shanti Narayan: A Text book of Analytical Geometry, S. Chand, & company, New Delhi.

Reference Books:

1. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons (Asia) Pvt. Ltd. 2002.
2. R.J.T. Bill, Elementary Treatise on Coordinate Geometry of Three Dimensions, McMillan India Ltd., 1994
3. Burchared Fine and E. D. Thompson. Coordinate Geometry, The Macmillan Company.

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
LSPS1001	**Constitution and Indian Polity**	2	0	0	2
Total Units to be Covered: 5		**Total Contact Hours: 30**			
Prerequisite(s):		**Syllabus version: 1.0**			

Course Objectives:

1. To enable the students to realize the importance of Fundamental Rights and Directive Principles and to examine the problems involved in their judicial enforcement.
2. To articulate the basic values which the Indian Constitution has identified and is attempting to actualize for justice and governance.
3. To enable the students to know and apply the basics of Constitutional philosophy.

Course Outcomes:

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

CO1. Demonstrate a basic knowledge and understanding of Constitutional Law

CO2.Analyze and interpret the various attributes of fundamental right and the regulatory mechanism for its enforcement.

CO3. Identify, distinguish, and apply critical use of judgments and articles to increase the ability to participate in academic debate on some controversial areas of Constitutional Law.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	-	-	-	-	-	-	-	-	1	-	3
CO2	-	1	-	-	-	-	-	-	-	-	2	-	-
CO3	-	-	2	-	-	-	-	-	-	-	2	-	-
Average	3	1	2	-	-	-	-	-	-	-	1.7	-	3

1. WEAK 2. MODERATE 3. STRONG

Syllabus

Unit 1: Introduction **3 Lecture Hours**

- Definition and Need for Constitution
- Written and Unwritten Constitution
- Unity and Federal Constitution
- Nature of Indian Constitution
- Structure of Indian Constitution

Unit 2: Fundamental Rights, DPSP and Fundamental Duties 9 Lecture Hours

- Nature and Scope of Fundamental Rights
- Importance of Fundamental Rights
- Right to Equality
- Freedom of Speech
- Right to Life, Religion
- Right to Education
- Constitutional Remedies
- DPSP-Nature and Need
- Fundamental Duties

Unit 3: Executive and Legislature 10 Lecture Hours

- President and Vice President
- Prime Minister and Council of Minister
- Governor
- Chief Minister and Council of Minister
- Union Legislature-Lok Sabha and Rajya Sabha
- State Legislature- Legislative Assembly and Legislative Council
- Centre-state Legislative relations
- Emergency and Amendment

Unit 4: Judiciary 5 Lecture Hours

- Appointment of Judges
- Collegium System
- Removal of Judges
- Jurisdiction
- Judicial Activism Public Interest Litigation
- Battle for supremacy: Executive vs Judiciary

Unit 5: Basic Issues in Indian Politics 3 Lecture Hours

- Communalism
- Casteism
- Corruption
- Good Governance
- Criminalisation of Politics

TEXTBOOKS:

1. N Laxmikant, Indian Polity, Tata Macgraw Hill of Education.
2. V.N. Shukla's Constitution of India, Eastern Book Company.

REFERENCE BOOKS:

1. Constitutional Law of India; by JN Pandey Shukla, Central Law Agency
2. Constitutional Law of India; by M.P. Jain, Wadhwa Publications.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

SEMESTER III

Course Code	Course name	L	T	P	C
MATH2048	**Ordinary Differential Equations**	3	0	1	4
Total Units to be Covered: 4	**Total Contact Hours: 45+30**				
Prerequisite(s):	**Calculus**	**Syllabus version: 1.0**			

Course Objectives

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1. To make the students understand the concept of differential equations and their solutions.
2. To make the students apply various techniques to solve Ordinary Differential Equations.
3. To make the students realize the importance of Ordinary Differential Equations in real world problems.

Course Outcomes

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

CO1. Define the concept of differential equations and their solutions.
CO2. Demonstrate various solution techniques of linear and nonlinear Ordinary Differential Equations.
CO3. Construct mathematical models for various real world problems using ordinary differential equations.
CO4. Examine the stability at equilibrium points of various real world models in ordinary differential equations.

Course Description

The course Ordinary Differential Equations is the most important part of Mathematics for understanding Physical sciences and Engineering applications. The scope of this course includes introduction to Differential Equations and Mathematical Models, Methods and Applications of differential equations in real world problems. These concepts are necessary for the study of dynamical behavior of a system through modeling. It helps the students to develop logical thinking and also to gain insight into the modeling process.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	3	2	-
CO2	3	2	2	-	-	-	-	-	2	1	3	2	1
CO3	3	2	2	-	-	-	-	2	2	2	3	2	2
CO4	3	2	2	-	-	-	-	2	2	2	3	2	1
Average	3	2	2	-	-	-	-	2	2	1.67	3	2	1.33

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: First order Ordinary Differential Equations 15 Lecture Hours

General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, nonlinear equations, equations solvable for x, y, p and Clairaut's equation, orthogonal trajectories, linear equations with variable coefficients.

Unit 2: Mathematical Models 05 Lecture Hours

Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, limited growth of population, limited growth with harvesting.

Unit 3: Higher order Ordinary Differential Equations 20 Lecture Hours

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, methods to solve linear homogeneous and non-homogeneous equations of higher order with constant and variable coefficients, Cauchy-Euler's equation, method of undetermined coefficients, method of variation of parameters, simultaneous linear differential equations.

Unit 4: Case Studies 05 Lecture Hours

Equilibrium points, interpretation of the phase plane, predatory-prey model and its analysis, epidemic model of influenza and its analysis, battle model and its analysis.

Text Books:

1. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.

Reference Books:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
2. Martha L Abell and James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
3. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18th Edition, S. Chand & Company Pvt. Ltd, 2016.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
	Ordinary Differential Equations Lab	0	0	0	0
Total Units to be Covered:	**Total Contact Hours:**				
Prerequisite(s):	**Basic knowledge of computer programming**	**Syllabus version: 1.0**			

Course Objectives

1. To provide the students with the practical knowledge of solving ordinary differential equations.
2. To make students gain insight on analyzing growth, decay, prey-predator, epidemic and battle models using software.

Course Outcomes

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

CO1. Demonstrate the knowledge of Software in obtaining the solutions of differential equations.

CO2. Develop programs to understand the dynamics of various real world systems modelled as ordinary differential equations.

Course Description

The course on differential equations is the most significant part of Mathematics for understanding physical sciences and engineering applications. Hence its lab is necessary for a clear and complete understanding of all the phenomena associated with differential equations and mathematical models. This course is designed in such a way that it enables the students to conceptualize, reason and to use concepts of differential equations to formulate and solve problems using technical computing software.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	2	-	-	-	2	2	2	3	2	2
CO2	3	2	2	2	-	-	-	2	2	2	3	2	2
Average	3	2	2	2	-	-	-	2	2	2	3	2	2

1. WEAK 2. MODERATE 3. STRONG

List of Experiments (using MATLAB/Python)

Experiment No: 01
Elementary math built-in functions.

Experiment No: 02
Operations on Arrays.

Experiment No: 03
Built-in functions for handling arrays.

Experiment No: 04
Visualization using 2D plots.

Experiment No: 05
Visualization using 3D plots.

Experiment No: 06
Control statements and loops.

Experiment No: 07
Symbolic computations.

Experiment No: 08
Analytical solution of first order initial value problems and Applications.

Experiment No: 09
Analytical solution of higher order initial and boundary value problems and applications.

Experiment No: 10
Numerical ode solvers.

Text Books:

1. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems, Computing and Modeling, Pearson Education India, 2005.

Reference Books:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
2. Amos Gilat, MATLAB: An Introduction with Applications, 4th Ed., John Wiley & Sons, Inc, 2011.

Modes of Evaluation: Continuous Evaluation

Components	Lab	
	Continuous Assessment	
	Lab records + Viva	Quiz/Exam
Weight %	(70%)	(30%)

Course Code	Course name	L	T	P	C
MATH2055	Real Analysis II	3	1	0	4
Total Units to be Covered: 3	Total Contact Hours: 45+15				
Prerequisite(s):	Real Analysis I	Syllabus version: 1.0			

Course Objectives

1. To provide the students with the knowledge of the integration of bounded functions on a closed and bounded interval and its extension to either the cases where the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration.
2. To understand the sequence and series of real valued functions, and an important class of series of functions.

Course Outcomes

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

CO1. Understand the families and properties of Riemann integrable functions; and the applications of the fundamental theorems of calculus.

CO2. Apply various tests on the sequence and series of functions for their uniform convergence.

CO3. Analyze the behavior of infinite series with special reference to power series.

Course Description

Real analysis is the soul of pure mathematics and this course is worth enough to feel so. The course develops a rigorous understanding of the integrable functions through Riemann criteria and roots into the concept of uniform convergence of sequence and series of functions. An inevitable ability of analysis is achieved to a student only after the concrete and rigorous understanding of this course.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	2	-	3	1	-
CO2	3	2	-	-	-	-	-	-	1	-	2	3	-
CO3	3	2	-	-	-	-	-	-	2	-	3	3	-
Average	3	2	-	-	-	-	-	-	1.67	-	2.67	2.3	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Riemann Integration **15 Lecture Hours**

Definition of Riemann integration, Inequalities for upper and lower Darboux sums, Necessary and sufficient conditions for the Riemann integrability, Definition of Riemann integration by Riemann sum and equivalence of the two definitions, Riemann integrability of monotone functions and continuous functions, Properties of

Riemann integrable functions, Definitions of piecewise continuous and piecewise monotone functions and their Riemann integrability, intermediate value theorem for integrals, Fundamental theorems (I and II) of calculus, and the integration by parts, Improper integral.

Unit 2: Sequence of Functions **15 Lecture Hours**

Pointwise and uniform convergence of sequence of functions, Theorem on the continuity of the limit function of a sequence of functions, Theorems on the interchange of the limit and derivative, and the interchange of the limit and integrability of a sequence of functions. Pointwise and uniform convergence of series of functions, Theorems on the continuity, Derivability and integrability of the sum function of a series of functions, Cauchy criterion and the Weierstrass M-Test for uniform convergence.

Unit 3: Series and its Convergence **15 Lecture Hours**

Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: Comparison test, Limit comparison test, Ratio Test, Cauchy's n^{th} root test, Integral test, Alternating series, Leibnitz test, Absolute and conditional convergence. Definition of power series, Radius of convergence, Absolute convergence (Cauchy Hadamard theorem), Uniform convergence, Differentiation of and integration of power series, Abel's theorem.

Text Books:

1. Bartle, Robert G., &Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. Delhi.
2. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones and Bartlett (Student Edition). First Indian Edition. Reprinted 2015.
3. Ghorpade, Sudhir R. &Limaye, B. V. (2006). A Course in Calculus and Real Analysis. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
4. Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer.

Reference Books:

1. Rudin, Walter. *Principles of mathematical analysis*. Vol. 3. New York: McGraw-hill, 1976.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH2056	**INTEGRAL CALCULUS**	3	0	1	4
Total Units to be Covered: 4		**Total Contact Hours: 45+30**			
Prerequisite(s):	**Mathematics up to Class 12th**	**Syllabus version: 1.0**			

Course Objectives

1. To prepare a foundation knowledge of integral and vector calculus for developing enhanced quantitative skills.
2. To enable the students, apply the concepts of integral and vector calculus in real life applications.

Course Outcomes

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

CO1. Understand the meaning of the definite integral as a limit of sum, and the relationship between the derivative and the definite integral using the Fundamental Theorem of Calculus.

CO2. Classify whether a sequence or a series is convergent or divergent by describing their convergence properties and evaluate area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.

CO3. Solve physical problems containing more variables.

CO4. Understand the concept of vector valued functions and solve problems involving line integrals and surface integrals.

Course Description

Calculus is a versatile and valuable fundamental tool in mathematics and its applications. This course provides a comprehensive introduction to integral and vector calculus. As well as covering basic concepts, this course addresses variety of applications and techniques which all students will subsequently be able to draw in various contexts. The Fundamental theorem of Calculus, relating differential and integral calculus, begins the study of Integral Calculus. Vector calculus is the extension of differential and integral calculus to higher dimensions and offers a mathematical framework for the study of a wide variety of physical systems.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	1	1	1	3	2	1
CO2	3	2	-	-	-	-	-	-	1	1	3	2	1
CO3	3	2	2	-	-	-	-	1	2	2	3	2	1
CO4	3	2	1	-	-			1	1	1	3	2	1
Average	3	3	1.5	-	-	-	-	1	1.25	1.25	3	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Fundamentals of Integral Calculus **12 Lecture Hours**

Recapitulation of definite integrals and its properties, Reduction formulae, Definite integrals as limit of the sum, Summation of series by integration, Continuity, differentiability and integrability of proper integrals as a function of a parameter, Fundamental theorem of integral calculus, Mean value theorems of integral calculus, Differentiation under the sign of integration.

Unit 2: Improper Integrals **10 Lecture Hours**

Improper integrals: classification and convergence, Comparison test, μ-test, Abel's test, Dirichlet's test, quotient test, Beta and Gamma function, Evaluation of integrals using Beta and Gamma functions. Quadrature, Rectification, Volumes, and surfaces of solids of revolution, Pappus theorem.

Unit 3: Multiple Integral **10 Lecture Hours**

Double integral, Evaluation of double integrals by changing the order of integration and change of variables, Area and mass by double integral, Triple integral, Evaluation of triple integral, Volume by triple integration, Dirichlet's theorem, Liouvelle's theorem for multiple integrals.

Unit 4: Vector Calculus **13 Lecture Hours**

Scalar and vector point functions, Vector Differentiation, Gradient of a scalar function, Normal on a surface, Directional Derivative, Divergence and Curl of a vector function, Vector Integration, Line integral, Applications of Line integrals: Work, Circulation and Flux, Surface integral, Volume integral, Green's theorem and applications, Gauss' divergence theorem and applications, Stokes' theorem and applications.

Text Books:

1. S. Narayan, P. K. Mittal, Integral Calculus, S. Chand and Co. Pvt. Ltd., ISBN: 9788121906814.
2. G. B. Thomas., R. L. Finney, Calculus and Analytical Geometry, Pearson, ISBN: 9788177583250.
3. M. Spiegel: Vector Analysis: Schaum's outline series, McGraw Hill Ed., ISBN: 9780070682580.

Reference Books:

1. H. Anton, I. Bivens and S. Davis, Calculus: Early Transcendentals, John Wiley and Sons, ISBN: 9780470647691.
2. J. Stewart, Calculus: Early Transcendentals, Cengage Learning, ISBN: 9780538498708.
3. J. B. Marion, Principles of Vector Analysis, Academic Press, ISBN: 9780124722682.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
	Integral Calculus Lab	0	0	0	0
Total Units to be Covered:	Total Contact Hours:				
Prerequisite(s):	Elementary Algebra and Elementary Geometry	Syllabus version: 1.0			

Course Objectives

1. To provide the students with the practical knowledge of Riemann integration.
2. To make students gain insight on fundamental theorem of calculus.

Course Outcomes

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

CO1. Demonstrate the knowledge of software(s) in computing Riemann sum.
CO2. Write programs for definite integral with desired accuracy.
CO3. Utilize software tools for fundamental theorem of calculus and its applications.

Course Description

Calculus is the most fundamental tool in mathematics and its applications. This lab course covers the practical involving integral calculus using various mathematical software(s). This lab course is designed in such a way that it enables the students to visualize, analyze, and understand integral calculus ideas and to verify their by-hand calculations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	3	-	-	-	1	2	2	3	2	2
CO2	3	2	-	3	-	-	-	2	2	2	3	2	2
CO3	3	2	-	3	-	-	-	2	2	2	3	2	2
Average	3	2	-	3	-	-	-	1.67	2	2	3	2	2

1. WEAK 2. MODERATE 3. STRONG

List of Experiments

Computer Software: Matlab/ Python/ R/ Maple/ Mathematica or any other software tool

Experiment No: 01 Definite Integrals

(i) Using Riemann sum to approximate definite integrals of a function.
(ii) Write a program to find distance when velocity is known.
(iii) Write a program to find velocity when acceleration is known.

Experiment No: 02 Definite Integrals with Desired Accuracy

(i) Using Riemann sum to approximate definite integrals of a function within a desired accuracy.

(ii) Write a program to find distance within a desired accuracy when velocity is known.
(iii) Write a program to find velocity within a desired accuracy when acceleration is known.

Experiment No: 03 The Fundamental Theorem of Calculus
Consider the following equality

$$\frac{d}{dx}\int_{a}^{x} f(t)dt = \lim_{h\to 0}\frac{\int_{x}^{x+h} f(t)dt}{h}$$

(i) Plot a graph illustrating the above equation.
(ii) Describe the meaning of the derivative in the equality in terms of a rate of change involving two quantities represented in your graph. Also describe what average rate is used to approximate this derivative.
(iii) How could you find a good over-estimate and under-estimate for the derivative? Include representations of your over-estimate and under-estimate on your graph. Use your graph to explain why the average rate identified in section (ii) is between the over-estimate and under-estimate

Experiment No: 04 The Fundamental Theorem of Calculus
(i) Let $F(x)$ be an antiderivative for $f(x)$. Explain what this means, both algebraically and graphically.
(ii) Draw a graph in which the definite integral $\int_a^b f(t)dt$ is approximated by a Riemann sum using an arbitrary evaluation point for each subinterval and write out the Riemann sum.
(iii) State the Mean Value Theorem applied to the function $F(x)$ over a single subinterval from your algebra and graph. Draw a picture of a single subinterval to illustrate this.

Experiment No: 05 Applications of Fundamental Theorem of Calculus
(i) Estimate definite integral from tabular values of a function.
(ii) Find area between two graphs.
(iii) Find area below a graph.

Text Books:

1. G. B. Thomas., R. L. Finney, Calculus and Analytical Geometry, Pearson, ISBN: 9788177583250.
2. H. Anton, I. Bivens and S. Davis, Calculus: Early Transcendentals, John Wiley and Sons, ISBN: 9780470647691.
3. J. Stewart, Calculus: Early Transcendentals, Cengage Learning, ISBN: 9780538498708.

Reference Books:

1. R. Courant and F. John, Introduction to Calculus and Analysis I, Springer-Verlag, ISBN: 9783642586040.
2. R. Courant and F. John, Introduction to Calculus and Analysis II, Springer-Verlag, ISBN: 9783540665700.
3. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, Pearson Education, ISBN: 9780130918710.

Modes of Evaluation: Continuous Evaluation

Components	Lab	
	Continuous Assessment	
	Lab records + Viva	Quiz/Exam
Weight %	(70%)	(30%)

SEMESTER IV

Course Code	Course name	L	T	P	C
MATH2054	Partial Differential Equations	3	0	1	4
Total Units to be Covered: 4		Total Contact Hours: 45+30			
Prerequisite(s):	Calculus and Ordinary Differential Equations	Syllabus version: 1.0			

Course Objectives

1. To make the students understand the concepts of calculus of several variable functions.
2. To make the students apply various techniques to solve Partial differential equations of various types.
3. To make the students understand applications related to vibrating string problem and heat conduction problem.

Course Outcomes

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

CO1. Define the concepts of calculus of functions of several variables and Partial Differential Equations.

CO2. Demonstrate the understanding of expansions, extrema of functions of several variables, and solutions of first order Partial Differential Equations.

CO3. Solve second order linear and nonlinear Partial Differential Equations.

CO4. Examine various applications of Partial Differential Equations.

Course Description

The course is the most important part of Mathematics for understanding physical sciences and engineering applications. The scope of this course includes calculus of several variables, first and second order Partial Differential Equation with related applications. These concepts are necessary for the study of dynamical behavior of a real world systems. It gives students an exposure to a wide range of solution techniques related to Partial Differential Equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	1	-	3	2	-
CO2	3	2	-	-	-	-	-	1	1	1	3	2	1
CO3	3	2	-	-	-	-	-	1	1	1	3	3	1
CO4	3	2	-	-	-	-	-	1	1	2	3	3	1
Average	3	2	-	-	-	-	-	1	1	1.3	3	2.5	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Calculus of Functions of Several Variables **10 Lecture Hours**

Functions of several variables: Review, partial derivatives and their geometrical interpretation, total derivative, derivatives of composite and implicit functions, Jacobians, homogeneous functions, Euler's theorem on homogeneous functions, harmonic functions, Taylor's expansion of functions of several variables, maxima and minima of functions of several variables, Lagrange's method of undetermined multipliers.

Unit 2: First Order Partial Differential Equations **10 Lecture Hours**

Introduction, formation, classification, and geometrical interpretation of first order Partial Differential Equations, equations solvable by direct integration, Cauchy's problem for first order equations, Lagrange's equations, various working rules using Lagrange's method for solving $Pp + Qq = R$, non-linear PDE of first order: complete solution, singular solution, general solution, Charpit's method and working rule, method of characteristics and general solutions.

Unit 3: Second Order Partial Differential Equations **15 Lecture Hours**

Partial Differential Equations of second order: classification of second order linear equations in two independent variables: hyperbolic, parabolic and elliptic types (with examples), reduction to canonical forms, homogeneous and non-homogeneous linear Partial Differential Equations with constant coefficients,
method of finding complementary function and particular integral, general solution, method of separation of variables for second order PDE, nonlinear equations of second order, Monge's method.

Unit 4: Applications of Partial Differential Equations **10 Lecture Hours**

Vibrating string problem, existence and uniqueness of solution of Vibrating string problem, Heat conduction problem, existence and uniqueness of solution of Heat conduction problem, non-homogeneous problems.

Text Books:

1. Sneddon, I. N., Elements of Partial Differential Equations, Dover Publications, 2006.
2. Myint-U, Tyn and Debnath, Lokenath, Linear Partial Differential Equation for Scientists and Engineers, 4th Ed, Springer, 2007.

Reference Books:

1. Stavroulakis, Ioannis P and Tersian, Stepan A., Partial Differential Equations: An Introduction with Mathematica and MAPLE, 2nd Ed, World Scientific, 2004.
2. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18th Ed, S. Chand & Company Pvt. Ltd, 2016.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
	Partial Differential Equations Lab	0	0	0	0
Total Units to be Covered:	Total Contact Hours:				
Prerequisite(s):	Basic Knowledge of Computer Programming	Syllabus version: 1.0			

Course Objectives

1. To provide the students with the practical knowledge of solving first order partial differential equations using MATLAB/Python.
2. To make students gain insight on plotting integral surfaces.
3. To enable students understand the solution of wave equation.

Course Outcomes

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

CO1. Demonstrate the knowledge of Software in obtaining the solutions of partial differential equations their visualizations.

CO2. Develop programs to understand the solution of wave equation.

Course Description

The course on Partial Differential equations is the most important part of mathematics for understanding physical sciences and engineering applications. Hence its lab is necessary for a clear and complete understanding of all the phenomena associated with partial differential equations. This course helps the students to gain hand on experience in obtaining and plotting the solutions of partial differential equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	2	-	-	-	1	2	2	3	2	1
CO2	3	2	2	2	-	-	-	1	2	2	3	2	1
Average	3	2	2	2	-	-	-	1	2	2	3	2	1

1. WEAK 2. MODERATE 3. STRONG

List of Practical's (using MATLAB/Python)

Experiment No: 01
Solution of Cauchy problem for first order PDE

Experiment No: 02
Plotting the characteristics of first order PDE

Experiment No: 03
Plotting the integral surfaces of a given first order PDE with initial data.

Experiment No: 04
Solution of wave equation.

Experiment No: 05
Solution of one dimensional heat equation.

Experiment No. 06
Pdepe solver

Text Books:

1. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th Ed, Springer, Indian reprint, 2006.
2. Matthew P. Coleman, An Introduction to Partial Differential Equations with MATLAB, 2nd Ed., CRS Press, 2013.

Reference Books:

1. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18th Ed, S. Chand & Company Pvt. Ltd, 2016.
2. Amos Gilat, MATLAB: An Introduction with Applications, 4th Ed., John Wiley & Sons, Inc, 2011.

Modes of Evaluation: Continuous Evaluation

Evaluation Scheme:

Components	Lab	
	Continuous Assessment	
	Lab records + Viva	**Quiz/Exam**
Weight %	(70%)	(30%)

Course Code	Course name	L	T	P	C
MATH2057	**COMPLEX ANALYSIS**	3	1	0	4
Total Units to be Covered: 3		**Total Contact Hours: 45+15**			
Prerequisite(s):	**UG level Physics**	**Syllabus version: 1.0**			

Course Objectives

1. To provide the students with the knowledge of complex function, analytic function; and the fundamental concepts of complex integration using Cauchy's theorems, series expansions and application of residue calculus.
2. To make the students to evaluate real integrals using contour integration.

Course Outcomes

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

CO1. Understand the significance of differentiability of complex functions leading to the understanding of analytic functions.

CO2. Evaluate the contour integrals along with the application of Cauchy's theorem and formulae.

CO3. Apply Cauchy Residue theorem for the evaluation of real integrals with suitably chosen contours.

Course Description

This course aims to introduce the basic ideas of analysis for complex functions in complex variables. The fundamental theorem of Cauchy and its extensions are part of the content. The later part covers the singularities, their nature and residue theorem to evaluate the real integrals using complex integration. This course is very helpful to gain a better insight into the branch of applied mathematics pertaining to partial differential equation and its further applications.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	2	-	3	1	-
CO2	3	2	-	-	-	-	-	-	1	1	2	3	1
CO3	3	2	-	-	-	-	-	-	2	-	3	3	-
Average	3	2	-	-	-	-	-	-	1.67	1	2.67	2.33	1

1. WEAK   2. MODERATE   3. STRONG

Course Content

Unit 1: Complex Functions and Analyticity **15 Lecture Hours**

Functions of complex variable, Linear mapping, Limits, Theorems on limits, Limits at infinity, Continuity, Derivatives, Differentiation formulae, Cauchy-Riemann equations, Sufficient conditions for differentiability; Analytic functions, Exponential function, Logarithmic function, Branches and derivatives of logarithms,

Unit 2: Complex Integration **15 Lecture Hours**

Definite integrals of functions, Contours, Contour integrals and its examples, ML-inequality, antiderivatives, Proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy's theorem. Cauchy integral formulae, Consequences of Cauchy integral formula, Liouville's theorem, and the fundamental theorem of algebra.

Unit 3: Residue Calculus **15 Lecture Hours**

Power series and radius of convergence, Absolute and uniform convergence of power series, Series representation of analytic function, Taylor's series and its examples; Singularity, Isolated singular points, Laurent series and its examples, Residue, residue at infinity, Cauchy residue theorem, Evaluation of definite integral of type $\int_0^{2\pi} F(\cos\theta, sin\,\theta)\, d\theta$. Evaluation of real integrals of type $\int_{-\infty}^{\infty} \frac{p(x)}{q(x)} dx$, $\int_{-\infty}^{\infty} \frac{p(x)\sin ax}{q(x)} dx$and $\int_{-\infty}^{\infty} \frac{p(x)\cos ax}{q(x)} dx$. Evaluation of real integral having integrand with poles on real axis.

Text Books:

1. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw Hill International Edition, 2009.
2. Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
3. Zills, Dennis G., & Shanahan, Patrick D. (2003). A First Course in Complex Analysis with Applications. Jones & Bartlett Publishers, Inc.

Reference Books:

1. Conway, John B. Functions of one complex variable. Springer Science & Business Media, 2012.
2. Martin, D., and L. V. Ahlfors. Complex analysis. McGraw-Hill, New York, 1966.

Modes of Evaluation: Continuous Evaluation

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MECH2073	Classical Mechanics		3	1	0	4
Total Units to be Covered: 4		Total Contact Hours: 45+15				
Prerequisite(s):	UG level Physics		Syllabus version: 1.0			

Course Objectives
1. To familiarize the students with the concepts of forces, equilibrium, gravity and then using calculus to solve the related problems.
2. To enable students to understand the fundamentals and principles of motion of particles, pendulums and laws of planetary motion.

Course Outcomes
On completion of this course, the students will be able to
CO1. understand the fundamental concepts of forces and equilibrium.
CO2. analyze the concept of center of gravity and moment of inertia in rigid bodies and solve related problems.
CO3. explain the motion of a particle in two dimensions and stability of orbits.
CO4. understand the laws of motion in three-dimensional space.

Course Description
This course is concerned with the two main branches of mechanics; statics and dynamics. This course provides a comprehensive introduction to statics and dynamics. Along with the basic concepts, this course addresses a variety of applications and techniques that contribute to the latter in various contexts. The first portion deals with the forces acting on a body at rest and focuses on the fundamentals of the vectorial forces, equilibrium, tension, and applications. The second portion intended to the fundamentals and principles of motion of particles, pendulums and laws of planetary motion.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	3	2	-
CO2	3	2	-	-	-	-	-	-	-	-	3	2	-
CO3	3	2	-	-	-	-	-	-	-	-	3	2	-
CO4	3	2	-	-	-	-	-	-	-	-	3	2	-
Average	3	3	-	-	-	-	-	-	-	-	3	2	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Force Systems and Equilibrium Analysis 12 Lecture Hours

Forces, Vector moment of a force, Varignon’s theorem on moment, Resultant of couples and coplanar force systems; Virtual work. Catenary, Three-dimensional force systems; Moment of a force about a point and an axis, Principle of moments, Couple and couple moment, Moment of a couple about a line, Distributed force system, Rigid-body equilibrium, Equilibrium of forces in two and three dimensions, Free-body diagrams, General equations of equilibrium, Constraints and statical determinacy.

Unit 2: Force Interactions for Rigid Bodies 11 Lecture Hours

Equations of equilibrium and friction, Frictional forces on screws and flat belts; Center of gravity, Center of mass and Centroid of a body and composite bodies; Theorems of Pappus and Guldinus, Moments and products of inertia for areas, composite areas and rigid body, Parallel-axis theorem, Moment of inertia of a rigid body about an arbitrary axis, Principal moments and principal axes of inertia.

Unit 3: Dynamics of Motion under Central and Inverse-Square Forces 11 Lecture Hours

Motion of a particle in two dimensions, Velocities and accelerations in Cartesian, polar, and intrinsic coordinates, Equations of motion referred to a set of rotating axes, Motion of a projectile in a resisting medium, Motion of a particle in a plane under different laws of resistance, Central forces, Stability of nearly circular orbits, Motion under the inverse square law, Kepler's laws, Time of describing an arc and area of any orbit, Slightly disturbed orbits.

Unit 4: Motion of Artificial Satellites and Rockets 11 Lecture Hours

Motion of artificial satellites, Problems of motion of varying mass such as falling raindrops and rockets, Tangential and normal accelerations, Motion of a particle on a smooth or rough curve, Principle of conservation of energy, Motion of a particle in three dimensions, Motion on a smooth sphere, cone, and on any surface of revolution.

Text Books:

1. R. C. Hibbeler, Engineering mechanics: Principles of statics and dynamics, Pearson Education, ISBN: 9789332584747.
2. E. W. Nelson, C. L. Best, Engineering mechanics: Dynamics (Schaum’s outline series), McGraw Hill, ISBN: 9780071321297.

Reference Books:

1. A. P. Roberts, Statics and Dynamics with Background in Mathematics, Cambridge University Press, ISBN: 9780521520874.
2. J. L. Synge, B. A. Griffith, Principles of mechanics, McGraw Hill, ISBN: 9780070626584.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

UPES
UNIVERSITY OF TOMORROW

SEMESTER V

Course Code	Course name	L	T	P	C
MATH3061	Probability & Statistics	3	1	0	4
Total Units to be Covered: 4		Total Contact Hours: 45+15			
Prerequisite(s):	Basic knowledge of Calculus and Combinatorial Probability	Syllabus version: 1.0			

Course Objectives

1. To learn the distributions to study the joint behavior of two random variables.
2. To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty.

Course Outcomes

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

CO1. Define the concept of random variables, distribution, mass/density functions, moments and its properties to evaluate certain probabilities.

CO2. Understand and use the concepts of some specific discrete and continuous type distributions to solve probability theory problems. Understand the concept of distributions to study the joint behavior of two random variables.

CO3. Apply the concept of distributions to study the joint behavior of two random variables and find conditional distribution and expectations.

CO4. Establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

Course Description

To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness. The course intends to render the students to several examples and exercises that blend their everyday experiences with their scientific interests.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	-	-	-	-	1	1	-	3	2	-
CO2	3	2	2	-	-	-	-	1	2	1	2	3	1
CO3	3	2	2	-	-	-	-	1	1	1	2	3	1
CO4	3	2	2	1	-	-	-	1	1	1	2	3	1
Average	3	2	2	1	-	-	-	1	1.25	1	1.75	2.75	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Introduction to Probability Theory **15 Lecture Hours**

Sample space, Probability set function, Real random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions, Transformations, Mathematical expectation, Moments, Moment generating function, Characteristic function.

Unit 2: Some Special Distributions **10 Lecture Hours**

Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions: Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.

Unit 3: Joint Distribution of Several Random Variables **10 Lecture Hours**

Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions, and expectations.

Unit 4: Correlation and Regression **10 Lecture Hours**

The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares, Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.

Text Books:

1. Hogg, Robert V., McKean, Joseph W., & Craig, Allen T., Introduction to Mathematical Statistics (7th ed.). Pearson Education, Inc., 2013.
2. Rohatgi, V. K., Saleh, A. K. M. E., An Introduction to Probability and Statistics. United States: Wiley, 2015.
3. Miller, Irwin & Miller, Marylees, John E., Freund's Mathematical Statistics with Applications (8th ed.). Pearson. Dorling Kindersley (India), 2014.
4. Ross, Sheldon M., Introduction to Probability Models (11th ed.). Elsevier Inc. AP, 2014.

Reference Books:

1. S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2018.
2. T.K.V. Iyengar, B. Krishna Gandhi, S. Ranganadham, M.V.S.S.N. Prasad, Probability and Statistics, S. Chand, 2019.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH3063	Abstract Algebra	3	1	0	4
Total Units to be Covered: 3	Total Contact Hours: 45+15				
Prerequisite(s):	Mathematics at 10+2	Syllabus version: 1.0			

Course Objectives

1. To let the students understand group theory.
2. To make the students familiar with structures like rings, fields, integral domains and the corresponding morphisms.

Course Outcomes

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

CO1. Understand the concept of group and its morphisms among sets.
CO2. Analyze the structure of a ring and its various kind of ideals.
CO3. Understand the concept of factorization and divisibility through prime and irreducible elements.

Course Description

Abstract algebra course provides a deep and microscopic insight to the structure of a set which leads to the development of set theoretic concepts. The course begins with the understanding of group structure and its decomposition into cosets. A higher class of sets is ring structure and domains, the understanding of which lets a student to analyze the factorization and divisibility among the field elements. This course opens the door to the core branches of computer science like cryptography, number theory and discrete structures.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	2	-	3	1	1
CO2	3	2	-	-	-	-	-	-	1	-	3	1	-
CO3	3	2	-	-	-	-	-	-	2	-	3	3	1
Average	3	2	-	-	-	-	-	-	1.7	-	3	1.67	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Groups and Subgroups **15 Lecture Hours**

Binary operation and Algebraic structure, Groups, Subgroups, Generators of a group, Permutation groups, Cyclic groups, Coset decomposition, Lagrange theorem and its consequences, Homomorphism and Isomorphism, Normal subgroups, Quotient group, Cayley's theorem. Fundamental theorems on homomorphism and isomorphism, Automorphism and inner automorphism.

Unit 2: Rings and Ideals **15 Lecture Hours**

Rings, Various types of rings, Rings with unity, Rings without zero divisors, Properties of rings, Sub rings. Ideals, Quotient rings, Principal ideals, Maximal ideals, Prime ideals, Principal ideal domains, Characteristic of a ring.

Unit 3: Factorization **15 Lecture Hours**

Integral domain, Field, Skew field, Field of quotients of an integral domain, Embedding of an integral domain in a field, Factorization in an integral domain, Divisibility, Units, Associates, Prime and irreducible elements, Unique Factorization Domain, Principal Ideal Domain, Euclidean rings.

Text Books:

1. I. N. Herstein: Topics in Algebra. Wiley Eastern Ltd.
2. N. Jacobson: Basic Algebra Vol I & II. Hindustan Publishing Co.
3. Joseph A. Gallian: Contemporary Abstract Algebra. Narosa Publishing House.

Reference Books:

1. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing house, New Delhi, 1999, ISBN: 978-0395861790.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
PHYS3030	Classical Mechanics	4	0	0	4
Total Units to be Covered: 4	Total Contact Hours: 60				
Prerequisite(s):	UG level Physics	Syllabus version: 1.0			

ASSC3001	SCIENTIFIC COMMUNICATION	L	T	P	C
Version 1.0		1	0	0	1
Pre-requisites/Exposure	-				
Co-requisites/Exposure	-				

Course Objectives

1. To teach the basic idea and importance of scientific communication.
2. To familiarize with different types of scientific communication, ethics.
3. To demonstrate the use of major referencing styles using reference managing tools.

Course Outcomes

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

CO1. Understand the basics and importance of scientific writing.
CO2. Identify and write different types of scientific writings.
CO3. Understand and apply technical tools in scientific writing.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	-	2	2	-	-	-	-	-	-	1	-
CO2	2	3	-	-	3	-	-	-	-	-	-	1	-
CO3	2	2	-	-	2	-	-	-	1	-	-	2	1
Average	2	2.3	-	2	2.3	-	-	-	1	-	-	1.3	1

1. WEAK 2. MODERATE 3. STRONG

Syllabus

Unit 1: Introduction **5 Lecture Hours**

Introduction: Overview of Research and Scientific writing, Purpose of Scientific writing, Steps in Science Writing. Communications- research journals, research reviews, conference papers, theses, book chapters, annual reports, newsletters, project proposals, lectures, meetings with individuals, leaflets, posters. Extension communications -extension manuals, newspaper reports, magazine articles, radio and

TV broadcasts, video, and demonstrations (field days). Effective communication: Audiences, Requirements for Producing Publications.

Unit II: Writing about your Research 5 Lecture Hours

Format of a Research Paper: Structure and introduction of main sections. Characteristics of a good scientific paper, Writing Research Paper, Review Articles, Permission to reproduce material, handling negative results.

Unit III: Ethics in Scientific Writing & Modern Tools usage 5 Lecture Hours

Plagiarism- Introduction and Different Types of Plagiarism, Introduction to Peer Reviewing. Overview of grant writing. Managing References: Introduction to reference managing tools

Text Books / Web Links / Tools:

1. Abebe Kirub, Essentials of Scientific Writing, EIAR, ISBN: 978-99944-53-98-6

2. Technical Writing: A Practical Guide for Engineers, Scientists, and Non-Technical Professionals. Phillip A. Laplante. Boca Raton: Taylor & Francis, CRC Press, 2018.

3. https://www.mendeley.com/reference-management/reference-manager

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

SEMESTER VI

Course Code	Course name		L	T	P	C
MATH3017	**Mathematical Modeling**		3	0	0	3
Total Units to be Covered: 3		**Total Contact Hours: 45**				
Prerequisite(s):	**Calculus, Differential and Difference Equations**	**Syllabus version: 1.0**				

Course Objectives

1. To help the students understand the concepts of mathematical modeling.
2. To make the students appreciate the value of mathematics in solving various practical problems.
3. To make the students realize the fundamental significance of continuous and discrete models.
4. To make the students understand formation of models using sound mathematical concepts and perform simulations.
5. To enable the students to interpret the concepts of mathematical modeling in real life applications and demonstrate the results.

Course Outcomes

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

CO1. Describe the importance, limitations and classification of mathematical models.
CO2. Translate problems into models based on ordinary differential equations of first and second orders.
CO3. Translate problems into models based on difference equations.
CO4. Interpret the real-life problems into a mathematical model and further interpret, analyze and apply numerical methods using computational tool(s) to draw meaningful inferences.

Course Description

This course aims to make use of mathematics as a means to build models, interpret real-life problems and subsequently draw meaningful results and conclusions. The students will be able to use the knowledge of calculus, differential and difference equations as tools to develop these models. The models would cover many different domains which would include problems from natural science, engineering, computer science, management, psychology, biology, economics, medicine etc. The students will learn to apply the tools to their domain specific problems, interpret and examine results and apply novel ideas to the content.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	1	-	3	2	-
CO2	3	2	2	2	-	-	-	1	1	1	3	2	1
CO3	3	2	2	2	-	-	-	1	1	1	3	2	1
CO4	3	2	2	2	-	-	-	1	1	1	3	2	1
Average	3	2	2	2	-	-	-	1	1	1	3	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Fundamentals of Mathematical Modeling 5 Lecture Hours

Introduction to Mathematical Modelling, Approaches to Mathematical Modeling: empirical models, stochastic models, simulation models, deterministic models, statistical models, units and dimension, dimensional analysis, scaling.

Unit 2: Continuous models 20 Lecture Hours

Introduction to continuous models, Steady state solutions and linear stability analysis, Phase plane diagrams of linear systems.
Mathematical models based on ordinary differential equations of first order: linear and non-linear growth/exponential and decay models (carbon dating, drug distribution, Malthusian, Logistic and Gomperzian growth models, Richardson's model for arms race, Lanchestar Combat Models, Lotka Volterra competition model), compartment models.
Mathematical models based on ordinary differential equations of second order: linear and non-linear growth and decay models (mathematical models on planetary motions, circular motions and motions of satellite, mechanical oscillations, flow of current in electrical circuits). Numerical solutions along with the graphical representations of the continuous models, using mathematical software tools.
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Unit 3: Discrete models 20 Lecture Hours

Introduction to difference equations, Steady state solution and linear stability analysis.

Mathematical models based on difference equations: linear and non-linear growth and decay models (economics and finance-Bank account and mortgage model, Harrod model of economic growth; population dynamics and genetics; and probability theory). Numerical solutions along with the graphical representations of the discrete models, using mathematical software tools.

Text Books:

1. Kapur, J. N., "Mathematical Modeling", New Age International, 2005
2. Jain, S. Modeling and Simulation using MATLAB - Simulink, 2^{nd} Ed,Wiley India, 2021

Reference Books:

1. Albright, B. and Fox, W.P., "Mathematical Modeling with Excel", CRCPress, Taylor and Francis group, 2019
2. Marotto, F. R., "Introduction to Mathematical Modeling using Discrete Dynamical Systems", Thomson Brooks/Cole, 2006
3. Edsberg, L., "Introduction to Computation and Modeling for Differential Equations", John Wiley and Sons, 2008
4. Murray, J. D., Mathematical Biology: An Introduction, Springer-Verlag New York, 2002

5. Mityushev, V., Nawalaniec, W. and Rylko, N., “Introduction to Mathematical Modeling and Computer Simulations”, CRC Press, Taylorand Francis group, 2018
6. Barnes, B. and Fulford, G. R., "Mathematical Modelling with Case Studies", CRC Press, Taylor and Francis Group, 2009
7. Mathematical Modeling: Models, Analysis and Applications, 2nd Ed, CRC Press, 2022
8. Giordano, F. R., Fox, W. P., Horton, S. B., and Weir, M. D., A First Course in Mathematical Modeling, 4th ed., Cengage Learning, 2013.
9. Heinz, S., Mathematical Modeling, Springer-Verlag, 2011
10. Mooney, D., and Swift, R., A First Course in Mathematical Modeling, MAA, 1999.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH3062	Numerical Analysis	3	0	1	4
Total Units to be Covered: 4		Total Contact Hours: 45+30			
Prerequisite(s):	Fundamentals of Calculus	Syllabus version: 1.0			

Course Objectives

1. To make the students realize the importance of numerical methods and errors inherited within.
2. To enable students understand the mechanism of iterative techniques.
3. To enable students derive appropriate numerical methods to solve a linear system of equations.
4. To make the students able to solve ODEs and PDEs numerically.

Course Outcomes

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

CO1. Understand the concept of error and implement iterative numerical methods to solve algebraic and transcendental equations in one variable.
CO2. Interpolate values of the dependent variable and its derivatives from equally and unequally spaced data.
CO3. Perform numerical integration from the available discrete data.
CO4. Solve the system of linear algebraic equations both by direct and iterative methods.
CO5. Solve numerically the initial and boundary value problems in ODEs and PDEs.

Catalog Description

Numerical analysis deals with the study of algorithms that use numerical approximation for the problems arising in science and engineering. The course is aimed to provide the knowledge of numerical methods along with their error analysis for solving a variety of mathematical models. It deals with the basic definitions, properties of various finite difference operators and their applications to engineering problems associated with polynomial interpolation, differentiation and integration from the given tabular data. It discusses various algorithms associated with the technique of finding zeros of the algebraic and transcendental equations. This course also provides a detailed knowledge of various direct and iterative methods to solve system of linear algebraic equations. Several techniques will be discussed for solving initial value problems of ordinary differential equations. The students will also get insight into the solutions of boundary value problems in both ordinary and partial differential equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	3	-	-	-	-	-	2	-	3	2	-
CO2	3	2	3	-	-	-	-	1	2	-	3	2	-
CO3	3	2	3	-	-	-	-	1	2	-	3	2	-
CO4	3	2	3	-	-	-	-	-	2	-	3	2	-
CO5	3	2	3	-	-	-	-	1	1	1	2	3	1
Average	3	2	3	-	-	-	-	1	1.8	1	2.8	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit I: Error Analysis and Root finding techniques 11 lecture hours

Exact and approximate numbers, rounding off numbers, significant digits, correct digits, various types of errors encountered in computations, propagation of errors, Bisection and Fixed-Point Iteration method with convergence criteria, False position and Secant methods with convergence criteria, Newton-Raphson method with convergence criteria. Order and rate of convergence of root finding methods.

Unit 2: Interpolation and Numerical Differentiation 11 lecture hours

Introduction to finite difference operators and properties, Factorial notation and Missing term techniques, Newton's Forward and Backward Interpolation, Gauss's Forward and Backward Interpolation, Stirling's and Bessel's Interpolation, Interpolation of unevenly spaced data by Lagrange's and Newton's divided difference formula, Numerical Differentiation.

Unit 3: Numerical Integration and System of Linear equations 11 lecture hours

Numerical Integration: Trapezoidal, Simpson's 1/3 and 3/8 rules with error terms, Composite integral methods: Trapezoidal, Simpson's 1/3 and 3/8 rules, Gauss Legendre 2-points and 3-points formulae, LU Decomposition, Doolittle, Crout's and Cholesky's methods, Gauss Jacobi & Gauss Seidel methods with convergence criteria,

Unit 4: Solutions of ODE and PDE 12 lecture hours

Taylor's series method, Euler's method, Modified Euler's method, 2nd and 4th order Runge-Kutta method, Milne Predictor Corrector method. Finite difference approximations, Solution of 2 point BVP, Five point finite difference approximations, Liebmann's Iteration process, Explicit and Implicit methods: Bendre - Schmidt Process, Crank-Nicholson method.

Text Books

1. Jain, M. K., Iyengar, S. R. K., Jain, R. K., Numerical Methods for Scientific and Engineering Computation, New Age International, ISBN 9788122420012.
2. Sastry, S. S., Introductory Methods of Numerical Analysis, PHI Learning, India, ISBN: 9788120345928.

Reference Books

1. Gerald, F. C., Wheatley, P. O., Applied Numerical Analysis, Pearson India, ISBN 9788131717400.
2. Pal, S., Numerical methods: Principles, analyses, and algorithms, Oxford University
3. Press, New Delhi, ISBN: 9780195693751.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
	Numerical Analysis Lab	0	0	0	0
Total Units to be Covered: 4	Total Contact Hours:				
Prerequisite(s):	Calculus, Differential equations, PDE and Systems of ODE	Syllabus version: 1.0			

Course Objectives

1. To provide the students with the basic knowledge of softwares for numerical computa-tions.
2. To make students gain insight on programming techniques using softwares.
3. To enable students use softwares to solve computational problems.

Course Outcomes

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

CO1. Develop programs for the solution of algebraic and transcendental equations of one variable.
CO2. Design programs for the solution of system of linear algebraic equations.
CO3. Develop programs for numerical interpolation, differentiation, and integration.
CO4. Develop Program for solving initial value problems.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2	3	-	-	-	2	1		2	1	-
CO2	2	2	2	3	-	-	-	2	1	-	2	1	-
CO3	2	2	2	3	-	-	-	2	1	1	2	1	1
CO4	2	2	2	3	-	-	-	2	1	1	2	1	1
Average	2	2	2	3	-	-	-	2	1	1	2	1	1

1. WEAK 2. MODERATE 3. STRONG

List of Practical's

1. Bisection method
2. Newton Raphson method
3. Secant method
4. Regula Falsi method
5. Gaussian Elimination
6. Gauss Jordan methods.
7. Gauss-Jacobi method
8. Gauss-Seidel method
9. Lagrange interpolation
10. Newton interpolation
11. Trapezoidal rule
12. Simpson's rule
13. Euler's method
14. Runge Kutta Method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and log-ical expressions, control statements and loop statements, Arrays should be introduced to the students.

Books Recommended

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008
3. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
4. Bala Guru Swamy, E., Numerical Methods, Tata McGraw Hill, India.
5. Steven C. Chapra, Applied Numerical Methods with MATLAB, 3rd Ed., Mcgraw Higher Ed., 2012.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**Lab**	
	Continuous Assessment	
	Lab records + Viva	**Quiz/Exam**
Weight %	(70%)	(30%)

Course Code	Course name	L	T	P	C
MATH3064	**LINEAR PROGRAMMING**	3	1	0	4
Total Units to be Covered: 3	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Mathematics at 10+2**	**Syllabus version: 1.0**			

Course Objectives

1. To know about linear programming problems.
2. To enable the students demonstrate various solution techniques of LPP.
3. To make the students realize the potential applications of LPP.

Course Outcomes

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

CO1. Formulate a linear optimization model from real life situation, and understand the feasible and optimal solution concept of linear optimization models, and their dual problems.

CO2. Compute the dual problem from the primal.

CO3. Implement the technique for solving linear optimization models in special linear optimization models: Transportation problems, Assignment problems.

CO4. Apply nonlinear unconstrained and constrained optimization models by search methods and gradient methods respectively.

Course Description

The course focuses on the fundamental concepts and principles of the Simplex Method, which is a crucial area of study in Operations Research, used for solving Linear Programming Problems. The course covers Linear Programming with applications to Transportation and Assignment Problem.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	-	-	-	-	-	1	1	3	2	1
CO2	3	2	1	-	-	-	-	-	1	-	3	2	-
CO3	3	2	2	-	-	-	-	1	1	1	3	2	1
CO4	3	2	2	-	-	-	-	1	1	1	3	2	1
Average	3	2	1.75	-	-	-	-	1	1	-	3	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Linear Programming **20 Lecture Hours**

The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution. Hyperplanes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points. Simplex Method: Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex algorithm and its Tableau Format; Revised simplex method; Artificial variables, Two-phase method, Big-M method.

Unit 2: Duality **10 Lecture Hours**

Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness; The Dual Simplex Method.

Unit 3: Transportation and Assignment Problem **15 Lecture Hours**

Transportation problem and its mathematical formulation, Transportation Table, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem Finding initial basic feasible solution, Test of optimality, Degeneracy, MODI method, Stepping Stone method, Solutions of Assignment problems, Hungarian method.

Text Books:

1. G. Hadley, Linear Programming, Narosa Publishing House, 1995.
2. S. I. Gass, Linear Programming: Methods and Applications (4th edition) McGraw-Hill, New York, 1975.
3. Kanti Swaroop, P.K. Gupta and Man Mohan, Operations Research, Sultan Chand & Sons, New Delhi, 1998.
4. Hamdy A. Taha, Operations Research, Prentice-Hall of India, 1997.
5. S.S. Rao, Optimization Theory and Applications, Wiley Eastern, 2004.

Reference Books:

1. Hillier F.S. and Lieberman, Introduction to Operations Research: Concepts and Cases, Tata Mc Graw Hill, 8th Ed., (Indian Adapted Edition), 2005.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

SEMESTER VII

Course Code	Course name		L	T	P	C
MATH4011	Advanced Numerical Techniques		2	0	0	2
Total Units to be Covered: 3		Total Contact Hours: 30				
Prerequisite(s):	Numerical Analysis		Syllabus version: 1.0			

Course Objectives

1. To make the students realize the importance of advanced numerical techniques and errors analysis within.
2. To enable students understand the mechanism of iterative techniques.
3. To enable students derive appropriate numerical methods to solve a nonlinear system of equations.
4. To make the students able to solve ODEs numerically.

Course Outcomes

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

CO1. Understand the concept of approximation of eigenvalues of a matrix using power methods.
CO2. Solve the nonlinear system of equations by fixed point and steepest descent methods.
CO3. Solve numerically the boundary value problems in ODEs.

Catalog Description

Numerical analysis deals with the study of algorithms that use numerical approximation for the problems arising in science and engineering. The course is aimed to provide the knowledge of advanced numerical techniques along with their error analysis for solving a variety of mathematical models. It discusses various algorithms associated with the technique of approximating the eigenvalues of a given matrix. This course also provides a detailed knowledge of iterative methods to solve the system of nonlinear equations. The students will also get insight into the solutions of boundary value problems that arise in ordinary differential equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	3	-	-	-	-	2	1	2	3	2	2
CO2	3	2	3	-	-	-	-	2	1	2	3	2	2
CO3	3	2	3	-	-	-	-	2	1	2	3	2	2
Average	3	2	3	-	-	-	-	2	1	2	3	2	2

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Eigenvalues approximation **10 lecture hours**

Linear algebra and eigenvalues, Gersgorin circle theorem, Power method, Symmetric Power method, Inverse Power method, Deflation methods, Householder's method, QR algorithm, Singular value decomposition, Least squares approximation.

Unit 2: Solution of nonlinear system of equations **10 lecture hours**

Fixed points of functions of several variables, Newton's method, Quasi-Newton methods, Broyden's method, Steepest descent techniques, The method of steepest descent.

Unit 3: Boundary value problems for ODE **10 lecture hours**

Linear shooting method, Shooting method for nonlinear problems, Finite difference methods for linear problems, Finite difference methods for nonlinear problems, Rayleigh-Ritz method.

List of Experiments

Experiment No: 01
Power Method

Experiment No: 02
Symmetric Power Method

Experiment No: 03
Inverse Power method

Experiment No: 04
Wielandt Deflation method

Experiment No: 05
Householder's method

Experiment No: 06
Newton's method for nonlinear system

Experiment No: 07
Broyden's method

Experiment No: 08
Steepest Descent Method

Experiment No: 09
Linear Shooting Method

Experiment No: 10
Nonlinear Shooting with Newton's Method

Experiment No: 11
Nonlinear BVP by finite difference method

Text books

3. Richard L Burden, J Douglas Faires, Numerical Analysis, Ninth Edition, Cengage Learning.
4. Sastry, S. S., Introductory Methods of Numerical Analysis, PHI Learning, India, ISBN: 9788120345928.

Reference Books

1. Jaan Kiusalaas, Numerical Methods in Engineering with Matlab, Cambridge University Press.
2. Jain, M. K., Iyengar, S. R. K., Jain, R. K., Numerical Methods for Scientific and Engineering Computation, New Age International, ISBN 9788122420012.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4012	**Discrete Mathematics**	3	0	0	3
Total Units to be Covered: 4	**Total Contact Hours: 45**				
Prerequisite(s):	**Mathematics up to Intermediate Level**	**Syllabus version: 1.0**			

Course Objectives

1. To enable students, understand the fundamentals of mathematical logic and its usage.
2. To inculcate the concepts of Number Theory and its applicability in solving emerging problems.
3. To make the students understand and use various advanced counting techniques in real world problems.

Course Outcomes

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

CO1. Apply the concepts of first order mathematical logic in real life applications.
CO2. Categorize and analyze various discrete set structures into posets and lattices.
CO3. Solve the recurrence relations using generating function techniques.
CO4. Solve the congruence equations and system of linear Diophantine equations.

Course Catalog

Mathematics is a necessary subject to a clear and complete understanding of virtually all phenomena. It helps us to develop logical thinking and to find the right way to solve problems. This course covers basic concepts of relations, recurrence relation, mathematical logic, posets, lattices and number theory. This discrete mathematics course would carefully blend and balance mathematical reasoning, combinatorial analysis, discrete structures and applications. This course is designed in such a way that it enables the students to cope confidently with the concepts of discrete mathematics needed in the real-life applications; and the curriculum aims at developing student's ability to conceptualize, reason and use discrete mathematics in order to formulate and solve problems in real life.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	2	-	3	2	-
CO2	3	2	-	-	-	-	-	1	1	-	2	3	-
CO3	3	2	-	-	-	-	-	1	2	-	3	2	-
CO4	3	2	-	-	-	-	-	1	2	-	3	2	-
Average	3	2	-	-	-	-	-	1	1.7	-	2.7	2.3	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit I: Mathematical Logic

8 Lecture Hours

Mathematical logic, Proposition, Connectives, Tautologies and Contradictions, Algebra of propositions. Logical equivalences, Principal normal forms and applications. Rules of Inferences, Interpretation of an argument and its validity (with and without truth table), Predicates and Quantifiers, Negation of quantified statements.

Unit 2: Posets and Lattices **14 Lecture Hours**

Relations and Their types, Representing Relations, Composition of relations, Equivalence relation and classes, Closures of Relations, Partial order relations, decomposition theorems for partial orders. Posets, Hasse diagram, maximal and minimal elements, greatest and least elements, least upper bound and lower bounds. Totally ordered set, Well ordered set, Lexicographic order, Lattice, Bounded and distributive lattice, Complemented lattice, Modular lattice.

Unit 3: Basic Counting Principles **13 Lecture Hours**

Pigeonhole principle, Binomial coefficients and identities, discrete numeric function, Convolution product, Recurrence relations and solutions, Solution of linear recurrence relation with constant coefficients, Generating function techniques, Matrix method, principles of inclusion and exclusion and its applications.

Unit 4: Number Theory **10 Lecture Hours**

Modular arithmetic, primes, fundamental theorem of arithmetic, GCD/LCM, Euclidean Algorithm, solving congruences, Linear Diophantine Equation, Chinese remainder theorem, Fermat's Little theorem, Discrete log.

Books Recommended:

1. Kenneth H Rosen: Discrete Mathematics and its Applications, McGraw Hill (2012).
2. R. C. Bose, B. Manvel: Introduction to Combinatorial Theory, Wiley Series in Probability and Mathematical Statistics.
3. Winfield K Grassmann and Jean-Paul Tremblay: Logic and Discrete Mathematics: A Computer Science Perspective, Prentice-Hall (1996).
4. Seymour Lipschutz, Marc Lipson: Theory and Problems on Discrete Mathematics. McGraw-Hill.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
ASRM4001	Research Methodology & Ethics	2	0	0	2
Total Units to be Covered: 6		Total Contact Hours: 30			
Prerequisite(s):	Basic knowledge of research terminology and concepts	Syllabus version: 1.0			

Course Objective

1. To introduce students to the fundamental concepts of research ethics and IPR and their importance in scientific inquiry.
2. To provide students with a thorough understanding of responsible conduct of research, including integrity and transparency in research, data management and sharing, and conflict of interest and authorship.
3. To familiarize students with copyrights, licensing, and technology transfer and their role in commercialization of research findings.
4. To develop students' ability to apply the concepts of research ethics and IPR to real-world research problems.
5. To provide students with hands-on experience in conducting research with IPR and ethical considerations in mind.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Understand the principles of research design (Remembering and Understanding).
CO2: Apply various research methods and techniques (Applying).
CO3: Analyze and interpret data (Analyzing and Evaluating).
CO4: Write and present research reports (Creating and Evaluating).
CO5: Understand ethical considerations in research (Understanding and Analyzing).

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	3	-	-	-	-	2	-	2	-	-	3
CO2	3	-	3	-	-	3	-	-	-	-	-	-	3
CO3	3		3	-	-	-	-	-	3	-	-	-	3
CO4	3	-	3	3	-	-	3	-	-	-	-	-	3
CO5	3	2	3	-	2	-	-	-	3	2	-	-	3
Average	3	2	3	-	2	3	3	2	2	2	-	-	3

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Introduction to research ethics and IPR

Importance of research ethics and IPR in scientific inquiry. Overview of research methods and designs with respect to ethical considerations. Introduction to IPR and its role in research

Unit 2: Ethical considerations in research
Ethical principles and codes of conduct in research. Informed consent, confidentiality, and data protection. Institutional Review Boards (IRBs) and ethical guidelines

Unit 3: Responsible conduct of research
Integrity and transparency in research. Data management and sharing. Conflict of interest and authorship

Unit 4: Intellectual Property Rights (IPR)
Types of IPRs and their relevance to research. Patentability requirements and patent drafting. Copyrights and licensing

Unit 5: Commercialization and technology transfer
Innovation and entrepreneurship in research. Commercialization of research findings. Technology transfer and licensing

Unit 6: Application of research ethics and IPR to real-world problems
Research proposal development with ethical and IPR considerations. Conducting research with IPR and ethical considerations in mind. Reporting research findings with attention to ethical and IPR issues

Text Books:

1) Research Methodology: A Step-by-Step Guide for Beginners by Ranjit Kumar
2) Ethics in Science: Ethical Misconduct in Scientific Research by John T. Noonan Jr. and Kenneth W. Freeman.
3) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches by John W. Creswell
4) Intellectual Property Law for Engineers and Scientists by Howard B. Rockman.

Modes of Evaluation**:** Quiz/Assignment/ presentation/ Written Examination

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

SEMESTER VIII

Course Code	Course name		L	T	P	C
DIST4102	Dissertation		0	0	6	6
Total Units to be Covered:		Total Contact Hours:				
Prerequisite(s):	Basic Knowledge of Mathematics, Data Collection and Presentation of Data	Syllabus version: 1.0				

Course Objectives

1. To get exposure on how to pursue scientific and mathematical facts.
2. To develop skills to summaries scientific and mathematical literature.
3. To discuss scientific and mathematical data related to the question at hand.
4. To present scientific and mathematical data and conclusions in written and oral form addressed to different groups.

Course Outcomes

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

CO1. Understand the planning and performance of a scientific and mathematical work.
CO2. Compute/measure scientific and mathematical data.
CO3. Summarize the scientific and mathematical literature and data and process data.
CO4. Analyze the scientific data and ethical issues in an adequate manner related to the scientific work.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	-	-	-	-	2	3	2	2	3	3
CO2	2	-	-	2	-	3	-	2	3	2	2	3	3
CO3	3	3	2	2	-	3	-	2	3	2	2	3	3
CO4	3	3	2	-	-	-	-	2	3	2	2	3	3
Average	3	3	2	2	-	3	-	2	3	2	2	3	3

1. WEAK 2. MODERATE 3. STRONG

Broad Topics

1. Differential Geometry, Mathematical Modeling, Data Mining, Reliability Analysis & optimization, Wavelet theory, Control Theory, Quasilinear System of Partial Differential Equations, Analytical and Numerical Solutions of Nonlinear Wave Problems in Gas-dynamics, Lie Group Invariance for Solutions of PDEs. Special functions, Numerical Analysis, Applied Mathematics, Computational Mathematics, Differential equations. Operational matrices. Singular integral equation of Abel type. Fluid Dynamics, Image Processing, Fixed Point Theory, Ferrohydrodynamic, Approximation Theory.

2. Computational Mathematics, Numerical Analysis, Applied Mathematics, Fluid Organics, Multi-objective Optimization, Reliability Optimization and Evolutionary Algorithms, Reliability of Complex Systems, Reliability Theory and Fuzzy Reliability Theory, Operations Research and Decision Making, Bayesian Modelling of Satellite Based data Set, Multi Criteria Decision Making, Mathematical Modeling, Differential Equations, Theory of Games, Ant Colony Optimization, Soft Computing, Programming in MATLAB.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	Internal Assessment	End Semester
Weight %	50	50

Course Code	Course name	L	T	P	C
MATH4022	**Integral Equations And Calculus Of Variations**	3	0	0	3
Total Units to be Covered: 4		**Total Contact Hours: 45**			
Prerequisite(s):	**Graduate Level Mathematics**	**Syllabus version: 1.0**			

Course Objectives

3. To enable the students explain the fundamental concepts of the theory of Integral equations and calculus of variations.
4. To make the students able to understand transformation between integral equations and differential equations.
5. To enable the students solve integral equations of several types.
6. To help the students understand solution of differential equations using calculus of variations method.

Course Outcomes

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

CO1. understand the difference between differential equations and integral equations and conversion of one type to the other.

CO2. solve linear Volterra and Fredholm integral equations using various methods.

CO3. determine the extrema of a functional using calculus of variations technique, establish maximum principles for various equations and comprehend consequences.

CO4. solve some classical problems using principles of calculus of variations.

Course Description

This course aims at introducing basics of integral equations and calculus of variations and their applications. Integral equations are useful in various fields of science and has various applications in elasticity, plasticity, heat and mass transfer, oscillation theory, fluid dynamics, filtration theory, electrostatics, electrodynamics, biomechanics, game theory, control, queuing theory, electrical engineering, economics and medicine. Exact solutions of integral equations play an important role in the proper understanding of qualitative features of many phenomena and processes in various areas of natural science. In this course the students will go through Volterra and Fredholm integral equations. They will also learn to find extrema of a functional using calculus of variations technique.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	1	-	-	3	2	-
CO2	3	2	-	-	-	-	-	1	-	-	3	2	-
CO3	3	2	1	-	-	-	-	1	1	1	3	2	1
CO4	3	2	1	-	-	-	-	1	1	1	3	2	1
Average	2.75	3	1	-	-	-	-	1	1	1	3	2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Integral Equations and Their Classification 9 Lecture Hours

Integral equations: basic concept and classifications, Method of converting an initial value problem to a Volterra integral equation, method of converting a boundary value problem to a Fredholm integral equation, Conversion of integral equations into differential equations.

Unit 2: Methods for Solving Integral Equations 12 Lecture Hours

Solution of integral equations with separable kernels, Eigenvalues and Eigen functions. Solution by the successive approximations, Neumann series and resolvent kernel. Solution of integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green's function approach.

Unit 3: Solving Integral Equations with Convolution Type Kernels 12 Lecture Hours

Fredholm method of solution and Fredholm theorems. Successive approximations, Neumann series and resolvent kernel. Equations with convolution type kernels, Singular integral equations, Hilbert-transform, Cauchy type integral equations.

Unit 4: Introduction to the Calculus of Variations 12 Lecture Hours

Basic concepts of the calculus of variations: functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler`s equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler`s equations. Variational problem in parametric form. Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries, Broken extremals: Weierstrass – Erdmann conditions. Rayleigh-Ritz variation method.

Text Books:

1. M. D. Raisinghania, Integral equations and boundary value problems, S. Chand Publishing, ISBN: 9352838955
2. A.S. Gupta, Calculus of variations with applications, Prentice Hall India Learning Private Ltd., ISBN: 8120311205.

Reference Books:

1. A. Jerri: Introduction to integral equations with applications, Wiley–Blackwell, ISBN: 0471317349.
2. R. P. Kanwal, Linear integral equations theory and technique, Academic Press, ISBN: 9780817639402.
3. R. Weinstock, Calculus of variations: with applications to physics and engineering, Dover Publications, ISBN: 0486630692.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4023	Topology	3	0	0	3
Total Units to be Covered: 4	Total Contact Hours: 45				
Prerequisite(s):	UG level Mathematics	Syllabus version: 1.0			

Course Objectives

1. To enable the students understand the basic concepts of metric and topological spaces.
2. To make the students able to understand the mathematical study of spaces.
3. To help the students develop the skills related to construction of various topologies on a non-empty general set by using different kinds of techniques.
4. To enable the students understand the separation axioms.

Course Outcomes

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

CO1. Explain basic concepts of metric spaces.

CO2. Understand various notions of structures using order and box topology.

CO3. Determine the concept of connectedness and compactness in a topological space.

CO4. Illustrate the concepts of the countability and separation axioms in a topological space.

Course Description

Topology plays a significant role in many areas of mathematics, engineering and natural sciences. It introduces the fundamental concepts of topology, the topology of real number system and its generalizations to metric spaces and topological spaces. A major part of the content is devoted to the deep concepts of connectedness, compactness and separation. This course is designed in such a way that it enables the students to cope confidently with the mathematics needed in their future subjects and the curriculum aims at developing student's ability how to simplify many types of complex problems using fundamental theory of topology.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	-	-	-	-	-	-	-	-	3	2	-
CO2	3	3	-	-	-	-	-	-	-	-	3	2	-
CO3	3	3	-	-	-	-	-	-	-	-	3	2	-
CO4	3	3	-	-	-	-	-	-	-	-	3	2	-
Average	3	3	-	-	-	-	-	-	-	-	3	2	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Metric Spaces **12 Lecture Hours**

Metric spaces, open sets, limit point, closed sets, closure, interior, exterior, boundary of set, dense and non-dense sets, sequence and subsequence in metric space, complete metric spaces, Cantor's intersection theorem, Baire's category theorem.

Unit 2: Topological Spaces **12 Lecture Hours**

Open sets, closed sets, closures, interiors of sets, base and sub bases, subspace and relative topology, basis for a topology, sub basis, T1 and T2 spaces, order topology, weak topology, product topology, box topology, subspace topology, accumulation points and derived sets, continuous function, general product topology, metric space and its topology, quotient topology.

Unit 3: Connectedness and Compactness **9 Lecture Hours**

Connected spaces, connected subspaces, local connectedness, compact subspace, limit point, compactness, local compactness, continuity, and compactness.

Unit 4: Separation Theorem **12 Lecture Hours**

Countability axioms, separation axioms, regular, normal spaces, and completely normal spaces, Urysohn's lemma, product spaces, Urysohn Metrization theorem, Tietze extension theorem, Tychonoff theorem.

Text Books:

1. Simmons G.F. Introduction to topology and modern analysis. Tokyo; 1963.
2. Munkres J.R, Munkres JR. Topology: a first course. Englewood Cliffs, NJ: Prentice-Hall; 1975.

Reference Books:

1. Bredon GE. Topology and geometry. Springer Science & Business Media; 2013.
2. Willard S. General topology. Courier Corporation; 2004.
3. Patty CW. Foundations of topology. Jones & Bartlett Learning; 2009.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Minors

Course Code	Course name		L	T	P	C
MATH1057	**Linear Algebra-I**		3	1	0	4
Total Units to be Covered: 3		**Total Contact Hours: 45+15**				
Prerequisite(s):	**Mathematics at 10+2**		**Syllabus version: 1.0**			

Course Objective

1. To make the students acquire the knowledge of matrix algebra and diagonalization.
2. To make the students acquire knowledge of vector spaces and linear transformations.
3. To make the students prove certain isomorphism theorems.

Course Outcomes

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

CO1. Determine the solution of linear system of equations, eigenvalues and eigenvectors of a matrix.

CO2. understand the concept of vector spaces, subspaces, and their dimensions.

CO3. illustrate the concepts of matrix of a linear transformation and similar transformation.

Course Description

Algebra plays a significant role in many areas of mathematics, engineering, and natural sciences. It provides a foundation of important mathematical ideas that will engage students in sound mathematical thinking and reasoning. This course covers the fundamental theory of matrix algebra, vector spaces and linear transformations which is extensively used in the field of approximation theory and numerical methods. This course is designed in such a way that it enables the students to cope confidently with the mathematics needed in their future subjects and the curriculum aims at developing student's ability how to simplify many types of complex problems using fundamental theory of matrix algebra.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	1	-	3	1	-
CO2	3	2	-	-	-	-	-	-	1	-	3	1	-
CO3	3	2	-	-	-	-	-	1	2	-	3	-	-
Average	3	1.3	-	-	-	-	-	1	1.3	-	1.7	0.7	-

2. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Matrix Algebra 15 Lecture Hours

Rank of a matrix, Echelon form, Normal form, Linear independence of vectors, Solution of homogeneous and non-homogeneous system of equations, Characteristic Equation of a matrix, Eigenvalues and eigenvectors, Diagonalization, Powers of matrix.

Unit 2: Vector Spaces 15 Lecture Hours

Field, Definition of vector space, Span, Linear independence/dependence of vectors, Basis and dimension, Subspaces and their intersection, Sum of subspaces, Direct sum.

Unit 3: Linear Transformation 15 Lecture Hours

Linear mapping, Matrix as a linear mapping, Kernel and range space, Rank nullity theorem, Solution space of $Ax = 0$, Singular and non-singular mappings, Isomorphisms, Operations with linear mappings, Algebra $A(V)$ of linear operators, Similarity of matrices, Change of basis.

Text Books:

4. G. Strang, Linear Algebra and its Applications, Cengage Learning, ISBN: 9788131501726.
5. S. Lipschutz and M. Lipson, Schaum's Series: Linear Algebra, Tata McGraw-Hill Company Limited, ISBN: 9780070605022.
6. S. H. Friedberg, A. J. Insel and L.E. Spence, Linear Algebra, PHI Learning Private Limited, ISBN: 9788120326064.

Reference Books:

4. David C. Lay, Linear Algebra and its Applications, Pearson Education India, ISBN: 9788177583335.
5. G. Strang, Linear Algebra and its Applications, Cengage Learning, ISBN: 9788131501726.
6. E. G. Goodaire and M. Parmenter, Discrete Mathematics with Graph Theory, Pearson
   Education, ISBN: 9789353433017.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH1030	**Calculus**	3	1	0	4
Total Units to be Covered: 4	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Mathematics at 10+2**	**Syllabus version: 1.0**			

Course Objectives

1. To help the students understand the concepts of limit, continuity, and differentiability.
2. To make the students learn successive and partial differentiation.
3. To enable them to understand the fundamentals of curve tracing.
4. To make the students find double and triple integration.
5. To help the students apply the concepts of integral calculus to find area and volume.

Course Outcomes

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

CO1. Find the value of the limit, continuity, and differentiability of a function at a point and perform successive differentiation and partial differentiation.

CO2. Calculate the tangents, normal, asymptotes and singular points of a given curve and sketch the different graphs (polynomials, parametric and polar curves).

CO3. Solve the problems related to double and triple integration.

CO4. Apply the concepts of double and triple integration to find the area and volume.

Catalog Description

Mathematics is necessary to have a clear and complete understanding of virtually all phenomena. It helps us to develop logical thinking and also to find the right way to solve problems. This course covers understanding of limit, continuity, and differentiability of functions, mean value theorems, successive and partial differentiation, various aspects of curve tracing, double and triple integration, and their applications with proofs of important results. This course is designed in such a way that it enables the students to cope confidently with the mathematics needed in their future subjects and the curriculum aims at developing student's ability to conceptualize, reason and to use mathematics to formulate and solve problems in their core subjects.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	1	-	-	3	2	-
CO2	3	2	-	-	-	-	-	1	-	-	2	3	-
CO3	3	2	-	-	-	-	-	1	1	-	2	3	-
CO4	3	2	-	-	-	-	-	1	2	-	2	3	-
Average	3	2	-	-	-	-	-	-	1.5	-	2.2	2.7	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Differential Calculus **12 Lecture Hours**

Limit and Continuity of a function, Types of discontinuities, Intermediate value theorem, Differentiability of functions, Rolle's theorem, Mean Value theorems, Taylor's and Maclaurin's series expansions, Indeterminate forms, Successive differentiation, Leibnitz's theorem, Partial differentiation, Euler's theorem on homogeneous functions.

Unit 2: Application of Differential Calculus **10 Lecture Hours**

Maxima and Minima, Tangents and Normals (cartesian, polar and parametric curves), Curvature, Asymptotes, Singular points, Points of inflexion, Curve tracing.

Unit 3: Integral Calculus **12 Lecture Hours**

Integral as a limit of sum, Properties of definite integrals, Fundamental theorem of integral calculus, Summation of series by integration, Infinite integrals, differentiation under the integral sign, Introduction to Multiple Integration, Double integration (cartesian and polar coordinates), Change of order of integration in double integrals, Triple integration (cartesian, spherical and cylindrical coordinates), Change of variables.

Unit 4: Applications of Integral Calculus **11 Lecture Hours**

Jacobians, Beta and Gamma functions, Length of curves, Area of curves (cartesian and polar), Area by double integration, Volume by triple integration.

Text Books:

1. T. M. Apostol: Calculus, John Willey and Sons, New York
2. M. Ray: Differential Calculus, Shiva Lal Agarwal and Co., Agra
3. G. B. Thomas., R. L. Finney, Calculus and Analytical Geometry, Pearson, ISBN: 9788177583250.
4. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005, ISBN: 978-0-387-97976-2
5. H. S. Dhami: Integral Calculus, New Age International, New Delhi

Reference Books:

1. R. Courant and F. John, Introduction to Calculus and Analysis I, Springer-Verlag, ISBN: 9783642586040.
2. R. Courant and F. John, Introduction to Calculus and Analysis II, Springer-Verlag, ISBN: 9783540665700.
3. H. Anton, I. Bivens and S. Davis, Calculus: Early Transcendentals, John Wiley and Sons, ISBN: 9780470647691.
4. S. Lang: A First Course in Calculus, Addison Wesley Publishing Co., Philippines
5. J. Stewart, Calculus: Early Transcendentals, Cengage Learning, ISBN: 9780538498708.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH2048	Ordinary Differential Equations		3	0	1	4
Total Units to be Covered: 4		Total Contact Hours: 45+30				
Prerequisite(s):	Calculus		Syllabus version: 1.0			

Course Objectives

1. To make the students understand the concept of differential equations and their solutions.
2. To make the students apply various techniques to solve Ordinary Differential Equations.
3. To make the students realize the importance of Ordinary Differential Equations in real world problems.

Course Outcomes

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

CO1. Define the concept of differential equations and their solutions.
CO2. Demonstrate various solution techniques of linear and nonlinear Ordinary Differential Equations.
CO3. Construct mathematical models for various real world problems using ordinary differential equations.
CO4. Examine the stability at equilibrium points of various real world models in ordinary differential equations.

Course Description

The course Ordinary Differential Equations is the most important part of Mathematics for understanding Physical sciences and Engineering applications. The scope of this course includes introduction to Differential Equations and Mathematical Models, Methods and Applications of differential equations in real world problems. These concepts are necessary for the study of dynamical behavior of a system through modeling. It helps the students to develop logical thinking and also to gain insight into the modeling process.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	-	3	2	-
CO2	3	3	3	2	-	-	-	2	2	-	3	3	1
CO3	3	3	3	2	-	-	-	2	2	-	3	3	1
CO4	3	3	3	2	-	-	-	2	2	-	3	3	1
Average	3	2.75	3	2	-	-	-	2	2	-	3	2.75	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: First order Ordinary Differential Equations 15 Lecture Hours

General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, nonlinear equations, equations solvable for x, y, p and Clairaut's equation, orthogonal trajectories, linear equations with variable coefficients.

Unit 2: Mathematical Models 05 Lecture Hours

Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, limited growth of population, limited growth with harvesting.

Unit 3: Higher order Ordinary Differential Equations 20 Lecture Hours

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, methods to solve linear homogeneous and non-homogeneous equations of higher order with constant and variable coefficients, Cauchy-Euler's equation, method of undetermined coefficients, method of variation of parameters, simultaneous linear differential equations.

Unit 4: Case Studies 05 Lecture Hours

Equilibrium points, interpretation of the phase plane, predatory-prey model and its analysis, epidemic model of influenza and its analysis, battle model and its analysis.

Text Books:

1. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.

Reference Books:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
2. Martha L Abell and James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
3. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18^{th} Edition, S. Chand & Company Pvt. Ltd, 2016.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
	Ordinary Differential Equations Lab		0	0	0	0
Total Units to be Covered:		Total Contact Hours:				
Prerequisite(s):	Ordinary differential equations (MATH2048)	Syllabus version: 1.0				

Course Objectives

1. To provide the students with the practical knowledge of solving ordinary differential equations.
2. To make students gain insight on analyzing growth, decay, prey-predator, epidemic and battle models using software.

Course Outcomes

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

CO1. Demonstrate the knowledge of Software in obtaining the solutions of differential equations.

CO2. Develop programs to understand the dynamics of various real world systems modelled as ordinary differential equations.

Course Description

The course on differential equations is the most significant part of Mathematics for understanding physical sciences and engineering applications. Hence its lab is necessary for a clear and complete understanding of all the phenomena associated with differential equations and mathematical models. This course is designed in such a way that it enables the students to conceptualize, reason and to use concepts of differential equations to formulate and solve problems using technical computing software.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	-	-	3	2	-	3	3	3
CO2	3	3	3	3	-	-	-	3	2	-	3	3	3
Average	3	3	3	3	-	-	-	3	2	-	3	3	3

1. WEAK 2. MODERATE 3. STRONG

List of Experiments (using MATLAB/Python)

Experiment No: 01
Elementary math built-in functions.

Experiment No: 02
Operations on Arrays.

Experiment No: 03
Built-in functions for handling arrays.

Experiment No: 04

Visualization using 2D plots.

Experiment No: 05
Visualization using 3D plots.

Experiment No: 06
Control statements and loops.

Experiment No: 07
Symbolic computations.

Experiment No: 08
Analytical solution of first order initial value problems and Applications.

Experiment No: 09
Analytical solution of higher order initial and boundary value problems and applications.

Experiment No: 10
Numerical ode solvers.

Text Books:

1. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems, Computing and Modeling, Pearson Education India, 2005.

Reference Books:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
2. Amos Gilat, MATLAB: An Introduction with Applications, 4th Ed., John Wiley & Sons, Inc, 2011.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**Lab**	
	Continuous Assessment	
	Lab records + Viva	**Quiz/Exam**
Weight %	(70%)	(30%)

Course Code	Course name	L	T	P	C
MATH2054	**Partial Differential Equations**	3	0	1	4
Total Units to be Covered: 4		**Total Contact Hours: 45+30**			
Prerequisite(s):	**Calculus and Ordinary Differential Equations**	**Syllabus version: 1.0**			

Course Objectives

1. To make the students understand the concepts of calculus of several variable functions.
2. To make the students apply various techniques to solve Partial differential equations of various types.
3. To make the students understand applications related to vibrating string problem and heat conduction problem.

Course Outcomes

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

CO1. Define the concepts of calculus of functions of several variables and Partial Differential Equations.

CO2. Demonstrate the understanding of expansions, extrema of functions of several variables, and solutions of first order Partial Differential Equations.

CO3. Solve second order linear and nonlinear Partial Differential Equations.

CO4. Examine various applications of Partial Differential Equations.

Course Description

The course is the most important part of Mathematics for understanding physical sciences and engineering applications. The scope of this course includes calculus of several variables, first and second order Partial Differential Equation with related applications. These concepts are necessary for the study of dynamical behavior of a real world systems. It gives students an exposure to a wide range of solution techniques related to Partial Differential Equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	-	3	2	-
CO2	3	3	3	2	-	-	-	2	2	-	3	3	1
CO3	3	3	3	2	-	-	-	2	2	-	3	3	1
CO4	3	3	3	2	-	-	-	2	2	-	3	3	1
Average	3	2.75	3	2	-	-	-	2	2	-	3	2.75	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Calculus of Functions of Several Variables 10 Lecture Hours

Functions of several variables: Review, partial derivatives and their geometrical interpretation, total derivative, derivatives of composite and implicit functions, Jacobians, homogeneous functions, Euler's theorem on homogeneous functions, harmonic functions, Taylor's expansion of functions of several variables, maxima and minima of functions of several variables, Lagrange's method of undetermined multipliers.

Unit 2: First Order Partial Differential Equations 10 Lecture Hours

Introduction, formation, classification, and geometrical interpretation of first order Partial Differential Equations, equations solvable by direct integration, Cauchy's problem for first order equations, Lagrange's equations, various working rules using Lagrange's method for solving $Pp + Qq = R$, non-linear PDE of first order: complete solution, singular solution, general solution, Charpit's method and working rule, method of characteristics and general solutions.

Unit 3: Second Order Partial Differential Equations 15 Lecture Hours

Partial Differential Equations of second order: classification of second order linear equations in two independent variables: hyperbolic, parabolic and elliptic types (with examples), reduction to canonical forms, homogeneous and non-homogeneous linear Partial Differential Equations with constant coefficients,
method of finding complementary function and particular integral, general solution, method of separation of variables for second order PDE, nonlinear equations of second order, Monge's method.

Unit 4: Applications of Partial Differential Equations 10 Lecture Hours

Vibrating string problem, existence and uniqueness of solution of Vibrating string problem, Heat conduction problem, existence and uniqueness of solution of Heat conduction problem, non-homogeneous problems.

Text Books:

1. Sneddon, I. N., Elements of Partial Differential Equations, Dover Publications, 2006.
2. Myint-U, Tyn and Debnath, Lokenath, Linear Partial Differential Equation for Scientists and Engineers, 4th Ed, Springer, 2007.

Reference Books:

3. Stavroulakis, Ioannis P and Tersian, Stepan A., Partial Differential Equations: An Introduction with Mathematica and MAPLE, 2nd Ed, World Scientific, 2004.
4. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18th Ed, S. Chand & Company Pvt. Ltd, 2016.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
	Partial Differential Equations Lab	0	0	0	0
Total Units to be Covered:		**Total Contact Hours:**			
Prerequisite(s):	**Basic Knowledge of Computer Programming**	**Syllabus version: 1.0**			

Course Objectives

1. To provide the students with the practical knowledge of solving first order partial differential equations using MATLAB/Python.
2. To make students gain insight on plotting integral surfaces.
3. To enable students understand the solution of wave equation.

Course Outcomes

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

CO1. Demonstrate the knowledge of Software in obtaining the solutions of partial differential equations their visualizations.

CO2. Develop programs to understand the solution of wave equation.

Course Description

The course on Partial Differential equations is the most important part of mathematics for understanding physical sciences and engineering applications. Hence its lab is necessary for a clear and complete understanding of all the phenomena associated with partial differential equations. This course helps the students to gain hand on experience in obtaining and plotting the solutions of partial differential equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	-	-	3	2	-	3	3	3
CO2	3	3	3	3	-	-	-	3	2	-	3	3	3
Average	3	3	3	3	-	-	-	3	2	-	3	3	3

1. WEAK 2. MODERATE 3. STRONG

List of Practical's (using MATLAB/Python)

Experiment No: 01
Solution of Cauchy problem for first order PDE

Experiment No: 02
Plotting the characteristics of first order PDE

Experiment No: 03
Plotting the integral surfaces of a given first order PDE with initial data.

Experiment No: 04
Solution of wave equation.

Experiment No: 05
Solution of one dimensional heat equation.

Experiment No. 06
Pdepe solver

Text Books:

1. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th Ed, Springer, Indian reprint, 2006.
2. Matthew P. Coleman, An Introduction to Partial Differential Equations with MATLAB, 2nd Ed., CRS Press, 2013.

Reference Books:

3. M. D. Rai Singhania, Ordinary and Partial Differential Equations, 18th Ed, S. Chand & Company Pvt. Ltd, 2016.
4. Amos Gilat, MATLAB: An Introduction with Applications, 4th Ed., John Wiley & Sons, Inc, 2011.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	Lab	
	Continuous Assessment	
	Lab records + Viva	Quiz/Exam
Weight %	(70%)	(30%)

Course Code	Course name		L	T	P	C
MATH3061	Probability & Statistics		3	1	0	4
Total Units to be Covered: 4		Total Contact Hours: 45+15				
Prerequisite(s):	Basic knowledge of Calculus and Combinatorial Probability		Syllabus version: 1.0			

Course Objectives

1. To learn the distributions to study the joint behavior of two random variables.
2. To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty.

Course Outcomes

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

CO1. Define the concept of random variables, distribution, mass/density functions, moments and its properties to evaluate certain probabilities.

CO2. Understand and use the concepts of some specific discrete and continuous type distributions to solve probability theory problems. Understand the concept of distributions to study the joint behavior of two random variables.

CO3. Apply the concept of distributions to study the joint behavior of two random variables and find conditional distribution and expectations.

CO4. Establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

Course Description

To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness. The course intends to render the students to several examples and exercises that blend their everyday experiences with their scientific interests.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	-	-	-	-	-	1	-	3	2	-
CO2	3	2	2	-	-	-	-	-	1	-	2	3	-
CO3	3	2	2	-	-	-	-	-	1	-	2	3	-
CO4	3	2	2	-	-	-	-	-	1	-	2	3	-
Average	3	2	2	-	-	-	-	-	1	-	2.2	2.7	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Introduction to Probability Theory **15 Lecture Hours**

Sample space, Probability set function, Real random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions, Transformations, Mathematical expectation, Moments, Moment generating function, Characteristic function.

Unit 2: Some Special Distributions **10 Lecture Hours**

Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions: Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.

Unit 3: Joint Distribution of Several Random Variables **10 Lecture Hours**

Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions, and expectations.

Unit 4: Correlation and Regression **10 Lecture Hours**

The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares, Bivariate
normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.

Text Books:

1. Hogg, Robert V., McKean, Joseph W., & Craig, Allen T., Introduction to Mathematical Statistics (7th ed.). Pearson Education, Inc., 2013.
2. Rohatgi, V. K., Saleh, A. K. M. E., An Introduction to Probability and Statistics. United States: Wiley, 2015.
3. Miller, Irwin & Miller, Marylees, John E., Freund's Mathematical Statistics with Applications (8th ed.). Pearson. Dorling Kindersley (India), 2014.
4. Ross, Sheldon M., Introduction to Probability Models (11th ed.). Elsevier Inc. AP, 2014.

Reference Books:

1. S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2018.
2. T.K.V. Iyengar, B. Krishna Gandhi, S. Ranganadham, M.V.S.S.N. Prasad, Probability and Statistics, S. Chand, 2019.

Modes of Evaluation:

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH3062	Numerical Analysis		3	0	1	4
Total Units to be Covered: 4		Total Contact Hours: 45+30				
Prerequisite(s):	Fundamentals of Calculus		Syllabus version: 1.0			

Course Objectives

1. To make the students realize the importance of numerical methods and errors inherited within.
2. To enable students understand the mechanism of iterative techniques.
3. To enable students derive appropriate numerical methods to solve a linear system of equations.
4. To make the students able to solve ODEs and PDEs numerically.

Course Outcomes

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

CO1. Understand the concept of error and implement iterative numerical methods to solve algebraic and transcendental equations in one variable.
CO2. Interpolate values of the dependent variable and its derivatives from equally and unequally spaced data.
CO3. Perform numerical integration from the available discrete data.
CO4. Solve the system of linear algebraic equations both by direct and iterative methods.
CO5. Solve numerically the initial and boundary value problems in ODEs and PDEs.

Catalog Description

Numerical analysis deals with the study of algorithms that use numerical approximation for the problems arising in science and engineering. The course is aimed to provide the knowledge of numerical methods along with their error analysis for solving a variety of mathematical models. It deals with the basic definitions, properties of various finite difference operators and their applications to engineering problems associated with polynomial interpolation, differentiation and integration from the given tabular data. It discusses various algorithms associated with the technique of finding zeros of the algebraic and transcendental equations. This course also provides a detailed knowledge of various direct and iterative methods to solve system of linear algebraic equations. Several techniques will be discussed for solving initial value problems of ordinary differential equations. The students will also get insight into the solutions of boundary value problems in both ordinary and partial differential equations.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	3	-	-	-	-	-	2	-	2	3	-
CO2	3	2	3	-	-	-	-	-	2	-	2	3	-
CO3	3	2	3	-	-	-	-	-	2	-	2	3	-
CO4	3	2	3	-	-	-	-	-	2	-	2	3	-
CO5	3	2	3	-	-	-	-	-	2	-	2	3	-
Average	3	2	3	-	-	-	-	-	2	-	2	3	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit I: Error Analysis and Root finding techniques 11 lecture hours

Exact and approximate numbers, rounding off numbers, significant digits, correct digits, various types of errors encountered in computations, propagation of errors, Bisection and Fixed-Point Iteration method with convergence criteria, False position and Secant methods with convergence criteria, Newton-Raphson method with convergence criteria. Order and rate of convergence of root finding methods.

Unit 2: Interpolation and Numerical Differentiation 11 lecture hours

Introduction to finite difference operators and properties, Factorial notation and Missing term techniques, Newton's Forward and Backward Interpolation, Gauss's Forward and Backward Interpolation, Stirling's and Bessel's Interpolation, Interpolation of unevenly spaced data by Lagrange's and Newton's divided difference formula, Numerical Differentiation.

Unit 3: Numerical Integration and System of Linear equations 11 lecture hours

Numerical Integration: Trapezoidal, Simpson's 1/3 and 3/8 rules with error terms, Composite integral methods: Trapezoidal, Simpson's 1/3 and 3/8 rules, Gauss Legendre 2-points and 3-points formulae, LU Decomposition, Doolittle, Crout's and Cholesky's methods, Gauss Jacobi & Gauss Seidel methods with convergence criteria,

Unit 4: Solutions of ODE and PDE 12 lecture hours

Taylor's series method, Euler's method, Modified Euler's method, 2nd and 4th order Runge-Kutta method, Milne Predictor Corrector method. Finite difference approximations, Solution of 2 point BVP, Five point finite difference approximations, Liebmann's Iteration process, Explicit and Implicit methods: Bendre - Schmidt Process, Crank-Nicholson method.

Text Books

1. Jain, M. K., Iyengar, S. R. K., Jain, R. K., Numerical Methods for Scientific and Engineering Computation, New Age International, ISBN 9788122420012.
2. Sastry, S. S., Introductory Methods of Numerical Analysis, PHI Learning, India, ISBN: 9788120345928.

Reference Books

1. Gerald, F. C., Wheatley, P. O., Applied Numerical Analysis, Pearson India, ISBN 9788131717400.
2. Pal, S., Numerical methods: Principles, analyses, and algorithms, Oxford University
3. Press, New Delhi, ISBN: 9780195693751.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
	Numerical Analysis Lab		0	0	0	0
Total Units to be Covered:		**Total Contact Hours:**				
Prerequisite(s):	**Calculus, Differential equations, PDE and Systems of ODE**	**Syllabus version: 1.0**				

Course Objective

1. To provide the students with the basic knowledge of softwares for numerical computations.
2. To make students gain insight on programming techniques using softwares.
3. To enable students use softwares to solve computational problems.

Course Outcomes

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

CO1. Develop programs for the solution of algebraic and transcendental equations of one variable.
CO2. Design programs for the solution of system of linear algebraic equations.
CO3. Develop programs for numerical interpolation, differentiation, and integration.
CO4. Develop Program for solving initial value problems.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	-	2	2	3	-	-	2	2	2	-	-	3	3
CO2	-	2	2	3	-	-	2	2	2	-	-	3	3
CO3	-	2	2	3	-	-	2	2	2	-	-	3	3
CO4	-	2	2	3	-	-	2	2	2	-	-	3	3
Average	-	2	2	3	-	-	2	2	2	-	-	3	3

1. WEAK 2. MODERATE 3. STRONG

List of Experiments

1. Bisection method
2. Newton Raphson method
3. Secant method
4. Regula Falsi method
5. Gaussian Elimination
6. Gauss Jordan methods.
7. Gauss-Jacobi method
8. Gauss-Seidel method
9. Lagrange interpolation
10. Newton interpolation
11. Trapezoidal rule
12. Simpson's rule

13. Euler's method
14. Runge Kutta Method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and log-ical expressions, control statements and loop statements, Arrays should be introduced to the students.

Books Recommended

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008
3. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
4. Bala Guru Swamy, E., Numerical Methods, Tata McGraw Hill, India.
5. Steven C. Chapra, Applied Numerical Methods with MATLAB, 3rd Ed., Mcgraw Higher Ed., 2012.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**Lab**	
	Continuous Assessment	
	Lab records + Viva	**Quiz/Exam**
Weight %	(70%)	(30%)

Course Code	Course name	L	T	P	C
MATH4013	**Discrete Mathematics**	3	1	0	4
Total Units to be Covered: 4	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Mathematics up to Intermediate Level**	**Syllabus version: 1.0**			

Course Objectives

1. To enable students, understand the fundamentals of mathematical logic and its usage.
2. To inculcate the concepts of Number Theory and its applicability in solving emerging problems.
3. To make the students understand and use various advanced counting techniques in real world problems.

Course Outcomes

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

CO1. Apply the concepts of first order mathematical logic in real life applications.
CO2. Categorize and analyze various discrete set structures into posets and lattices.
CO3. Solve the recurrence relations using generating function techniques.
CO4. Solve the congruence equations and system of linear Diophantine equations.

Course Catalog

Mathematics is a necessary subject to a clear and complete understanding of virtually all phenomena. It helps us to develop logical thinking and to find the right way to solve problems. This course covers basic concepts of relations, recurrence relation, mathematical logic, posets, lattices and number theory. This discrete mathematics course would carefully blend and balance mathematical reasoning, combinatorial analysis, discrete structures and applications. This course is designed in such a way that it enables the students to cope confidently with the concepts of discrete mathematics needed in the real-life applications; and the curriculum aims at developing student's ability to conceptualize, reason and use discrete mathematics in order to formulate and solve problems in real life.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	2	-	3	2	-
CO2	3	2	-	-	-	-	-	-	1	-	2	3	-
CO3	3	2	-	-	-	-	-	-	2	-	3	2	-
CO4	3	2	-	-	-	-	-	-	2	-	3	2	-
Average	3	2	-	-	-	-	-	-	1.7	-	2.7	2.3	-

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit I: Mathematical Logic

8 Lecture Hours

Mathematical logic, Proposition, Connectives, Tautologies and Contradictions, Algebra of propositions. Logical equivalences, Principal normal forms and applications. Rules of Inferences, Interpretation of an argument and its validity (with and without truth table), Predicates and Quantifiers, Negation of quantified statements.

Unit 2: Posets and Lattices **14 Lecture Hours**

Relations and Their types, Representing Relations, Composition of relations, Equivalence relation and classes, Closures of Relations, Partial order relations, decomposition theorems for partial orders. Posets, Hasse diagram, maximal and minimal elements, greatest and least elements, least upper bound and lower bounds. Totally ordered set, Well ordered set, Lexicographic order, Lattice, Bounded and distributive lattice, Complemented lattice, Modular lattice.

Unit 3: Basic Counting Principles **13 Lecture Hours**

Pigeonhole principle, Binomial coefficients and identities, discrete numeric function, Convolution product, Recurrence relations and solutions, Solution of linear recurrence relation with constant coefficients, Generating function techniques, Matrix method, principles of inclusion and exclusion and its applications.

Unit 4: Number Theory **10 Lecture Hours**

Modular arithmetic, primes, fundamental theorem of arithmetic, GCD/LCM, Euclidean Algorithm, solving congruences, Linear Diophantine Equation, Chinese remainder theorem, Fermat's Little theorem, Discrete log.

Books Recommended:
1. Kenneth H Rosen: Discrete Mathematics and its Applications, McGraw Hill (2012).
2. R. C. Bose, B. Manvel: Introduction to Combinatorial Theory, Wiley Series in Probability and Mathematical Statistics.
3. Winfield K Grassmann and Jean-Paul Tremblay: Logic and Discrete Mathematics: A Computer Science Perspective, Prentice-Hall (1996).
4. Seymour Lipschutz, Marc Lipson: Theory and Problems on Discrete Mathematics. McGraw-Hill.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4019	**Integral Equations And Calculus Of Variations**	3	1	0	4
Total Units to be Covered: 4		**Total Contact Hours: 45+15**			
Prerequisite(s):	**UG level Mathematics**	**Syllabus version: 1.0**			

Course Objectives

1. To enable the students explain the fundamental concepts of the theory of Integral equations and calculus of variations.
2. To make the students able to understand transformation between integral equations and differential equations.
3. To enable the students solve integral equations of several types.
4. To help the students understand solution of differential equations using calculus of variations method.

Course Outcomes

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

CO1. understand the difference between differential equations and integral equations and conversion of one type to the other.

CO2. solve linear Volterra and Fredholm integral equations using various methods.

CO3. determine the extrema of a functional using calculus of variations technique, establish maximum principles for various equations and comprehend consequences.

CO4. solve some classical problems using principles of calculus of variations.

Course Description

This course aims at introducing basics of integral equations and calculus of variations and their applications. Integral equations are useful in various fields of science and has various applications in elasticity, plasticity, heat and mass transfer, oscillation theory, fluid dynamics, filtration theory, electrostatics, electrodynamics, biomechanics, game theory, control, queuing theory, electrical engineering, economics and medicine. Exact solutions of integral equations play an important role in the proper understanding of qualitative features of many phenomena and processes in various areas of natural science. In this course the students will go through Volterra and Fredholm integral equations. They will also learn to find extrema of a functional using calculus of variations technique.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	3	2	2	1	-	1	3	3	3	2	3
CO2	3	3	3	2	2	1	-	1	3	3	3	2	3
CO3	3	3	3	2	2	1	-	1	3	3	3	2	3
CO4	3	3	3	2	2	1	-	1	3	3	3	2	3
Average	2.75	3	3	2	2	1	-	1	3	3	3	2	3

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Integral Equations and Their Classification 9 Lecture Hours
Integral equations: basic concept and classifications, Method of converting an initial value problem to a Volterra integral equation, method of converting a boundary value problem to a Fredholm integral equation, Conversion of integral equations into differential equations.

Unit 2: Methods for Solving Integral Equations 12 Lecture Hours
Solution of integral equations with separable kernels, Eigenvalues and Eigen functions. Solution by the successive approximations, Neumann series and resolvent kernel. Solution of integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green's function approach.

Unit 3: Solving Integral Equations with Convolution Type Kernels 12 Lecture Hours
Fredholm method of solution and Fredholm theorems. Successive approximations, Neumann series and resolvent kernel. Equations with convolution type kernels, Singular integral equations, Hilbert-transform, Cauchy type integral equations.

Unit 4: Introduction to the Calculus of Variations 12 Lecture Hours
Basic concepts of the calculus of variations: functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler`s equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler`s equations. Variational problem in parametric form. Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries, Broken extremals: Weierstrass – Erdmann conditions. Rayleigh-Ritz variation method.

Text Books:

3. M. D. Raisinghania, Integral equations and boundary value problems, S. Chand Publishing, ISBN: 9352838955
4. A.S. Gupta, Calculus of variations with applications, Prentice Hall India Learning Private Ltd., ISBN: 8120311205.

Reference Books:

4. A. Jerri: Introduction to integral equations with applications, Wiley–Blackwell, ISBN: 0471317349.
5. R. P. Kanwal, Linear integral equations theory and technique, Academic Press, ISBN: 9780817639402.
6. R. Weinstock, Calculus of variations: with applications to physics and engineering, Dover Publications, ISBN: 0486630692.

Modes of Evaluation: Continuous Evaluation
Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

ELECTIVE COURSE: DATA SCIENCE

Course Code	Course name	L	T	P	C
MATH4020P	**Bayesian Data Analysis**	3	1	0	4
Total Units to be Covered: 5		**Total Contact Hours: 45+15**			
Prerequisite(s):	**Probability and Statistics**	**Syllabus version: 1.0**			

Course Objectives

1. To understand the principles of Bayesian inference.
2. To study the necessary concepts required to work with data using Bayesian principles.
3. To apply the Bayesian concepts in regression model.

Course Outcomes

On completion of this course, the students will be able to
CO1. Understand the principles of Bayesian inference.
CO2. Describe the fundamentals of Bayesian data analysis.
CO3. Create Markov-models for Bayesian computations.
CO4. Apply Bayesian concepts in regression models.
CO5. Describe nonlinear and nonparametric models.

Course Description

This course focuses on the theory of Bayesian learning, models for Bayesian analysis, and algorithms for Bayesian inference. The theory, models, and algorithms covered will be of general interest and therefore applicable to a wide range of domains beyond machine learning and computational statistics. This course should be of interest to researchers in a variety of fields where there is a need to analyze data, including natural language processing, information retrieval, data mining, bioinformatics, computer vision, computational finance, health informatics, and robotics.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	1	3	2	1
CO2	3	2	-	-	-	-	-	2	2	1	2	3	1
CO3	3	2	-	-	-	-	-	2	2	1	2	3	1
CO4	3	2	-	-	-	-	-	2	2	1	3	2	1
CO5	3	2	-	-	-	-	-	2	2	1	2	3	1
Average	3	2	-	-	-	-	-	2	2	1	2.4	2.6	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Fundamentals of Bayesian Inference **10 Lecture Hours**

Probability and inference: Bayesian inference, Bayesian inference in applied statistics, Single-parameter models: Estimating a probability from binomial data, Summarizing posterior inference, standard single-parameter models, multi-parameter models:

Normal data with a non-informative and conjugate prior distribution, Multivariate normal models, Hierarchical models: parameterized prior distribution, conjugate hierarchical models, Hierarchical modeling for meta-analysis.

Unit 2: Fundamentals of Bayesian Data Analysis 10 Lecture Hours

Model checking: requirement, Posterior and graphical predictive checking, Evaluating, comparing, and expanding models: Measures of predictive accuracy, Information criteria and cross-validation, Model comparison based on predictive performance, Model comparison using Bayes factors, Modeling accounting for data collection: Data-collection models, Sample surveys, Designed experiments , Observational studies; Decision analysis: Bayesian decision theory, regression predictions, Multistage decision making, Hierarchical decision analysis.

Unit 3: Advanced Computations 10 Lecture Hours

Introduction to Bayesian computation: Numerical integration, Distributional approximations, sampling, Computing environments, Debugging Bayesian computing, Basics of Markov chain simulation: Gibbs sampler, Metropolis and Metropolis-Hastings algorithms, Inference and assessing convergence, computationally efficient Markov chain simulation: Efficient Gibbs samplers, Efficient Metropolis jumping rules.

Unit 4: Regression Models 10 Lecture Hours

Introduction to regression models: Conditional modeling, Bayesian analysis of the classical regression model, Assembling the matrix of explanatory variables, Including numerical prior information, Hierarchical linear models: Regression coefficients exchangeable in batches, Interpreting a normal prior distribution as additional data, Varying intercepts and slopes, Generalized linear models: Standard generalized linear models, Models for multivariate and multinomial responses, Models for missing data.

Unit 5: Nonlinear and Nonparametric Models 5 Lecture Hours

Parametric nonlinear models, Basis function models, Gaussian process models, Finite mixture models, Dirichlet process model.

Text Books:

1. Gelman, Carlin, Stern and Rubin (2004), Bayesian Data Analysis, 2nd edition
2. Lunn, David, et al. "The BUGS book." A Practical Introduction to Bayesian Analysis, Chapman Hall, London (2013).

Reference Books:

1. Rasmussen and Williams (2006), Gaussian Processes.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
ATH4014P	**Time Series And Forecasting Methods**	3	1	0	4
Total Units to be Covered: 4	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Basic Knowledge of Mathematics and Probability**	**Syllabus version: 1.0**			

Course Objectives

To develop a fundamental understanding of time series data and its properties, including trend, seasonality, and stationarity.

1. To introduce students to a range of statistical models suitable for analyzing time series data, such as ARIMA, and exponential smoothing models.
2. To enable students to critically analyze and interpret results from time series analysis and forecasting models.
3. To prepare students to apply time series analysis and forecasting methods to real-world problems and make informed decisions based on the results obtained.

Course Outcomes

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

CO1. Compute and interpret a correlogram and a sample spectrum.
CO2. Understand the properties of ARIMA and state-space models.
CO3. Apply an appropriate ARIMA model for a given set of data and fit the model using an appropriate package.
CO4. Analyze forecasts for a variety of linear methods and models.

Course Description

This course is designed to provide students with a comprehensive understanding of time series analysis and forecasting methods. Time series data are ubiquitous in many fields, such as finance, economics, engineering, and natural sciences. The ability to analyse and forecast such data is crucial for making informed decisions in a wide range of applications. In this course, we will cover the fundamental concepts of time series analysis, including trend, seasonality, and stationarity. We will also introduce a variety of statistical models suitable for analysing time series data, such as ARMA, ARIMA, and exponential smoothing models.

Furthermore, this course will equip students with the necessary skills to evaluate and compare different forecasting methods. We will also discuss the practical applications of time series analysis and forecasting, including inventory management, financial forecasting, and demand forecasting.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	3	-	-	-	-	-	-	1	3	2	1
CO2	3	2	3	-	-	-	-	-	-	1	2	3	1
CO3	3	2	3	-	-	-	-	2	2	1	2	3	1
CO4	3	2	3	-	-	-	-	-	-	1	3	2	1
Average	3	2	3	-	-	-	-	2	2	1	2.5	2.5	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Stochastic Process and Time series **15 Lecture Hours**

Stochastic process. Time series (as a discrete stochastic process. Stationarity). Stationary stochastic processes. Stationarity as the main characteristic of stochastic component of time series. Wold decomposition. Lag operator.

Unit 2: Probability Models for Time Series **15 Lecture Hours**

Stationarity. Moving average (MA), Autoregressive (AR), Condition of invertibility ARMA and ARIMA models. Estimating the autocorrelation function and fitting ARIMA models. Box-Jenkins' approach.

Unit 3: Forecasting **15 Lecture Hours**

Introduction to forecasting, Exponential smoothing, Forecasting from ARIMA models. Stationary processes in the frequency domain: The spectral density function, the periodogram, spectral analysis. State-space models: Dynamic linear models and the Kalman filter.

Unit 4: Non-stationary Time Series **15 Lecture Hours**

Non-stationary time series, TSP or DSP: methodology of research. Segmented trends and structure changes. Regressive dynamic models. Autoregressive models with distributed lags (ADL). Causality in time series, Granger causality, Hypothesis testing on rational expectations.

Text Books:

1. William W.S., Time Series Analysis: Univariate and Multivariate Methods. Pearson, 2005.
2. Shumway R. H. and Stoffer D. S., Time Series Analysis and Its Applications: With R Examples. Springer, 2006.
3. Chatfield C., The Analysis of Time Series: An Introduction. Chapman & Hall / CRC, 2003.

Reference Books:

1. Brockwell P. J. and Davis R. A., Time Series: Theory and Methods. Springer, 1991.
2. Hamilton J., Time Series Analysis. Princeton University Press, 1994.
3. Harvey A. C., Time Series Models. Harvester wheatsheaf, 1993.

Modes of Evaluation: Continuous Evaluation
Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4015P	**Multivariate Statistics**	3	1	0	4
Total Units to be Covered: 3		**Total Contact Hours: 45+15**			
Prerequisite(s):	**Basic knowledge of probability and statistics**	**Syllabus version: 1.0**			

Course Objectives

1. To provide the students the basic knowledge required for analyzing multivariate data.
2. To enable the students to draw some basic inference based on multivariate data.
3. To provide students with the knowledge of some tools to reduce the number of components / variables in a dataset.
4. To provide students the tools of classification and clustering for datasets with several variables.

Course Outcomes

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

CO1. Classify multivariate data, understand its properties, understand its multivariate distributions, and draw some basic inference out of it.

CO2. Use the properties of sample mean vector and correlation in multivariate data. Use data reduction techniques such as Principal component analysis and Factor analysis.

CO3. Apply classification, clustering, scaling, and component analysis techniques in multivariate data.

Course Description

The course covers canonical methods for learning from multivariate data. It provides the knowledge of basic multivariate data analysis and inferential tools. A selection of more modern methods and topics are also included in the course, for example, component and factor analysis, classification and clustering.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	1	3	2	1
CO2	3	2	-	-	-	-	-	2	2	1	2	3	1
CO3	3	2	-	-	-	-	-	2	2	1	2	3	1
Average	3	2	-	-	-	-	-	2	2	1	2.3	2.6	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Introduction and Basic Inference **15 Lecture Hours**

Random Vectors and their distributions, Moments and Characteristic Functions, Orthogonal and Polar transformations, Generalization of univariate distribution, sampling theory, Linear combination of random vectors, Characterization and properties Linear forms, Multivariate normal distribution theory, Inference about mean vectors, Inference on a single vector, Inference on several mean vectors, Maximum likelihood estimation and Likelihood ratio test.

Unit 2: Component and Factor Analysis **15 Lecture Hours**

Multivariate response linear regression, Analysis of covariance structure. Multivariate Analysis of Variance, Principal components, Sampling properties of principal components, Principal component projections, Factor analysis/factor models, Maximum likelihood factor analysis, Goodness of fit, Rotation of factors, Factor scores, Canonical correlations, Population and sample canonical correlation vectors, Variables and coefficients and their properties.

Unit 3: Classification and Clustering **15 Lecture Hours**

Introduction to classification and clustering, Fisher's LDA -QDA, Probabilities of misclassification, Discrimination and classification Clustering, Distances, and similarities, Hierarchical methods, K-means method, multi-dimensional scaling, Special topics (time permitting) Independent component analysis, Gaussian graphical models.

Text Books:

1. Anderson, T. W., An Introduction to Multivariate Statistical Analysis. United Kingdom: Wiley, 2003.
2. Johnson Richard A. and Wichern, Dean W., Applied Multivariate Statistical Analysis, 6th edition, Pearson/Prentice Hall, 2007.

Reference Books:

1. Everitt, B. and Hothorn, T., An Introduction to Applied Multivariate Analysis with R. Springer, 2011.
2. Zelterman, D., Applied Multivariate Statistics with R. Springer, 2015.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name		L	T	P	C
MATH4024P	Text Analytics		3	1	0	4
Total Units to be Covered: 5		Total Contact Hours: 45+15				
Prerequisite(s):	Python, Calculus, Probability, Linear Algebra and Optimization		Syllabus version: 1.0			

Course Objectives

1. To enable the students to understand the concepts of natural language processing in text mining.
2. To make the students to express the concepts of document representation, text clustering and document summarization.
3. To help the students to apply the text mining techniques in social media text data.

Course Outcomes

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

CO1. Understand the fundamentals of natural language processing.
CO2. Inferring the concepts of text clustering and document summarization.
CO3. Applying the parsing techniques in text mining.
CO4. Linking topic modelling and document summarization.
CO5. Applying text-mining techniques in social media text data.

Course Description

Text information is retrieved in abundance from the Internet. Retrieving useful information from text becomes increasingly challenging. The knowledge extracted from texts drives the modern world. Social behavior analysis and decision-making are two of the key areas in which text mining is applied. This course presents text mining, including natural language processing concepts, document representation, text categorization and clustering, document summarization, sentiment analysis, social network and social media analysis, probabilistic topic models, and text visualization.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	1	3	2	1
CO2	3	2	-	-	-	-	-	2	2	1	2	3	1
CO3	3	2	-	-	-	-	-	2	2	1	2	3	1
CO4	3	2	-	-	-	-	-	2	2	1	2	3	1
CO5	3	2	-	-	-	-	-	2	2	1	2	3	1
Average	3	2	-	-	-	-	-	2	2	1	2.2	2.8	1

1. WEAK   2. MODERATE   3. STRONG

Course Content

Unit 1: Natural Language Processing **10 Lecture Hours**

Basic techniques in natural language processing, tokenization, part-of-speech tagging, chunking, syntax parsing and named entity recognition. Public NLP toolkits. Document representation: Unstructured text documents with appropriate format and structure to support automated text mining algorithms.

Unit 2: Text categorization and Clustering **8 Lecture Hours**

Supervised text categorization algorithms, Naive Bayes, k Nearest Neighbor (kNN) and Logistic Regression, Support Vector Machines and Decision Trees, Clustering: connectivity-based clustering and centroid-based clustering.

Unit 3: Parsing **10 Lecture Hours**

Shallow Parsing: Part of Speech (POS) Tagging; HMM based POS tagging; Maximum Entropy Models and POS; Random Fields and POS; DNN for POS. Parsing: Constituency and Dependency Parsing; Theories of Parsing; Scope Ambiguity and Attachment Ambiguity Resolution; Rule Based Parsing Algorithms; Probabilistic Parsing; Neural Parsing.

Unit 4: Topic modeling and document summarization **9 Lecture Hours**

Probabilistic Latent Semantic Indexing (pLSI) and Latent Dirichlet Allocation (LDA), and their variants for classification, imagine annotation, collaborative filtering, and hierarchical topical structure modeling. Extraction based summarization methods.

Unit 5: Applications and visualization **8 Lecture Hours**

Social network: inter-connectivity, PageRank algorithm: social influence analysis and social media analysis. Sentiment analysis: sentiment polarity prediction, review mining, and aspect identification; Visual representations of abstract data to reinforce human cognition. Mathematical and programming tools to visualize a large collection of text documents.

List of Practical:

Experiment No: 01
Text cleaning manually.

Experiment No: 02
Preparing text-data with libraries.

Experiment No: 03
Implementation of Bag-of-Words Model.

Experiment No: 04
Sentiment data analysis.

Experiment No: 05
Implementing word embedding models.

Experiment No: 06
Implementation for text classification.

Experiment No: 07
Image captioning.

Text Books:
1. Mining Text Data. Charu C. Aggarwal and ChengXiang Zhai, Springer, 2012.
2. Speech & Language Processing. Dan Jurafsky and James H Martin, Pearson EducationIndia, 2000.

Reference Books:
1. Introduction to Information Retrieval. Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schuetze, Cambridge University Press, 2007.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4017P	**Financial Data Analysis**	3	1	0	4
Total Units to be Covered: 3	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Time Series Analysis**	**Syllabus version: 1.0**			

Course Objectives

1. To understand the principles of corporate finance.
2. To study the Capital Management.
3. To apply finance data analysis to capital budgeting.

Course Outcomes

On completion of this course, the students will be able to
CO1. Understand the financial data and their properties.
.CO2. Describe asset volatility and volatility models.
CO3. Analyze high frequency financial data.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	2	2	1	3	2	1
CO2	3	2	-	-	-	-	-	2	2	1	2	3	1
CO3	3	2	-	-	-	-	-	2	2	1	2	3	1
Average	3	2	-	-	-	-	-	2	2	1	2.3	2.7	1

1. WEAK 2. MODERATE 3. STRONG

Course Description

The goal of this course is to provide comprehensive information on financial analysis in the areas of planning and control suited to anyone at any level desiring this information for either professional or personal use.

Course Content

Unit 1: Financial Data and Their Properties **15 Lecture Hours**

Asset Returns, Bond Yields and Prices, Implied Volatility, R Packages and Demonstrations, Installation of R Packages, The Quantmod Package, Some Basic R Commands, Examples of Financial Data, Distributional Properties of Returns, Review of Statistical Distributions and Their Moments, Visualization of Financial Data, Some Statistical Distributions, Normal Distribution, Lognormal Distribution, Stable Distribution, Scale Mixture of Normal Distributions, Multivariate Returns, Linear Models For Financial Time Series: Correlation and Autocorrelation Function, White Noise and Linear Time Series, Simple Autoregressive Models, Simple Moving Average Models, Simple ARMA Models, Unit-Root Nonstationarity, Seasonal Models.

Unit 2: Case Studies of Linear Time Series and Asset Volatility and Volatility Models **15 Lecture Hours**

Weekly Regular Gasoline Price, Global Temperature Anomalies, US Monthly Unemployment Rates, Characteristics of Volatility Structure of A Model, Model Building, Testing For ARCH Effect, The ARCH Model, The GARCH Model, The Integrated GARCH Model, The Exponential Garch Model, The Threshold Garch Model, Asymmetric Power ARCH Models, Nonsymmetric GARCH Model, The stochastic volatility model, long-memory stochastic volatility models, alternative approaches and applications of volatility models.

Unit 3: High Frequency Financial Data and Value at Risk 15 Lecture Hours

Nonsynchronous Trading, Bid–Ask Spread of Trading Prices, Empirical Characteristics of Trading Data, Models for Price Changes, Duration Models, Realized Volatility, Risk Measure and Coherence, Remarks on Calculating Risk Measures, Riskmetrics, An Econometric Approach, Quantile

Estimation, Extreme Value Theory, An Extreme Value Approach to Var, Peaks Over Thresholds, The Stationary Loss Processes

Text Books:

1. Analysis of Financial Time Series, 3rd Edition, by Ruey S. Tsay.

Reference Books:

1. An Introduction to Analysis of Financial Data with R, 1st Edition, by Ruey S. Tsay.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

ELECTIVE COURSE: COMPUTATIONAL MATHEMATICS

Course Code	Course name		L	T	P	C
MATH3042P	Optimization Techniques		3	1	0	4
Total Units to be Covered: 5		Total Contact Hours: 45+15				
Prerequisite(s):	Basic Knowledge of linear and nonlinear programming	Syllabus version: 1.0				

Course Objectives

1. To make students realize the importance linear and nonlinear optimization for effective decision-making.
2. To enable students to understand the solution concept of different optimization models.
3. To enable students to understand the mechanism of different optimization techniques.
4. To enable students able to use the mathematical result and solution techniques of optimization theory in real-life engineering problems.

Course Outcomes

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

CO1. Define an integer linear optimization model from real life situation, and understand the feasible and optimal solution for the same.
CO2. Solve dynamic programming problems.

CO3. Explain the techniques for PERT analysis and scheduling problems.
CO4. Apply various queuing models in different scenario.
CO5. Solve nonlinear unconstrained and constrained optimization problems by direct and gradient-based search methods respectively.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	-	3	2	-	-	-	-	-	-	1	3	-
CO2	2	-	3	2	-	-	-	-	-	1	1	3	1
CO3	2	-	3	2	-	-	-	-	-	1	1	2	1
CO4	2	-	3	2	-	-	-	-	-	1	1	2	1
CO5	2	-	3	2	-	-	-	-	-	1	1	2	1
Average	2	-	3	2	-	-	-	-	-	1	1	2.5	1

1. WEAK 2. MODERATE 3. STRONG

Course Description

This course enables students to understand the advanced optimization techniques and their applications. It also help in solving various constrained and unconstrained linear and nonlinear problems in single variable as well as multivariable and apply the methods of optimization in real-life situation.

Course Content

Unit 1: Integer Linear Programming **10 Lecture Hours**

Review of LPP, Introduction and cutting plane method, Gomory's cutting plane method for all integer LPP and mixed integer LPP, Branch and bound techniques, Travelling salesman problem, Cargo loading or Knapsack problem, Balas algorithm for linear zero-one problem.

Unit 2: Dynamic Programming **10 Lecture Hours**

Introduction to a simple Dynamic programming problem, Bellmen's optimality principle, Multiplicative and More General recursive relationships, Continuous state problems, The direction of computations, Tabular form, Multi-state variable problems and the limitations of dynamic programming.

Unit 3: Network Analysis and Sequencing **10 Lecture Hours**

Network definition and network diagram, Probability in PERT analysis, Project time cost trade off, Introduction to resource smoothing and allocation, Introduction to Sequencing, Processing N jobs through two machines, Processing N jobs through three machines, Processing N jobs through m machines.

Unit 4: Inventory Model and Queuing Models **10 Lecture Hours**

Introduction to inventory control, Deterministic inventory model, EOQ model with quantity discount, Concepts relating to queuing systems, Basic elements of queuing model, Role of Poison & exponential distribution, Concepts of birth and death process.

Unit 5: Search Techniques **5 Lecture Hours**

Direct and gradient based search techniques for single and multivariable unconstrained optimization problems.

Text Books:

1. J. C. Pant, Introduction to Optimization, Jain Brothers, 2008.
2. L.R. Foulds, Optimization Techniques An Introduction, Springer.

Reference Books:

1. S.S. Rao, Optimization Theory and Applications, Wiley Eastern, 2004.
2. K.V. Mittal, Optimization Methods, Wiley Eastern, 2003.
3. H.A. Taha, Operations Research, Pearson, 2007.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4014P	**Time Series And Forecasting Methods**	3	1	0	4
Total Units to be Covered: 4		**Total Contact Hours: 45+15**			
Prerequisite(s):	**UG level Physics**	**Syllabus version: 1.0**			

Course Objectives

To develop a fundamental understanding of time series data and its properties, including trend, seasonality, and stationarity.

1. To introduce students to a range of statistical models suitable for analyzing time series data, such as ARIMA, and exponential smoothing models.
2. To enable students to critically analyze and interpret results from time series analysis and forecasting models.
3. To prepare students to apply time series analysis and forecasting methods to real-world problems and make informed decisions based on the results obtained.

Course Outcomes

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

CO1. Compute and interpret a correlogram and a sample spectrum.
CO2. Understand the properties of ARIMA and state-space models.
CO3. Apply an appropriate ARIMA model for a given set of data and fit the model using an appropriate package.
CO4. Analyze forecasts for a variety of linear methods and models.

Course Description

This course is designed to provide students with a comprehensive understanding of time series analysis and forecasting methods. Time series data are ubiquitous in many fields, such as finance, economics, engineering, and natural sciences. The ability to analyse and forecast such data is crucial for making informed decisions in a wide range of applications.

In this course, we will cover the fundamental concepts of time series analysis, including trend, seasonality, and stationarity. We will also introduce a variety of statistical models suitable for analysing time series data, such as ARMA, ARIMA, and exponential smoothing models.

Furthermore, this course will equip students with the necessary skills to evaluate and compare different forecasting methods. We will also discuss the practical applications of time series analysis and forecasting, including inventory management, financial forecasting, and demand forecasting.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	3	-	-	-	-	-	-	1	3	2	1
CO2	3	2	3	-	-	-	-	-	-	1	2	3	1
CO3	3	2	3	-	-	-	-	2	2	1	2	3	1
CO4	3	2	3	-	-	-	-	-	-	1	3	2	1
Average	3	2	3	-	-	-	-	2	2	1	2.5	2.5	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit 1: Stochastic Process and Time series **15 Lecture Hours**

Stochastic process. Time series (as a discrete stochastic process. Stationarity). Stationary stochastic processes. Stationarity as the main characteristic of stochastic component of time series. Wold decomposition. Lag operator.

Unit 2: Probability Models for Time Series **15 Lecture Hours**

Stationarity. Moving average (MA), Autoregressive (AR), Condition of invertibility ARMA and ARIMA models. Estimating the autocorrelation function and fitting ARIMA models. Box-Jenkins' approach.

Unit 3: Forecasting **15 Lecture Hours**

Introduction to forecasting, Exponential smoothing, Forecasting from ARIMA models. Stationary processes in the frequency domain: The spectral density function, the periodogram, spectral analysis. State-space models: Dynamic linear models and the Kalman filter.

Unit 4: Non-stationary Time Series **15 Lecture Hours**

Non-stationary time series, TSP or DSP: methodology of research. Segmented trends and structure changes. Regressive dynamic models. Autoregressive models with distributed lags (ADL). Causality in time series, Granger causality, Hypothesis testing on rational expectations.

Text Books:

4. William W.S., Time Series Analysis : Univariate and Multivariate Methods. Pearson, 2005.
5. Shumway R. H. and Stoffer D. S., Time Series Analysis and Its Applications: With R Examples. Springer, 2006.
6. Chatfield C., The Analysis of Time Series: An Introduction. Chapman & Hall / CRC, 2003.

Reference Books:

4. Brockwell P. J. and Davis R. A., Time Series: Theory and Methods. Springer, 1991.
5. Hamilton J., Time Series Analysis. Princeton University Press, 1994.
6. Harvey A. C., Time Series Models. Harvester wheatsheaf, 1993.

Modes of Evaluation: Continuous Evaluation
Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
ATH4021P	**Boolean Algebra & Automata Theory**	3	1	0	4
Total Units to be Covered: 6		**Total Contact Hours: 45+15**			
Prerequisite(s):	**UG level Physics**	**Syllabus version: 1.0**			

Course Objectives

1. To enable the students, understand the basic definitions and concepts of Boolean algebra and automata theory.
2. To make the students familiar with the concepts of Boolean polynomials, Karnaugh diagrams, and applications of switching circuits.
3. To provide the students with detailed knowledge of the finite state automata, regular languages, context free grammars and pushdown automata.
4. To enable the students, understand Turing machine and undecidability problems.

Course Outcomes

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

CO1. Discuss definitions and concepts of Boolean algebra and automata theory.

CO2. Describe lattices, Boolean algebra, Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams and switching circuits.

CO3. Demonstrate deterministic and non-deterministic finite automata, regular expressions and regular languages, their properties and pumping lemma.

CO4. Explain the concepts of context free grammars and pushdown automata.

CO5. Demonstrate Turing machine and its variants, recursively enumerable and recursive languages, halting and undecidability problems.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	-	-	-	-	-	-	2	1	3	3	1
CO2	3	2	-	-	-	-	-	-	2	1	3	2	1
CO3	3	2	-	-	-	-	-	-	3	1	3	3	1
CO4	3	3	-	-	-	-	-	-	3	1	3	3	1
CO5									3	1	3	3	1
Average	3	2.3	-	-	-	-	-	-	2.6	1	3	2.8	1

1. WEAK 2. MODERATE 3. STRONG

Course Description

This course is designed to give an idea of Boolean algebra and theory of automata. It discusses the concepts of lattices, Boolean algebra and Boolean polynomials, Karnaugh maps and switching circuits. It gives a solid foundation to theoretical computer science topics such as deterministic and non- deterministic finite state machines, theory of formal languages, context free grammars, pushdown automata. It also discusses Turing machines, halting and undecidability problems and related problems.

Course Content

Unit 1: Lattice Theory **8 Lecture Hours**

Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms. Definition, examples and properties of modular and distributive lattices.

Unit 2: Boolean Algebra **8 Lecture Hours**

Boolean algebras, Boolean polynomials, minimal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, switching circuits and applications of switching circuits.

Unit 3: Finite State Automata **8 Lecture Hours**

Alphabets, strings, and languages. Finite Automata and Regular Languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

Unit 4: Theory of Formal Languages **8 Lecture Hours**

Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context free languages; normal forms, pumping lemma, closure properties, decision properties.

Unit 5: Turing Machine **8 Lecture Hours**

Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.

Unit 6: Recursive and Enumerable Languages **5 Lecture Hours**

Recursively enumerable and recursive languages, undecidable problems about Turing machines:halting problem, Post Correspondence Problem, and undecidability problems about CFGs.

Text Books:

1. B A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990, ISBN:9780521784511.

2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore) P.Ltd., Indian Reprint 2003, ISBN: 9780131679955.

2. J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, 2nd Ed., Addison-Wesley, 2001, ISBN:9788131720479.

Reference Books:

1. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997, ISBN: 9789332549890.

2. J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006, ISBN: 9780511607202.
3. Rudolf Lidl and Günter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts In Mathematics, Springer (SIE), Indian reprint, 2004, ISBN:9781475729412.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	**THEORY**		
	IA	**Mid-Sem**	**End-Sem**
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4025P	Riemann Integration And Series Of Functions	3	1	0	4
Total Units to be Covered: 4	Total Contact Hours:45+15				
Prerequisite(s):	Mathematics up to 12th level, Real Analysis	Syllabus version: 1.0			

Course Objectives

1. To enable the students to develop an insight into the theory of Riemann integration.
2. To make the students to understand fundamental theorem of calculus and convergence of improper integrals.
3. To impart the knowledge of sequence of functions, power series and their convergence.
4. To make the students to prove certain fundamental results.

Course Outcomes

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

CO1. Illustrate the basic concepts of Riemann Stieltjes integration.
CO2. Examine the convergence of sequence of functions and certain improper integrals.
CO3. Discuss properties and radius of convergence of power series.
CO4. Construct rigorous mathematical proofs of certain theorems.

Relationship between the Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs):

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	-	-	-	-	-	-	2	2	1	3	1	1
CO2	3	2	-	-	-	-	-	2	2	1	3	2	1
CO3	3	2	-	-	-	-	-	2	2	1	3	2	1
CO4	3	-	-	-	-	-	-	2	2	1	3	-	1
Average	3	2	-	-	-	-	-	2	2	1	3	1.2	1

1. WEAK 2. MODERATE 3. STRONG

Course Content

Unit I: Riemann integration **10 Lecture Hours**

Riemann integration; inequalities of upper and lower sums; Riemann conditions of integrability. Riemann integrability of monotone and continuous functions, Intermediate Value theorem for Integrals. Fundamental theorems of Calculus.

Unit 2: Riemann Stieltjes integration **12 Lecture Hours**

The Riemann Stieltjes integral: Introduction, Partition of a set, Lower and upper Rieman–Stieltjes sums, The lower and upper Riemann–Stieltjes integrals, The Riemann–Stieltjes integrals, The Riemann–Stieltjes integral as a limit of sum, Algebra of R-S integrable functions, Reduction of Riemann–Stielijes integral into Riemann integral.

Unit 3: Improper integrals 8 Lecture Hours

Improper integrals: Proper and Improper integrals, Convergence of improper integrals, Absolute and conditionally convergence of improper integrals, Convergence of Beta and Gamma functions.

Unit 4: Convergence of Sequences and series of functions 15 lecture hours

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, deriv-ability and integrability of the limit function of a sequence of functions. Series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test. Metric spaces: definition and examples. Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, Cantor's theorem. Limit superior and Limit inferior. Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation, and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem. Differentiation under the Integral sign: Leibnitz's rule for differentiation under the integral sign.

Books Recommended

1. K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
2. R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
3. Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Course Code	Course name	L	T	P	C
MATH4018P	**Finite Element Methods**	3	1	0	4
Total Units to be Covered: 3	**Total Contact Hours: 45+15**				
Prerequisite(s):	**Basic Knowledge of Ordinary and Partial Differential Equations**	**Syllabus version: 1.0**			

Course Objectives

1. To help the students distinguish between FDM and FEM methods for the solution of differential equations.
2. To enable the students calculate various types of FEA elements.
3. To make the students solve ordinary and partial differential equations using associated FEM methods.
4. To make the students explain concepts of discretization with curved boundaries and modeling considerations.

Course Outcomes

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

CO1. Discuss the concepts of variational and weighted residual methods in FEM and their comparison with FDM.

CO2. Apply weighted residual methods for the solution of ordinary differential equations.

CO3. Identify the application and characteristics of FEA elements.

CO4. Explain discretization with curved boundaries, interpolation functions, numerical integration and modeling considerations.

CO5. Solve two dimensional partial differential equations under different geometric conditions using FEM.

Relationship between the Course Outcomes (COs) and Program Outcomes (POs)

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	3	2	-
CO2	3	2	-	-	-	-	-	-	-	-	2	3	-
CO3	3	2	-	-	-	-	-	-	-	-	2	3	-
CO4	3	2	-	-	-	-	-	-	-	-	3	2	-
CO5	3	2	-	-	-	-	-	-	-	-	2	3	-
Average	3	2	-	-	-	-	-	-		-	2.4	2.6	-

1. WEAK 2. MODERATE 3. STRONG

Course Description

Applied mathematics is emerging in almost all the engineering problems. This course gives the detailed study of finite element methods to solve the differential equations. The course begins with the fundamental concepts in finite element methods and covers methods to solve complex ODE's and PDE's in subtle way. This course is designed in such a way that it enables the students to solve the dynamical engineering problems involving complex differential equations.

Course Content

Unit 1: Solution to Boundary Value Problems **15 Lecture Hours**

Introduction to finite element methods, comparison with finite difference methods, Methods of weighted residuals, collocations, least squares and Galerkin's method. Variational formulation of boundary value problems equivalence of Galerkin and Ritz methods. Applications to solving simple problems of ODE.

Unit 2: Solution of Assembled Systems **15 Lecture Hours**

Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system. Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly, discretization with curved boundaries.

Unit 3: Solution of Partial Differential Equations **15 Lecture Hours**

Interpolation functions, numerical integration, double integration, error analysis, modeling considerations. Solution of two dimensional partial differential equations under different geometric conditions: Heat equation, wave equation and Laplace equation.

Text Books

1. J.N. Reddy, Introduction to the Finite Element Methods, Tata McGraw-Hill, 2003.
2. K.J. Bathe, Finite Element Procedures, Prentice-Hall, 2001.
3. R.D. Cook, D.S. Malkus and M.E. Plesha, Concepts and Applications of Finite Element Analysis, John Wiley and Sons, 2002.

Reference books:

1. Thomas J.R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publication, 2000.
2. George R. Buchanan, Finite Element Analysis, McGraw Hill, 1994.

Modes of Evaluation: Continuous Evaluation

Examination Scheme:

Components	THEORY		
	IA	Mid-Sem	End-Sem
Weight (%)	(50%)	(20%)	(30%)

Version Control

Details		Name	Date
Created by	Cluster Head/ Programme head		
Checked by	IQAC		
Approved by	Dean		

CCC/ DCC meeting date	
Board of Studies Approval Date	
AC subcommittee approval date	
Academic Council approval Date	

Version: Approval Date: