ST. JOSEPH’S COLLEGE (AUTONOMOUS), DEVAGIRI, CALICUT

DEGREE OF BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS

(UNDER SJCBCSSUG 2019 SYSTEM)

Syllabus of Newly Proposed (B.Sc.) Honours Mathematics

Programme to be Commenced in 2022-23

1. Title of the Programme

This Degree shall be called **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS**

2. Eligibility for admission

Admission to **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** Degree Programme shall be open only to candidates who have passed the Plus Two in science with Mathematics as one of the subjects of the Higher Secondary Board of Kerala or Pre-Degree of any University in Kerala or that of any other University or Board of Examinations in any state recognized as equivalent to the Plus Two of the Higher Secondary Board in Kerala, provided they have secured marks in aggregate as follows: General Category- 70%, OBC- 65%, SC- 60%, and ST- 55% is eligible for Admission.

An admission test comprising of questions from Higher Secondary Level Mathematics, Logical Reasoning and Quantitative Aptitude shall be conducted. The entrance test containing only multiple choice questions shall be for a period of two hours with a maximum of hundred marks. The final rank list shall be prepared by giving equal weightage to scores in the entrance test and the scores in the plus two examinations.

3. Duration of the Programme

The duration of the **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** programme of study is three academic years with six semesters.

4. Medium of Instruction

The medium of instruction and examination shall be English.

5. Courses of Study

Total courses for the **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** Programme are divided into:

(i) Common Course
(ii) Core Courses and Project
(iii) Elective Courses
(iv) Ability Enhancement Courses

6. Attendance

A candidate shall attend at least a minimum of 75% of the number of classes actually held for each of the courses in each semester to be eligible for appearing for the examination in that course. If the candidate has shortage of attendance in any course in a semester he/she shall not be allowed to appear for any examination in that semester. However the College may condone shortage if the candidate applies for it as laid down in College procedures.

7. Internal Assessment

20% weight shall be given to the internal assessment. The remaining 80% weight shall be for the external evaluation. The internal assessment shall be based on a predetermined transparent system involving written test/assignments/seminars/viva and attendance in respect of theory courses. Internal assessment of the project will be based on its content, method of presentation, final conclusion and orientation to research aptitude. Components with percentage of marks of Internal Evaluation of Theory Courses are Attendance 25%, Assignment/ Seminar/ Viva 25% and Test paper 50%.

The split up of marks for test paper and attendance for internal evaluation are as follows:

Split up of marks for Test Paper

Range of Marks	
Less than 20	2
20 to <30	3
30 to < 40	4
40 to <50	5
50 to <60	6
60 to <70	7
70 to <75	8
75 to <85	9
85 to 100	10

Split up of marks for Attendance

Range of Attendance (%)	Marks
75 to 75.99	1
76 to 79.99	2
80 to 84.99	3
85 to 89.99	4
90 to 100	5

To ensure transparency of the evaluation process, the internal assessment marks awarded to the students in each course in a semester shall be notified on the notice board at least one week before the commencement of external examination. There shall not be any chance for improvement for internal marks. The course teacher(s) shall maintain the academic record of each student registered for the course.

8. External Examination

The College shall conduct semester examinations for each of the courses. The duration of the examination shall be three hours for each course. Provisions of the common regulation for the conduct of the examination will be applicable in this case.

9. Practical Examination

Practical examinations shall be conducted by the College as prescribed by the Board of studies. External viva-voce, if any, shall be conducted along with the practical examination/ project evaluation. The model of question papers may be prepared by the concerned Board of Studies. Each question should aim at- (1) assessment of the knowledge acquired (2) standard application of knowledge (3) application of knowledge in new situations. Different types of questions shall possess different marks to quantify their range.

Project evaluation shall be conducted at the end of sixth semester. 20% of marks are awarded through internal assessment.

10. Requirement for passing the course

- The pass minimum for all the courses including project report shall be 50% marks for both internal and external.
- For passing the **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** Degree Programme the student shall be required to achieve a minimum of 120 credits of which 3 credits shall be from common course, 117 credits from core courses and 16 credits from Ability Enhancement Courses. A student shall be required to achieve 50% marks (internal and external put together) in all the courses including project report for passing the **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** Degree Programme.
- Credits achieved from Ability Enhancement Courses are not counted for SGPA or CGPA.
- Evaluation of the courses (both internal and external) shall be carried out by assigning marks in indirect grading system.
- Over all grading at the end of the Programme shall be done on a 7- point scale.
- Each course is evaluated by assigning marks with a letter grade (A+, A, B, C, D, E or F) to that course by the method of indirect grading.
- Appearance for Internal Evaluation (IE) and End Semester Evaluation (external) are compulsory and no grade shall be awarded to a candidate if she/he is absent for IE/ESE or both.

INDIRECT GRADING SYSTEM

Marks	Grade	Interpretation
95% and Above	A+	Outstanding
90% - Below 95%	A	Excellent
80% - Below 90 %	B	Very Good
70% - Below 80 %	C	Good
60% - Below 70%	D	Satisfactory
50% - Below 60 %	E	Pass / Adequate
Below 50%	F	Failure

11. Project Report

Regarding the individual project work, the following directions shall be followed. Each student must prepare a project report on any mathematical topic of their interest under the guidance of a faculty member of the Mathematics Department. The topic selected should be the one at par or above the undergraduate level and the content should at large deal with concepts not discussed in the syllabus of any of the courses he /she is being offered under this programme. The report should be neatly typewritten, and the content should be spread into at least 30 pages.

11.1 Evaluation of the Project Report

The project report shall be subject to internal and external evaluation followed by a viva-voce. Internal evaluation is to be done by the supervising teacher and external evaluation by an external evaluation board consisting of an examiner appointed by the College and the Head of the Department or his nominee. A viva-voce related to the project work will also be conducted by the external evaluation board and students must attend the viva- voce individually. Marks are to be awarded to the students combining the internal evaluation, external evaluation, and viva-voce. The student should get a minimum of 50% marks for both internal and external in the project report for a pass. If the student fails to get minimum 50% marks in project report, he or she shall submit the project report after modifying it based on the recommendations of the examiners.

11.2 Criteria for Evaluating the Project Report

Internal		External	
	Marks		**Marks**
Originality	4	Relevance of the Topic, Statement of Objectives	15
Methodology	4	Reference/ Bibliography, Presentation, quality of Analysis/ Use of Statistical Tools	15
Scheme/ Organization of Report	6	Findings and recommendations	25
Viva Voce	6	Viva-Voce	25
Total		**Total**	**80**

12. Disclaimer

In respect of all other matters, which are not specified in this regulation, regarding the conduct of **BACHELOR OF SCIENCE (B.Sc.) HONOURS IN MATHEMATICS** Programme of St. Joseph's College (Autonomous), Devagiri under St. Joseph's Choice Based Credit and Semester System for Under Graduate, the common regulation for SJCBCSS-UG-2019 will be applicable.

DETAILED BREAK UP OF COURSES IS PRESENTED IN FOLLOWING TABLE

FIRST SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Common Course	GENG1A08T	Communication English	4	3	20	80	100
Core Course	GMAH1B01T	Theory of Equation and Complex Numbers	5	4	20	80	100
Core Course	GMAH1B02T	Calculus I	5	4	20	80	100
Core Course	GMAH1B03T	Probability and Statistics	5	4	20	80	100
Core Course	GMAH1B04T	Computer Fundamentals and Introduction to Programming	6	4	20	80	100
		TOTAL	25	19	100	400	500

SECOND SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Core Course	GMAH2B05T	Two-Dimensional Geometry	5	4	20	80	100
Core Course	GMAH2B06T	Calculus II	5	4	20	80	100
Core Course	GMAH2B07T	Number Theory	5	4	20	80	100
Core Course	GMAH2B08T	Distribution Theory	5	4	20	80	100
Core Course	GMAH2B09T	Introduction to Python Programming	5	4	20	80	100
		TOTAL	25	20	100	400	500

THIRD SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Core Course	GMAH3B10T	Real Analysis I	5	4	20	80	100
Core Course	GMAH3B11T	Calculus III	5	4	20	80	100
Core Course	GMAH3B12T	Differential Equations	5	4	20	80	100
Core Course	GMAH3B13T	Statistical Inference	5	4	20	80	100
Core Course	GMAH3B14T	Advanced Python Programming	5	4	20	80	100
		TOTAL	25	20	100	400	500

FOURTH SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Core Course	GMAH4B15T	Real Analysis II	5	4	20	80	100
Core Course	GMAH4B16T	Calculus IV	5	4	20	80	100
Core Course	GMAH4B17T	Linear Programming and Applications	5	4	20	80	100
Core Course	GMAH4B18T	Numerical Computing	5	4	20	80	100
Core Course	GMAH4B19P	Statistical Data Analysis using R	5	4	20	80	100
		TOTAL	25	20	100	400	500

FIFTH SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Core Course	GMAH5B20T	Algebra- I	5	4	20	80	100
Core Course	GMAH5B21T	Complex Analysis	5	4	20	80	100
Core Course	GMAH5B22T	Linear Algebra	5	4	20	80	100
Core Course	GMAH5B23T	Object Oriented Programming using C++	5	4	20	80	100
Core Course	GMAH5EXXT	Elective- I	5	4	20	80	100
		TOTAL	25	20	100	400	500

SIXTH SEMESTER

Course	Course Code	Title of the Course	Hours per week	Credits	Internal	External	Total Marks
Core Course	GMAH6B24T	Algebra- II	5	4	20	80	100
Core Course	GMAH6B25T	Graph Theory	5	4	20	80	100
Core Course	GMAH6B26T	Data Structures using C++	4	4	20	80	100
Core Course	GMAH6EXXT	Elective- II	5	4	20	80	100
Core Course	GMAH6B27P	Practical (Data Structures)	4	3	20	80	100
Core Course	GMAH6B28D	Project Work and Viva-Voce	2	2	20	80	100
		TOTAL	25	21	120	480	600

Electives

Semester V

1. GMAH5E01T **- Topology**
2. GMAH5E02T **- Mathematical Finance**
3. GMAH5E03T **- Differential Geometry**
4. GMAH5E04P **- Mathematical documentation using LaTex**

Semester VI

1. GMAH6E05T **- Mathematical Economics**
2. GMAH6E06T **- Fuzzy Mathematics**
3. GMAH6E07P **- Programming Using Scilab**

PROGRAMME OUTCOMES

PSs	PROGRAMME OUTCOMES
PS01	The students can express and formulating applied problems in terms of mathematical and statistical languages.
PS02	The students can apply the programming concepts to mathematical investigations and problem solving in real life.
PS03	The students can improve life skills including critical thinking, effective communication, social interaction, ethics, self-directed learning.
PS04	The students will have the ability to communicate various concepts of mathematics effectively using examples and their geometrical visualization.
PS05	The students can apply mathematical modeling as required in various subjects such as physical sciences, economics, and business studies.
PS06	This programme will help to know about the advances in various branches of mathematics.
PS07	The students will have the capacity to work independently and do in depth study of various notions of mathematics.
PS08	Ability to pursue advanced studies and research in pure and applied mathematical sciences.
PS09	To produce graduates with good communication skills and Function effectively, individually and in teams, to accomplish tasks.
PS10	To produce graduates prepared for life-long learning and subsequent graduate studies.
PS11	To produce graduates with professional, ethical, legal, security and social responsibilities appropriate to the discipline.

SEMESTER I

GMAH1B01T: THEORY OF EQUATION AND COMPLEX NUMBERS

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To learn about Polynomials and solutions of the same.
- To learn about Complex numbers

Course Outcomes

- Use different ways of solving equations and they begin to prove many properties in their own way regarding numbers.
- Get idea of Complex numbers their properties, complex functions and special power functions.

Module I **Text (1)** **(20 Hours)**

Chapter II (Text 1)

II.1 Integral rational functions or polynomials
II.2 Multiplication of polynomials
II.3 Division of polynomials, quotient and remainder, method of detached coefficients
II.4 The remainder theorem
II.5 Synthetic Division
II.6 Horner's process
II.7 Taylor formula, expansion of a polynomial in powers of $x - c$
II.8 Highest common divisor of two polynomials

Chapter III (Text 1)

III.1 Algebraic equations, roots, maximum number of roots
III.2 Identity theorem
III.3 The Fundamental theorem of Algebra (statement only), factorisation to linear factors, multiplicity of roots
III.4 Imaginary roots of equations with real coefficients
III.5 Relations between roots and coefficients
III.6 Discovery of multiple roots

Module II **Text (1)** **(20 Hours)**

IV.1 Limits of roots
IV.2 Method to find upper limit of positive roots
IV.3 Limit for moduli of roots [only the method to find out upper limit from the auxiliary equation is required; derivation omitted]

IV.4 Integral roots
IV.5 Rational roots

Chapter V (Text 1)
V.1 What is the solution of an equation?
V.2 Cardan's formulas
V.3 Discussion of solution
V.4 Irreducible case
V.5 Trigonometric solution
V.6 Solutions of biquadratic equations, Ferrari method [example2 omitted]

Module III **Text (1)** **(20 Hours)**
Chapter VI (Text 1)
VI.1 Object of the Chapter
VI.2 The sign of a polynomial for small and large values of variables- locating roots of polyno- mial between two numbers having values of opposite sign-geometric illustration only-[rigorous reasoning in the starred section omitted]
VI.4 Corollaries- roots of odd and even degree polynomial, number of roots in an interval counted according to their multiplicity
VI.5 Examples
VI.7 Rolle's Theorem [proof omitted], use in separating roots
VI.10 Descarte's rule of signs-only statement and illustrations are required

Module IV: Complex Numbers **(20 Hours)**
Sums and Products; Basic Algebraic properties; Further properties, Vectors and Moduli; Complex conjugates; Exponential form; Product and powers in exponential form; Arguments of products and quotients; Roots of complex numbers; Regions in the complex plane. (Sections 1 to 11 of Chapter 1 of Text 2)

Text
1. Theory of Equations: J V Uspensky McGraw Hill Book Company, Inc. ISBN: 07-066735-7.
2. J.W. Brown and Ruel V. Churchill: Complex Variables and Applications, 8th Ed., McGraw Hill.

References

1. Dickson L.E.: Elementary Theory of Equations John Wiley and Sons, Inc. NY (1914)
2. Turnbull H.W.: Theory of Equations (4/e) Oliver and Boyd Ltd. Edinburg (1947)
3. Todhunter I.: An Elementary Treatise on the Theory of Equations (3/e) Macmillan and Co. London(1875)
4. William Snow Burnside and Arthur William Panton: The Theory of Equations with An Introduction to Binary Algebraic Forms Dublin University Press Series (1881)
5. James Ward Brown, Ruel Vance Churchill: Complex variables and applications (8/e), McGraw- Hill Higher Education, (2009)

6. Alan Jeffrey: Complex Analysis and Applications (2/e), Chapman and Hall/CRC Taylor Francis Group (2006).
7. Saminathan Ponnusamy, Herb Silverman: Complex Variables with Applications Birkhauser Boston (2006).
8. John H. Mathews & Russell W. Howell: Complex Analysis for Mathematics and Engi- neering (6/e)
9. H A Priestly: Introduction to Complex Analysis (2/e), Oxford University Press, (2003),
10. Jerrold E Marsden, Michael J Hoffman: Basic Complex Analysis (3/e) W.H Freeman, N.Y. (1999).

SEMESTER I

GMAH1B02T: CALCULUS I

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To introduce students to the fundamental ideas of limit, continuity, and differentiability and to some basic theorems of differential calculus.
- To deal with the other branch of calculus i.e., integral calculus.

Course Outcomes

- To show how these ideas of differential calculus can be applied in the problem of sketching of curves and in the solution of some optimization problems of interest in real life.
- To understand the geometric problem of finding out the area of a planar region and practical way of evaluating the definite integral which establishes the close connection between the two branches of Calculus.
- To find the arc length of a plane curve, volume, and surface areas of solids and so on.
- To use integration as a powerful tool in solving problems in physics, chemistry, biology, engineering, economics, and other fields.

Module I **(15 Hours)**

1.1 Intuitive introduction to Limits- A Real- Life Example, Intuitive Definition of a Limit, One-Sided Limits, Using Graphing Utilities to Evaluate Limits.

1.2 Techniques for finding Limits- Computing Limits Using the Laws of Limits, Limits of Polynomial and Rational Functions, Limits of Trigonometric Functions, The Squeeze Theorem.

1.3 Precise Definition of a Limit- $\varepsilon - \delta$ definition of limit, A Geometric Interpretation, Some illustrative examples.

1.4 Continuous Functions- Continuity at a Number, Continuity at an Endpoint, Continuity on an Interval, Continuity of Composite Functions, Intermediate Value Theorem

2.1 The Derivatives- Definition only.

2.9 Differentials and Linear Approximations- increments, Differentials, Error Estimates, Linear Approximations, Error in Approximating Δy by dy.

Module II **(25 Hours)**

3.1 Extrema of Functions- Absolute Extrema of Functions, Relative Extrema of Functions, Fermat's Theorem**,** Finding the Extreme Values of a Continuous Function on a Closed Interval, An Optimization Problem.

3.2 The Mean Value Theorem- Rolle's Theorem, The Mean Value Theorem**,** Some

Consequences of the Mean Value Theorem, Determining the Number of Zeros of a Function.

3.3 Increasing and Decreasing Functions- definition, inferring the behaviour of function from sign of derivative, Finding the Relative Extrema of a Function, first derivative test.

3.4 Concavity and Inflection points- Concavity, Inflection Points, The Second Derivative Test, The roles of ‘and f'' in determining the Shape of a Graph.

3.5 Limits involving Infinity; Asymptotes- Infinite Limits, Vertical Asymptotes, Limits at Infinity, Horizontal Asymptotes, Infinite Limits at Infinity, Precise Definitions

3.6 Curve Sketching- The Graph of a Function, Guide to Curve Sketching, Slant Asymptotes, Finding Relative Extrema Using a Graphing Utility

3.7 Optimization Problems- guidelines for finding absolute extrema, Formulating Optimization Problems- application involving several real life problems

Module III **(25 Hours)**

4.1 Anti derivatives, Indefinite integrals, Basic Rules of Integration, a few basic integration formulas and rules of integration, Differential Equations, Initial Value Problems

4.3 Area- An Intuitive Look, The Area Problem, Defining the Area of the Region Under the Graph of a Function-technique of approximation [‘Sigma Notation’ and ‘Summation Formulas’ Omitted] An Intuitive Look at Area (Continued), Defining the Area of the Region Under the Graph of a Function-precise definition, Area and Distance

4.4 The Definite Integral- Definition of the Definite Integral, Geometric Interpretation of the Definite Integral, The Definite Integral and Displacement, Properties of the Definite Integral, More General Definition of the Definite Integral

4.5 The Fundamental Theorem of Calculus- How Are Differentiation and Integration Related? The Mean Value Theorem for Definite Integrals, The Fundamental Theorem of Calculus: Part I, inverse relationship between differentiation and integration, Fundamental Theorem of Calculus: Part 2, Evaluating Definite Integrals Using Substitution, Definite Integrals of Odd and Even Functions, The Definite Integral as a Measure of Net Change.

Module IV **(15 Hours)**

5.1 Areas between Curves- A Real Life Interpretation, The Area Between Two Curves, Integrating with Respect to -adapting to the shape of the region, What Happens When the Curves Intertwine?

5.2 Volume- Solids of revolution, Volume by Disk Method, Region revolved about the x-axis, Region revolved about the y-axis, Volume by the Method of Cross Sections [‘Washer Method’ omitted]

5.4 Arc Length and Areas of surfaces of revolution- Definition of Arc Length, Length of a Smooth Curve, arc length formula, The Arc Length Function, arc length differentials, Surfaces of Revolution, surface area as surface of revolution

Text

1. Calculus: Soo T Tan Brooks/Cole, Cengage Learning (2010).

References

1. Joel Hass, Christopher Heil & Maurice D. Weir: Thomas' Calculus (14/e) Pearson (2018).
2. Robert A Adams & Christopher Essex: Calculus Single Variable (8/e) Pearson Education Canada (2013).
3. Jon Rogawski & Colin Adams: Calculus Early Transcendentals (3/e) W. H. Freeman and Company (2015).
4. Anton, Bivens & Davis: Calculus Early Transcendentals (11/e) John Wiley & Sons, Inc. (2016).
5. James Stewart: Calculus (8/e) Brooks/Cole Cengage Learning(2016)
6. Jerrold Marsden & Alan Weinstein: Calculus I and II (2/e) Springer Verlag NY (1985).

SEMESTER I

GMAH1B03T: PROBABILITY AND STATISTICS

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To tabulate statistical information given in descriptive form and to use graphical techniques to interpret.
- To compute various measures of central tendency, dispersion, skewness, and kurtosis.
- To find the probabilities of events.
- To analyze data pertaining to discrete and continuous variables and to interpret the results.
- To find the correlation between two variables and form regression lines.

Course Outcomes

- Acquaintance with various methods of collecting data and get familiar with some elementary methods viz. Measures of central tendency.
- Understanding the basic concepts of probability and to find probabilities of various events.
- To recognize and evaluate the relationship between two quantitative variables through simple linear correlation and regression.

Quick Review Prerequisites

Basic idea about Statistical data: Concept of primary and secondary data. Concepts of statistical population and sample from a population, quantitative and qualitative data, Nominal, ordinal and time series data, discrete and continuous data. Frequency distribution, formation of a frequency distribution, Graphic representation *viz*. Histogram, Frequency Curve, Polygon, Ogives, bar diagram and Pie diagram.

Module I **(20 Hours)**

Measure of central tendency- Arithmetic Mean, Median, Mode, Geometric Mean, Harmonic Mean, Combined Mean, Advantages and disadvantages of each average, Measures of dispersion- Range, Quartile Deviation, Mean Deviation, Standard Deviation, Combined Standard Deviation, Percentiles, Deciles, Relative Measures of Dispersion, Coefficient of variation, Skewness and Kurtosis- Pearson's and Bowley's coefficient of skewness, Measure of Kurtosis.

Module II **(20 Hours)**

Bivariate data- relationship of variables, correlation analysis, methods of studying correlation, Scatter Diagram, Karl Pearson's Coefficient of Correlation, Spearman's rank correlation, Regression analysis- linear regression, Regression Equations, Identifying the Regression Lines, properties of regression coefficients, numerical problems.

Module III **(20 Hours)**

Introduction to Probability: Random experiment, Sample space, events, classical definition of probability, statistical regularity, axiomatic definition of probability and simple properties, addition theorem (two and three events), conditional probability of two events, multiplication theorem, independence of events-pair wise and mutual, Bayes theorem and its applications.

Module IV **(20 Hours)**

Random variables: Discrete and continuous, probability mass function (pmf) and probability density function (pdf)- properties and examples, Cumulative distribution function and its properties, change of variables (univariate case only)

References

1. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, (11^{th} edition) Sultan Chand and Sons.
2. S P Gupta, Statistical Methods, Sultan Chand and Sons
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
4. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3^{rd} Edition (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
5. John E Freund, Mathematical Statistics, Pearson Edition, New Delhi.

SEMESTER I

GMAH1B04T: COMPUTER FUNDAMENTAL & INTRODUCTION TO PROGRAMMING

Contact Hours	**: 96 (6 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To learn digital fundamentals of computing.
- To learn the concept of programming.
- To study C Programming language.
- To equip the students to write programs for solving simple computing problems.

Course Outcomes

- Identifies basics of digital computing.
- Develops an in depth understanding of functional and logical concepts of C Programming.
- Provides exposure to problem solving through C Programming.

Module I **(23 Hours)**

Introduction to computers, Characteristics of Computers, Block diagram of computer. Types of computers and features, Types of memory, Features of Digital Systems- Number system- decimal, binary, octal and hexadecimal number, interconversion of decimal to binary and vice versa. Binary arithmetic- Addition and Subtraction, Multiplication, Division, Floating Point, Binary codes- BCD codes, Gray codes, ASCII Code- Basic of Boolean Algebra- Laws, Rules, De-Morgan's theorem- Logic gates- OR, AND, NOT, NAND, NOR, XOR, XNOR.

Module II **(23 Hours)**

Introduction to Problem solving- Algorithm- definition, Characteristics, notations. Flowchart- definition, Symbols used in writing the flow-chart Writing an algorithm and flow-chart of simple problems. An overview of Programming languages, Classification of programming languages.

Fundamentals of 'C': Features of C language, structure of C program, comments, header files, data types, constants and variables, operators, expressions, evaluation of expressions, type conversion, precedence and associativity, I/O functions.

Module III **(30 Hours)**

Control Structures in 'C': Simple statements, Decision making statements, Looping statements, Nesting of control structures, break and continue statement, go to statement.

Array & String: Concept of array, One and Two dimensional arrays, declaration and initialization of arrays, String, String storage, Built-in string functions. Functions: Concept of user defined functions, prototype, definition of function, parameters, parameter passing, calling a function, recursive functions

Module IV **(20 Hours)**

Pointers: Basics of pointers Passing pointers as function arguments, Accessing array elements through pointers, Passing arrays as function arguments, Arrays of pointers, Pointers to pointers, Structure and Union, File Handling: Creating, Processing, Opening and closing a data file.

References

1. Digital Fundamentals, Thomas L Floyd, Universal Book Stall
2. Fundamentals of Computers, V. Rajaraman.
3. Computer Concepts and C Programming, P.B. Kotur
4. Let us C, Yashwanth Kanetkar
5. ANSI C, Balagurusamy

SEMESTER II

GMAH2B05T: TWO-DIMENSIONAL GEOMETRY

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Introduce to analytical geometry of 2 dimensional.
- To get basic knowledge about Circle, Cone, Parabola, Hyperbola, Ellipse etc.
- Accurately identify the equations, properties and graphs of the parabola, circle, ellipse, and hyperbola.

Course Outcomes

- Find equation in various form of line, circle, ellipse, sphere, cones etc.
- Understand polar coordinates and its relationship with cartesian coordinates.
- Sketch various curves.

Module 1 **(20 Hours)**

Change of axes, Pair of lines (Sections 3.1 to 3.5, 4.1 to 4.4)

Module II **(20 Hours)**

Parabola (Sections 7.1 to 7.8)

Module III **(20 Hours)**

Ellips, Hyperbola (Sections 8.1 to 8.8, 9.1 to 9.6)

Module IV **(20 Hours)**

General Second Degree Equations andTracing of Conics, Polar Equation of a conic (Sections 10.1 to 10.5, 11.1 to 11.4)

Text

1. P Jain, K Ahmad, Text Book of Analytical Geometry of Two Dimensions, New Age International(P) Ltd., 1996.

References

1. P K Jain, Ahmed Khalil : A Textbook of Analytical Geometry of Two Dimensions *(2/e), New Age International Private Limited (2021)*

2. D. Chatterjee: Analytical Geometry of two dimension, *Narosa Pub House, ISBN-13 978-8173198960*

3. Harbanslal & Satpal : Calculus *Single Variable (2/e) New Age International Pvt Ltd (1996)*

4. Krishna Singh: A Textbook of Two Dimensional Geometry, *Daya Publishing House (2013)*

SEMESTER II

GMAH2B06T: CALCULUS II

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To introduce the idea of definite integral, the natural logarithm function and to define its inverse function namely the natural exponential function and the general exponential function.
- To introduce the combinations of exponential functions namely hyperbolic functions that also arise very frequently in applications such as the study of shapes of cables hanging under their own weight.
- To introduce the idea of improper integrals, their convergence and evaluation.
- To contribute to the thinking skills of logic, deductive reasoning and skills in problem solving using Geometry.
- To introduce the foundation stones for the creation of analytic geometry.

Course Outcomes

- To exponentially model a wide variety of phenomenon of interest in science, engineering, mathematics and economics.
- To practically apply several different tests such as integral test, comparison test and so on. As a special case, a study on power series- their region of convergence, differentiation, and integration etc., is also done.
- Understanding the basic concepts of probability and to find probabilities of various events.
- To get the idea of parametrization of curves; how to calculate the arc length, curvature etc.
- To recognize and evaluate the area of surface of revolution of a parametrized plane curve.

Module I **(20 Hours)**

6.1 The Natural logarithmic function- definition, The Derivative of $ln\ x$, Laws of Logarithms, The Graph of the Natural Logarithmic Function, The Derivatives of Logarithmic Functions, Logarithmic Differentiation, Integration Involving Logarithmic Functions

6.3 Exponential Functions- The number e, Defining the Natural Exponential Function, properties, The Laws of Exponents, The Derivatives of Exponential Functions, Integration of the Natural Exponential Function

6.4 General Exponential and Logarithmic Functions - Exponential Functions with Base a, laws of exponents, The Derivatives of a^x and a^u, Graphs of y= a^x, integrating a^x, Logarithmic Functions with Base a, change of base formula, The Power Rule (General Form), The Derivatives of Logarithmic Functions with Base a, The Definition of the Number e as a Limit [‘Compound Interest’ omitted]

6.6 Hyperbolic functions- The Graphs of the Hyperbolic Functions, Hyperbolic Identities, Derivatives and Integrals of Hyperbolic Functions, Inverse Hyperbolic Functions, representation in terms of logarithmic function, Derivatives of Inverse Hyperbolic Functions, An Application

6.7 Indeterminate forms and l’Hôpital rule- motivation, The Indeterminate Forms $\frac{0}{0}$ and $\frac{\infty}{\infty}$, The Indeterminate Forms $\infty - \infty$ and $0.\infty$, The Indeterminate forms 0^0, ∞^0 and 1^∞.

Module II **(20 Hours)**

7.6 Improper integrals- definition, Infinite Intervals of Integration, Improper Integrals with Infinite Discontinuities, A Comparison Test for Improper Integrals.

9.1 Sequences- definition, recursive definition, Limit of a Sequence, limit laws, squeeze theorem, Bounded Monotonic Sequences, definition, monotone convergence theorem (only statement; its proof omitted).

9.2 Series- defining the sum, convergence and divergence, Geometric Series, The Harmonic Series, The Divergence Test, Properties of Convergent Series.

9.3 The Integral Test- investigation of convergence, integral test, The p Series, its convergence and divergence.

9.4 The Comparison Test- test series, The Comparison Test, The Limit Comparison Test.

Module III **(20 Hours)**

9.5 Alternating Series- definition, the alternating series test, its proof, examples, Approximating the Sum of an Alternating Series by S_n.

9.6 Absolute Convergence- definition, conditionally convergent, The Ratio Test, The Root Test, Summary of Tests for Convergence and Divergence of Series, Rearrangement of Series.

9.7 Power Series- definition, Interval of Convergence, radius of convergence, Differentiation and Integration of Power Series.

9.8 Taylor and Maclaurin Series- definition, Taylor and Maclaurin series of functions, Techniques for Finding Taylor Series.

Module IV **(20 Hours)**

10.2 Plane Curves and Parametric Equations- Why We Use Parametric Equations, Sketching Curves Defined by Parametric Equations.

10.3 The Calculus of parametric equations- Tangent Lines to Curves Defined by Parametric Equations, Horizontal and Vertical Tangents, Finding $\frac{d^2y}{dx^2}$ from Parametric Equations, The Length of a Smooth Curve, The Area of a Surface of Revolution.

10.4 Polar coordinates- The Polar Coordinate System, Relationship between Polar and Rectangular Coordinates, Graphs of Polar Equations, Symmetry, Tangent Lines to

Graphs of Polar Equations.

10.5 Areas and Arc Lengths in polar coordinates- Areas in Polar Coordinates, *area bounded by polar curves*, Area Bounded by Two Graphs, Arc Length in Polar Coordinates, Area of a Surface of Revolution, Points of Intersection of Graphs in Polar Coordinates.

Text

1. Calculus: Soo T Tan Brooks/Cole, Cengage Learning (2010).

References

1. Joel Hass, Christopher Heil & Maurice D. Weir: Thomas' Calculus (14/e) Pearson (2018).
2. Robert A Adams & Christopher Essex: Calculus Single Variable (8/e) Pearson Education Canada (2013).
3. Jon Rogawski & Colin Adams: Calculus Early Transcendentals (3/e) W. H. Freeman and Company (2015).
4. Anton, Bivens & Davis: Calculus Early Transcendentals (11/e) John Wiley & Sons, Inc. (2016).
5. James Stewart: Calculus (8/e) Brooks/Cole Cengage Learning (2016).
6. Jerrold Marsden & Alan Weinstein: Calculus I and II (2/e) Springer Verlag NY (1985).

SEMESTER II

GMAH2B07T: NUMBER THEORY

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Define and interpret the concepts of divisibility, congruence, greatest common divisor, prime, and prime factorization.
- Produce rigorous arguments (proofs) centered on the material of number theory, most notably in the use of Mathematical Induction and/or the Well Ordering Principal in the proof of theorems.

Course Outcomes

- Find quotients and remainders from integer division
- Apply Euclid's algorithm and backwards substitution
- Understand the definitions of congruence, residue classes and least residues add and subtract integers, modulo n, multiply integers and calculate powers, modulo n
- Determine multiplicative inverses, modulo n and use to solve linear congruence.

Module 1 **(20 Hours)**

The division Algorithm, The Greatest Common Divisor, The Euclidean Algorithm, The Diophantine Equation (Section 2.1 to 2.5).

Module 2 **(20 Hours)**

The fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture, Basic (Section 3.1, 3.2, 3.3, 4.2).

Module 3 **(20 Hours)**

Properties of Congruences, Binary and Decimal Representation of Integers, Linear Congruence and the Chinese Remainder Theorem (Section 4.2, 4.3, 4.4).

Module 4 **(20 Hours)**

Fermat's Little Theorem, Wilson's Theorem, The Sum and Number of divisors, Mobius Inversion Formula (Section 5.2, 5.3, 6,1, 6.2).

Text

1. Elementary Number Theory (7^{th} Edition), David M .Burton, McGraw-Hill.

References

1. A Classical Introduction to Modern Number Theory, Kenneth Ireland and Michael

Rosen, Springer Science + Business Media, LLC.

2. An Introduction to the Theory of Numbers (4^{th} Edition), G. H. Hardy and E. M. Wright, Oxford at the Clarendon Press.
3. An Introduction to the Theory of Numbers, Ivan Niven, Herbert S. Zuckerman and Hugh L. Montgomery, Wiley (1991), ISBN 9780471625469 (ISBN10: 0471625469).

SEMESTER II

GMAH2B08T: DISTRIBUTION THEORY

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- Provide students with a formal treatment of probability theory.
- Equipping students with essential tools for statistical analyses at the graduate level.
- Fostering understanding through real-world statistical applications.

Course Outcomes

- Identify the characteristics of various discrete and continuous probability distributions
- Use discrete and continuous probability distributions including requirements, mean and variance and making decisions
- Identify the situations to which these distributions can be applied.
- Use of different distributions to solve simple practical problems.
- Use of standing normal distribution on appropriate area.
- Understand the importance of central limit theorem and laws of large numbers.

Module I **(10 Hours)**

Mathematical expectations (univaraite): Definition, raw and central moments (definition and relationships), moment generating function and properties, characteristic function (definition and use only), Skewness and kurtosis using moments.

Module II **(20 Hours)**

Bivariate random variable: joint pmf and joint pdf, marginal and conditional probability, independence of random variables, function of random variable. Bivariate Expectations, conditional mean and variance, covariance, Karl Pearson Correlation coefficient, independence of random variables based on expectation.

Module III **(20 Hours)**

Standard distributions: Discrete type-Bernoulli, Binomial, Poisson, Geometric (definition, properties and applications), Uniform (mean, variance and mgf) and Negative Binomial (definition only).

Module IV **(20 Hours)**

Standard distributions Continuous type- Uniform, exponential and Normal (definition, properties and applications); Gamma (mean, variance, mgf); Lognormal, Beta, Pareto and Cauchy (Definition only).

Module V **(10 Hours)**

Limit theorems: Chebyshev's inequality, Convergence in probability (definition and example only), weak law of large numbers (iid case), Bernoulli law of large numbers, Convergence in distribution (definition and examples only), Central limit theorem (Lindberg levy- iid case)**.**

References

1. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
2. S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons.
3. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edition, (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
4. John E Freund, Mathematical Statistics, Pearson Edition, New Delhi.

SEMESTER II

GMAH2B09T: INTRODUCTION TO PYTHON PROGRAMMING

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- To learn basics of Python programming.
- To learn decision making, looping and functions in Python.
- Understand Object Oriented Programming using Python.

Course Outcomes

- Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.
- Express proficiency in the handling of strings and functions.
- Determine the methods to create and manipulate Python programs by utilizing the data structures like lists, dictionaries, tuples, and sets.

Module I

Introduction to python, features, IDLE, python interpreter, Writing and executing python scripts, comments, identifiers, keywords, variables, data type, operators, operator precedence and associativity, statements, expressions, user inputs, type function, eval function, print function.

Module II

Boolean expressions, Simple if statement, if-elif-else statement, compound boolean expressions, nesting, multi way decisions. Loops: The while statement, range functions, the for statement, nested loops, break and continue statements, infinite loops. controls flow- organizing code- functions, modules, packages- implementation of user defined modules and packages.

Module III

Functions, built-in functions, mathematical functions, date time functions, random numbers, writing user defined functions, composition of functions, parameter and arguments, default parameters, function calls, return statement, using global variables, recursion. String and string operations, List- creating list, accessing, updating and deleting elements from a list, basic list operations.

Module IV

Tuple- creating and accessing tuples in python, basic tuple operations. Dictionary, built in methods to access, update and delete dictionary values. Set and basic operations on a set. The

Object- Oriented Approach: Classes, Methods, Objects, and the Standard Objective Features; Exception Handling.

References

1. E. Balaguruswamy, Introduction to Computing and Problem Solving Using Python.
2. Richard L. Halterman, Learning To Program with Python.
3. Martin C. Brown, Python: The Complete Reference.
4. Learning python: orielly.

SEMESTER III

GMAH3B10T: REAL ANALYSIS I

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Define the real numbers, least upper bounds, and the triangle inequality.
- Define functions between sets; equivalent sets; finite, countable and uncountable sets.
- Recognize convergent, divergent, bounded, Cauchy and monotone sequences.

Course Outcomes

- Describe fundamental properties of the real numbers that lead to the formal development of real analysis.
- Comprehend rigorous arguments developing the theory underpinning real analysis.
- Demonstrate an understanding of limits and how they are used in sequences and series.

Module I **(20 Hours)**

Chapter 1: Preliminaries

1.3 Finite and Infinite Sets

Chapter 2: The Real Numbers

2.1 The Algebraic and Order Properties of $\mathbb{R}$

2.2 Absolute Value and the Real Line

Module II **(20 Hours)**

2.3 The Completeness Property of $\mathbb{R}$

2.4 Applications of the Supremum Property

2.5 Intervals

Chapter 3: Sequences and Series

3.1 Sequences and Their Limits

3.2 Limit Theorems

3.3 Monotone Sequences

Module III **(20 Hours)**

3.4 Subsequences and the Bolzano-Weierstrass Theorem

3.5 The Cauchy Criterion

3.6 Properties of divergent sequences

3.7 Infinite Series

Module IV **(20 Hours)**

Chapter 11: A Glimpse into topology

11.1 Open and Closed sets in $\mathbb{R}$

11.2 Compact Sets.

Text

1. Introduction to Real Analysis (4/e): Robert G Bartle, Donald R. Sherbert John Wiley & Sons (2011)

References

1. Charles G. Denlinger: Elements of Real Analysis Jones and Bartlett Publishers Sudbury, Massachusetts (2011).
2. David Alexander Brannan: A First Course in Mathematical Analysis, Cambridge University Press, US (2006).
3. John M. Howie: Real Analysis Springer Science & Business Media (2012) [Springer Undergraduate Mathematics Series].
4. James S. Howland: Basic Real Analysis Jones and Bartlett Publishers Sudbury, Massachusetts (2010).

SEMESTER III

GMAH3B11T: CALCULUS III

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- A detailed study of plane and space curves is taken up.
- Students are introduced into other coordinate systems which often simplify the equation of curves and surfaces and relationships between various coordinate systems are also taught.
- This course extends the immensely useful ideas and notions such as limit, continuity and derivative seen in the context of the function of a single variable to the function of several variables.

Course Outcomes

- Handle vectors in dealing with the problems involving geometry of lines, curves, planes and surfaces in space and have acquired the ability to sketch curves in plane and space given in vector valued form.
- Understand several contexts of the appearance of multivariable functions and their representation using graph and contour diagrams.
- Formulate and work on the idea of limit and continuity for functions of several variables.
- Understand the notion of partial derivatives, their computation and interpretation.
- Understand chain rule for calculating partial sums.
- Get the idea of directional derivative, its evaluation, interpretation and relationship between partial derivatives.
- Understand the concept of gradient, a few of its properties, application and interpretation.

Module I **(20 Hours)**

11.5 Lines and Planes in Space- Equations of Lines in Space, parametric equation, symmetric equation of a line, Equations of Planes in Space, standard equation, Parallel and Orthogonal Planes, The Angle Between Two Planes, The Distance Between a Point and a Plane.

11.6 Surfaces in Space- Traces, Cylinders, Quadric Surfaces, Ellipsoids, Hyperboloids of One Sheet, Hyperboloids of Two Sheets, Cones, Paraboloids, Hyperbolic Paraboloids

11.7 Cylindrical and Spherical Coordinates- The Cylindrical Coordinate System, converting cylindrical to rectangular and vice versa, The Spherical Coordinate System, converting spherical to rectangular and vice versa.

Module II **(30 Hours)**

12.1 Vector Valued functions and Space Curves- definition of vector function, Curves Defined by Vector Functions, [‘Example 7’ omitted] Limits and Continuity.

12.2 Differentiation and Integration of Vector- Valued Function- The Derivative of a Vector Function, Higher- Order Derivatives, Rules of Differentiation, Integration of Vector Functions.

12.3 Arc length and Curvature- Arc Length of a space curve, Smooth Curves, Arc Length Parameter, arc length function, Curvature, formula for finding curvature, Radius of Curvature.

12.4 Velocity and Acceleration- Velocity, Acceleration, and Speed; Motion of a Projectile

12.5 Tangential and Normal Components of Acceleration- The Unit Normal, principal unit normal vector, Tangential and Normal Components of Acceleration [The subsections ‘Kepler’s Laws of Planetary Motion’, and ‘Derivation of Kepler’s First Law’ omitted].

Module III **(30 Hours)**

13.1 Functions of two or more variables- Functions of Two Variables, Graphs of Functions of Two Variables, Level Curves, Functions of Three Variables and Level Surfaces.

13.2 Limits and continuity-An Intuitive Definition of a Limit, existence and non existence. of limit, Continuity of a Function of Two Variables, Continuity on a Set, continuity of polynomial and rational functions, continuity of composite functions, Functions of Three or More Variables, The Definition of a Limit.

13.3 Partial Derivatives- Partial Derivatives of Functions of Two Variables, geometric interpretation, Computing Partial Derivatives, Implicit Differentiation, Partial Derivatives of Functions of More Than Two Variables, Higher-Order Derivatives, Clairaut theorem, harmonic functions.

13.4 Differentials- Increments, The Total Differential, interpretation, Error in Approximating Δz by [only statement of theorem1 required; proof omitted] Differentiability of a Function of Two Variables, criteria, Differentiability and Continuity, Functions of Three or More Variables.

13.5 The Chain rule- The Chain Rule for Functions Involving One Independent Variable, The Chain Rule for Functions Involving Two Independent Variables, The General Chain Rule, Implicit Differentiation.

13.6 Directional Derivatives and Gradient vectors- The Directional Derivative, The Gradient of a Function of Two Variables, Properties of the Gradient, Functions of Three Variables.

Text

1. Calculus: Soo T Tan Brooks/Cole, Cengage Learning (2010).

References

1. Joel Hass, Christopher Heil & Maurice D. Weir: Thomas’ Calculus (14/e) Pearson (2018).
2. Robert A. Adams & Christopher Essex: Calculus Single Variable (8/e) Pearson

Education Canada (2013).
3. Jon Rogawski & Colin Adams: Calculus Early Transcendentals (3/e) W. H. Freeman and Company (2015).
4. Anton, Bivens & Davis: Calculus Early Transcendentals (11/e) John Wiley & Sons, Inc. (2016)
5. James Stewart: Calculus (8/e) Brooks/Cole Cengage Learning (2016).
6. Jerrold Marsden & Alan Weinstein: Calculus I and II (2/e) Springer Verlag NY (1985).

SEMESTER III

GMAH3B12T: DIFFERENTIAL EQUATIONS

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To model the physical world around us.
- To introduce many of the laws or principles governing natural phenomenon are statements or relations involving the rate at which one quality changes with respect to another.
- To formulate relations (modeling) that often results in an equation involving derivative (differential equation).
- To intend to find out ways and means for solving differential equations and the topic has wide range applications in physics, chemistry, biology, medicine, economics and engineering.

Course Outcomes

- Students could identify a number of areas where the modeling process results in a differential equation.
- They will learn what an ODE is, what it means by its solution, how to classify DEs, what it means by an IVP and so on.
- They will learn to solve DEs that are in linear, separable and in exact forms and also to analyze the solution.
- They will learn a method to approximate the solution successively of a first order IVP.
- They will become familiar with the theory and method of solving a second order linear homogeneous and nonhomogeneous equation with constant coefficients.
- Students acquire the knowledge of solving a differential equation using Laplace method which is especially suitable to deal with problems arising in the engineering field.
- Students learn the technique of solving partial differential equations using the method of separation of variables.

Module I **(20 Hours)**

(a) Introduction, Some Basic Mathematical Models; Direction Fields, Solutions of some Differential equations, Classification of Differential Equations, Historical Remarks. (Chapter 1- Sec. 1.1.1.2, 1.3, 1.4)

(b) First order differential equations: Linear equations with variable coefficients, Separable equations, Modeling with first order equations, Differences between linear and non linear equations, Exact equations and integrating factors , The existence and uniqueness theorem (proof omitted) (Chapter 2- Sec. 2.1, 2.2, 2.3, 2.4, 2.6, 2.8)

Module II **(25 Hours)**

(a) Second Order Linear Differential Equations: Homogeneous equation with constant coefficients, Fundamental solutions of Linear Homogeneous equations, Linear independence and Wronskian, Complex roots of characteristic equations, Repeated roots; Reduction of order, Non homogeneous equations; Method of Undetermined coefficients, Variation of parameters, Mechanical and Electrical vibrations(up to and including e.g. 1) (Chapter 3- Sec. 3.1 to 3.8).

(b) Systems of First Order Linear equations: Introduction, Basic theory of systems of first order Linear Equations (Chapter 7- Sec. 7.1, 7.4)

Module III: Laplace Transforms **(15 Hours)**

Definition of Laplace Transforms, Solution of Initial Value Problem, Step functions, Impulse functions, The Convolution Integral (Chapter 6- Sec. 6.1, 6.2, 6.3, 6.5, 6.6).

Module IV: Partial Differential Equations and Fourier Series **(20 Hours)**

Two point Boundary value problems, Fourier Series, The Fourier Convergence Theorem Even and odd functions, Separation of variables; Heat conduction in a rod, The Wave equation: Vibrations of an elastic string (Chapter 10- Sec. 10.1, 10.2, 10.3, 10.4, 10.5, 10.7).

Text

1. W.E. Boyce & R.C. Diprima, Elementary Differential Equations and Boundary Value Problems. John Wiley & Sons, 7th Edition.

References

1. S.L. Ross: Differential Equations, 3rd edition, Wiley.
2. A.H. Siddiqi & P. Manchanda: A First Course in Differential Equation with Applications, Macmillan, 2006.
3. E.A. Coddington: An Introduction to Ordinary Differential Equation, PHI.
4. G.F. Simmons: Differential Equation with Application and Historical Notes, 2nd edition.
5. M. Braun: Differential Equations and their Applications, Springer.

SEMESTER III

GMAH3B13T: STATISTICAL INFERENCE

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- To understand the basic concept of sampling distributions.
- To understand the construction of point estimators and method of estimators.
- To understand the construction of interval estimators.
- To analyze data by using parametric statistical tests.
- To analyze data by using non parametric statistical tests.

Course Outcomes

- Understand the basic components of sampling and have the knowledge on exact sampling distributions.
- Understand the problem of statistical inference, problem of point estimation, Properties of point estimation.
- Understand the problem of statistical inference, the problem of Interval estimation. Construction of confidence Interval.
- Understand the problem of statistical inference, the problem of testing hypotheses.
- Apply the different testing tools like t-test, F-test, chi-square test, ANOVA etc. to analyze the relevant real life problems.

Module I **(15 Hours)**

Sampling distributions: Parameter and Statistic, Sampling distribution of a statistic, Standard error, Sampling from normal distribution, distribution of sample mean, Sample variance, chi-square distribution, t distribution and F distribution (definition and relationships only).

Module II **(20 Hours)**

Theory of Estimation: Point Estimation, desirable properties of a good estimator, unbiasedness, consistency, sufficiency and efficiency, Fisher Neyman factorization theorem. Methods of Estimation: Method of maximum likelihood, method of moments.

Module III **(15 Hours)**

Interval Estimation: Interval estimates of mean, difference of means, variance, proportions and difference of proportions. Derivation of exact confidence intervals for means, variance and ratio of variances based on normal, t, chi square and F distributions

Module IV **(15 Hours)**

Testing of Hypotheses: concept of testing hypotheses, simple and composite hypotheses, null and alternative hypotheses, type I and II errors, critical region, level of significance and power of a test. Neyman Pearson approach: Large sample tests concerning mean equality of means, proportions, equality of proportions. Small sample tests based on t distribution for mean, equality of means and paired t test.

Module V **(15 Hours)**

Chi square distribution for variance, goodness of fit and independence of attributes. Tests based on F distribution for ratio of variances. Tests based on Analysis of variance-one way, two-way classifications**.**

References

1. Rohatgi V.K and Saleh A.K (2009) Introduction to probability and statistics Wiley India
2. George Casella and Roger Berger (2012) Statistical Inference Wadsworth and Brooks, California
3. S.C. Gupta and V. K. Kapoor Fundamentals of Mathematical Statistics, (11th edition) Sultan Chand and Sons
4. John E Freund, Mathematical Statistics (6th edition), Pearson Edn., New Delhi.

SEMESTER III

GMAH3B14T: ADVANCED PYTHON PROGRAMMING

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Students will be able to understand different tools used in data analytics.
- To be able to work with common Python libraries Numpy and pandas Data Frames.
- To be able to study 2-D plotting using visualization tools such as Matplotlib, pandas and Seaborn.
- Understand a broad collection of machine learning algorithms and problems.
- Apply structured thinking to unstructured problems.

Course Outcomes

- Develop an appreciation for what is involved in learning from data.
- Appreciate the importance of visualization in the data analytics solution.
- To understand the basic theory underlying machine learning.
- To be able to formulate machine learning problems corresponding to different applications.

Module I

Introduction to data analytics: what is data analytics, steps involved in data analytics, tools used, applications. NumPy: n-d array- understanding, creation, indexing and slicing, basic operations and manipulations. 2 D plotting with matplotlib.

Module II

Panda: input/output operations, 1D and 2D data structures(series and data frame), data alignment, aggregation, summarization, computataion and analysis, dealing with dates and times, visualization- 2D plotting with Pandas and Seaborn (line plots, bar plots, histograms, density plots, point plots, facet grids), categorical data.

Module III

Machine learning: introduction- supervised and unsupervised learning, batch and online learning, instant based versus model based learning, reinforcement learning. Machine learning with scikit- Learn: data sets, data acquisition & cleaning (missing values, categorical data), data standardization, variance scaling and normalization, classification, model development using linear regression, classification, clustering, model visualization, prediction and decision making, model evaluation: over-fitting, under-fitting, model selection.

References

1. Doing Math with Python: Amit Saha
2. Let's Python: Yashwant Kanetkar
3. Learning Python, 4th edition by Mark Lutz
4. Dive into Python: Mark Pilgrim

SEMESTER IV

GMAH4B15T: REAL ANALYSIS II

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- The course thoroughly exposes one to the methods of an analysis course.
- This course will teach one how to combine different definitions, theorems and techniques to solve problems that one has never seen before.
- This course should enable student to learn about convergence of sequence of functions and series.

Course Outcomes

- State the definition of continuous functions, formulate sequential criteria for continuity and prove or disprove continuity of functions using these criteria.
- Realize the difference between continuity and uniform continuity and equivalence of these ideas for functions on closed and bounded interval.
- Understand the significance of uniform continuity in continuous extension theorem.
- Develop the notion of Riemann integrability of a function using the idea of tagged partitions and calculate the integral value of some simple functions using the definition.
- Understand a few basic and fundamental results of integration theory
- Formulate Cauchy criteria for integrability and a few applications of it. In particular they learn to use Cauchy criteria in proving the non integrability of certain functions.
- Prove convergence and divergence of sequences of functions and series
- Understand the difference between point wise and uniform convergence of sequences and series of functions

Module I **(18 Hours)**

5.1 Continuous Functions
5.2 Combination of Continuous Functions
5.3 Continuous Functions on Intervals
5.4 Uniform Continuity [Weierstrass Approximation Theorem- only statement]
5.6 Monotone and Inverse Functions.

Module II **(22 Hours)**

7.1 Riemann Integral
7.2 Riemann Integrable Functions

7.3 The Fundamental Theorem
7.4 The Darboux Integral

Module III **(17 Hours)**

8.1 Point wise and Uniform Convergence

8.2 Interchange of Limits- [only statement of theorem 8.2.3 required; proofomitted], [Bounded convergence theorem- statement only] [8.2.6 Dini's theorem omitted].

Module IV **(23 Hours)**

9.1 Absolute Convergence

9.2 Tests for Absolute Convergence

9.3 Tests for Non absolute Convergence

9.4 Series of Functions- (A quick review of series of real numbers of section 3.7 without proof) (only up to and including 9.4.6)

Text

1. Introduction to Real Analysis (4/e): Robert G Bartle, Donald R. Sherbert John Wiley & Sons (2011)

References

1. Charles G. Denlinger: Elements of Real Analysis Jones and Bartlett Publishers Sudbury, Massachusetts (2011) ISBN: 0-7637-7947-4 [Indian edition].
2. David Alexander Brannan: A First Course in Mathematical Analysis Cambridge University Press, US (2006).
3. John M. Howie: Real Analysis Springer Science & BusinessMedia (2012)[Springer Undergraduate Mathematics Series].
4. James S. Howland: Basic Real Analysis Jones and Bartlett Publishers Sudbury, Massachusetts (2010).
5. Terrace Tao: Analysis 1(3/e) TRIM 37 Hindustan book agency (2016).
6. Richard R Goldberg: Methods of Real Analysis Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi (1970).

SEMESTER IV

GMAH4B16T: CALCULUS IV

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- The intention of the course is to extend the immensely useful ideas and notions such as limit, continuity, derivative and integral seen in the context of function of single variable to function of several variables.
- The results we develop in the course of calculus of multivariable is extremely useful in several areas of science and technology as many functions that arise in real life situations are functions of multivariable.

Course Outcomes

- Understand the concept of gradient, a few of its properties, application and interpretation
- Understand the use of partial derivatives in getting information of tangent plane and normal line.
- Calculate the maximum and minimum values of a multivariable function using second derivative test and Lagrange multiplier method.
- Extend the notion of integral of a function of single variable to integral of functions of two and three variables.
- Address the practical problem of evaluation of double and triple integral using Fubini's theorem and change of variable formula.
- Realize the advantage of choosing other coordinate systems such as polar, spherical, cylindrical etc. in the evaluation of double and triple integrals.
- Understand the notion of a vector field, the idea of curl and divergence of a vector field, their evaluation and interpretation.
- Learn three major results viz. Green's theorem, Gauss's theorem and Stokes' theorem of multivariable calculus and their use in several areas and directions.

Module I **(20 Hours)**

13.7 Tangent Planes and Normal Lines- Geometric Interpretation of the Gradient, Tangent Planes and Normal Lines, Using the Tangent Plane off to approximate the Surface z=f (x, y)

13.8 Extrema of Functions of two variables- Relative and Absolute Extrema, Critical Points- Candidates for Relative Extrema, The Second Derivative Test for Relative Extrema, Finding the Absolute Extremum Values of a Continuous Function on a Closed Set.

13.9 Lagrange Multipliers- Constrained Maxima and Minima, The Method of Lagrange Multipliers, Lagrange theorem, Optimizing a Function Subject to Two Constraints.

Module II **(30 Hours)**

14.1 Double integrals- An Introductory Example, Volume of a Solid between a Surface and a Rectangle, The Double Integral over a Rectangular Region, Double Integrals over General Regions, Properties of Double Integrals.

14.2 Iterated Integrals-Iterated Integrals over Rectangular Regions, Fubini's Theorem for Rectangular Regions, Iterated Integrals over Nonrectangular Regions- simple and-simple regions, advantage of changing the order of integration.

14.3 Double integrals in polar coordinates- Polar Rectangles, Double Integrals over Polar Rectangles, Double Integrals over General Regions, r-simple region, method of evaluation

14.5 Surface Area- Area of a Surface $z= (x)$, Area of Surfaces with Equations $y= (x,)$ and $x= h(y,z)$.

14.6 Triple integrals- Triple Integrals over a Rectangular Box, definition, method of evaluation as iterated integrals, Triple Integrals over General Bounded Regions in Space, Evaluating Triple Integrals over General Regions, evaluation technique.

14.7 Triple Integrals in cylindrical and spherical coordinates- evaluation of integrals in Cylindrical Coordinates, Spherical Coordinates.

14.8 Change of variables in multiple integrals- Transformations, Change of Variables in Double Integrals [only the method is required; derivation omitted], illustrations, Change of Variables in Triple Integrals.

Module III **(30 Hours)**

15.1 Vector Fields- V.F. in two and three dimensional space, Conservative Vector Fields

15.2 Divergence and Curl- Divergence- idea and definition, Curl- idea and definition.

15.3 Line Integrals- Line integral w.r.t. arc length-motivation, basic idea and definition, Line Integrals with Respect to Coordinate Variables, orientation of curve Line Integrals in Space, Line Integrals of Vector Fields.

15.4 Independence of Path and Conservative Vector Fields-path independence through example, definition, fundamental theorem for line integral, Line Integrals Along Closed Paths, work done by conservative vector field, Independence of Path and Conservative Vector Fields, Determining Whether a Vector Field Is Conservative, test for conservative vector field Finding a Potential Function, Conservation of Energy.

15.5 Green's Theorem- Green's Theorem for Simple Regions, proof of theorem for simple regions, finding area using line integral, Green's Theorem for More General Regions, Vector Form of Green's Theorem.

15.6 Parametric Surfaces-Why We Use Parametric Surfaces, Finding Parametric Representations of Surfaces, Tangent Planes to Parametric Surfaces, Area of a Parametric Surface [derivation of formula omitted].

15.7 Surface Integrals-Surface Integrals of Scalar Fields, evaluation of surface integral for surfaces that are graphs, [derivation of formula omitted; only method required] Parametric Surfaces, evaluation of surface integral for parametric surface, Oriented Surfaces, Surface Integrals of Vector Fields- definition, flux integral, evaluation of surface integral for graph [method only], Parametric Surfaces, evaluation of surface integral of a vector field for parametric surface [method only].

15.8 The Divergence Theorem- divergence theorem for simple solid regions (statement only), illustrations, Interpretation of Divergence.

15.9 Stokes Theorem- generalization of Green's theorem- Stokes Theorem, illustrations, Interpretation of Curl.

Text

1. Calculus: Soo T Tan Brooks/Cole, Cengage Learning (2010).

References

1. Joel Hass, Christopher Heil & Maurice D. Weir: Thomas' Calculus(14/e) Pearson (2018).
2. Robert A Adams & Christopher Essex: Calculus Single Variable (8/e) Pearson Education Canada (2013).
3. Jon Rogawski & Colin Adams: Calculus Early Transcendentals (3/e) W. H. Freeman and Company (2015).
4. Anton, Bivens & Davis: Calculus Early Transcendentals (11/e) John Wiley & Sons, Inc. (2016).
5. James Stewart: Calculus (8/e) Brooks/Cole Cengage Learning (2016).
6. Jerrold Marsden & Alan Weinstein: Calculus I and II (2/e) Springer Verlag NY (1985).

SEMESTER IV

GMAH4B17T: LINEAR PROGRAMMING AND APPLICATIONS

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- The emphasis of this course is on nurturing the linear programming skills of students via. the algorithmic solution of small-scale problems, both in the general sense and in the specific applications where these problems naturally occur.
- This course should enable the course to learn how solve linear programming problems geometrically.
- This course should enable the course to understand game theory.

Course Outcomes

- To understand the drawbacks of geometric methods
- To solve LP problems more effectively using Simplex algorithm via. the use of condensed tableau of A.W. Tucker.
- To convert certain related problems, not directly solvable by simplex method, into a form that can be attacked by simplex method.
- To understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization.
- To solve transportation and assignment problems by algorithms that take advantage of the simpler nature of these problems.
- To solve LP problems using Python Program.

Module I **(24 Hours)**

Chapter 1- Geometric Linear Programming: Profit Maximization and Cost Minimization, typical motivating examples, mathematical formulation, Canonical Forms for Linear Programming Problems, objective functions, constraint set, feasible solution, optimal solution, Polyhedral Convex Sets, convex set, extreme point, theorems asserting existence of optimal solutions, The Two Examples Revisited, graphical solutions to the problems, A Geometric Method for Linear Programming, the difficulty in the method, Concluding Remarks.

Chapter 2- The Simplex Algorithm: Canonical Slack Forms for Linear Programming Problems; Tucker Tableaus, slack variables, Tucker tableaus, independent variables or non basic variables, dependent variables or basic variables. An Example: Profit Maximization, method of solving a typical canonical maximization problem, The Pivot Transformation, The Pivot Transformation for Maximum and Minimum Tableaus, An Example: Cost Minimization, method of solving a typical canonical minimization problem, The Simplex Algorithm for Maximum Basic Feasible Tableaus, The Simplex Algorithm for Maximum

Tableaus, Negative Transposition; The Simplex Algorithm for Minimum Tableaus, Cycling, Simplex Algorithm Anti cycling Rules, Concluding Remarks **(Practical using Python Program).**

Module II **(20 Hours)**

Chapter 3- Non canonical Linear Programming Problems: Unconstrained Variables, Equations of Constraint, Concluding Remarks.

Chapter 4- Duality Theory: Duality in Canonical Tableaus, The Dual Simplex Algorithm, The Dual Simplex Algorithm for Minimum Tableaus, The Dual Simplex Algorithm for Maximum Tableaus, Matrix Formulation of Canonical Tableaus, The Duality Equation, Duality in Noncanonical Tableaus, Concluding Remarks **(Practical using Python Program).**

Module III **(18 Hours)**

Chapter 5 Matrix Games:- An Example; Two- Person Zero- Sum Matrix Games, Domination in a Matrix Game, Linear Programming Formulation of Matrix Games, The Von Neumann Minimax Theorem, The Example Revisited, Two More Examples, Concluding Remarks **(Practical using Python Program).**

Module IV **(18 Hours)**

Chapter 6- Transportation and Assignment Problems: The Balanced Transportation Problem, The Vogel Advanced-Start Method (VAM), The Transportation Algorithm, Another Example, Unbalanced Transportation Problems, The Assignment Problem, The Hungarian Algorithm, Concluding Remarks, The Minimum-Entry Method, The Northwest-Corner Method **(Practical using Python Program).**

Text

1. Linear Programming and Its Applications: James K. Strayer Under-graduate Texts in Mathematics Springer (1989).

References

1. Robert J. Vanderbei: Linear Programming: Foundations and Extensions (2/e) Springer Science + Business Media LLC (2001).
2. Frederick S Hiller, Gerald J Lieberman: Introduction to Operation Research (10/e) McGraw-Hill Education, 2 Penn Plaza, New York (2015).
3. Paul R. Thie, G.E. Keough: An Introduction to Linear Programming and Game Theory (3/e) John Wiley and Sons, Ins.(2008).
4. Louis Brickman: Mathematical Introduction to Linear Programming and Game Theory UTM, Springer Verlag, NY (1989).
5. Jiri Matoušek, Bernd Gartner: Understanding and Using Linear Programming University text, Springer- Verlag Berlin Heidelberg (2007).

SEMESTER IV

GMAH4B18T: NUMERICAL COMPUTING

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- The goal of numerical computing is to provide techniques and algorithms to find approximate numerical solution to problems in several areas of mathematics where it is impossible or hard to find the actual/closed form solution by analytical methods.
- This course should enable the student to make an error analysis to ascertain the accuracy of the approximate solution.

Course Outcomes

- Understand several methods such as bisection method, fixed point iteration method, regula falsi method etc. to find out the approximate numerical solutions of algebraic and transcendental equations with desired accuracy.
- Understand the concept of interpolation and also learn some well-known interpolation techniques.
- Understand a few techniques for numerical differentiation and integration and also realize their merits and demerits.
- Find out numerical approximations to solutions of initial value problems and also to understand the efficiency of various methods.
- To solve the problems using Python Program.

Module I: Solutions of Equations in One Variable **(14 Hours)**

2.1 The Bisection Method
2.2 Fixed-Point Iteration
2.3 Newton's Method and Its Extensions-Newton's Method (Newton- Raphson method), Convergence using Newton's Method, The Secant; Method, The Method of False Position. [derivation of formula omitted in each case] **(Practical using Python Program)**

Module II: Interpolation and Polynomial Approximation **(14 Hours)**

3.1 Interpolation and the Lagrange Polynomial- motivation, Lagrange Interpolating Polynomials, error bound.
3.3 Divided Differences- kth divided difference, Newton's divided difference formula, Forward Differences, Newton Forward- Difference Formula, Backward Differences, Newton Backward- Difference Formula, Centered Differences, Stirling's formula. [derivation of formula omitted in each case] **(Practical using Python Program)**

Module III: Numerical Differentiation and Integration **(18 Hours)**

4.1 Numerical Differentiation- approximation of first derivative by Forward difference formula, backward difference formula, Three-Point Formulas, Three-Point Endpoint Formula, Three-Point Midpoint Formula [Five-Point Formulas, Five-Point Endpoint Formula, Five-Point Midpoint Formula omitted] Second Derivative Midpoint Formula to approximate second derivative, Round- Off Error Instability;

4.3 Elements of Numerical Integration-numerical quadrature, The Trapezoidal Rule, Simpson's Rule, Measuring Precision, Closed Newton- Cotes Formulas, Simpson's Three-Eighths rule, Open Newton- Cotes Formulas.

4.4 Composite Numerical Integration- composite Simpson's rule, composite trapezoidal rule, composite midpoint rule, round off error stability. [derivation of formula omitted in each case] **(Practical using Python Program).**

Module IV: Initial-Value Problems for Ordinary Differential Equations **(18 Hours)**

5.1 The Elementary Theory of Initial- Value Problems.

5.2 Euler's Method- derivation using Taylor formula, Error bounds for Euler Method;

5.3 Higher- Order Taylor Methods- local truncation error, Taylor method of order n and order of local truncation error.

5.4 Runge- Kutta Methods- only Mid-Point Method, Modified Euler's Method and Runge- Kutta Method of Order Four are required [derivation of formula omitted in each case] **(Practical using Python program)**.

Text

1. Numerical Analysis (10/e): Richard L. Burden, J Douglas Faires, Annette M. Burden, Brooks Cole Cengage Learning(2016) ISBN:978-1-305-25366-7

References

1. Kendall E. Atkinson, Weimin Han: Elementary Numerical Analysis (3/e) John Wiley & Sons (2004) ISBN: 0-471-43337-3, Indian Edition by Wiley India.
2. James F. Epperson: An Introduction to Numerical Methods and Analysis (2/e) John Wiley & Sons (2013).
3. Timothy Sauer: Numerical Analysis (2/e) Pearson (2012).
4. S.S. Sastri: Introductory Methods of Numerical Analysis (5/e) PHI Learning Pvt. Ltd. (2012).
5. Ward Cheney, David Kincaid: Numerical Mathematics and Computing (6/e) Thomson Brooks/ Cole (2008).

SEMESTER IV

GMAH4B19P: STATISTICAL DATA ANALYSIS USING R (PRACTICAL)

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **2.5 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- To understand basics of Microsoft excel
- To develop scientific and experimental skills to correlate theoretical principles of statistics with application-based studies
- To familiarize the students with basics of statistical data analysis software R and SPSS

Course Outcomes

- To carry out elementary statistical data analysis using Microsoft excel, R and SPSS
- To construct various graphs and tables for different kind of data sets
- To make valid conclusions and results based on statistical theory using small and large sample data

Module I **(15 Hours)**

Introduction to MS- excel, Data entry in MS excel, Application of functions and formulae, Basic mathematical operations and graphical procedures using Excel, Data analysis with excel add-ins- calculation of descriptive statistics, correlation and regression.

Module II **(20 Hours)**

Introduction to the statistical software R, Data objects in R, Creating vectors, Creating matrices, Manipulating data, Accessing elements of a vector or matrix, Lists, Addition, Multiplication, Subtraction, Transpose, Inverse of matrices. Read a file. Boolean operators (application of above concepts in practical data).

Module III **(15 Hours)**

Descriptive statistics using R, Measures of central tendency, Measures of dispersion, R-Graphics- Histogram, Box-plot, Stem and leaf plot, Scatter plot, Matplot, Plot options; Multiple plots in a single graphic window, Adjusting graphical parameters. Looping- For loop, repeat loop, while loop, if command, if else command (application of above concepts in practical data).

Module IV **(20 Hours)**

Introduction to SPSS, Preparing data file, Inputting transforming and sorting data, Descriptive statistics using SPSS, Measures of central tendency, Measures of dispersion, Frequency tables, Graphical representation of data, Pearson correlation and rank correlation, Simple linear regression, multiple linear regression, logistic regression (application of above concepts in practical data).

Module V **(20 Hours)**

Statistical inference using SPSS, Checking normality of data, Independent sample t-test, Paired sample t-test, One-way ANOVA and two-way ANOVA, Cross tabs odds ratio and Chi-square test, Non parametric tests, Mann-Whitney U test, Wilcoxon signed rank test, Kruskal-Wallis test (application of above concepts in practical data).

References

1. Alain F. Zuur, Elena N. Ieno, and Erik Meesters (2009): "A Beginner's Guide to R" Springer, ISBN: 978-0-387-93836-3.
2. Michael J. Crawley (2005): "Statistics: An Introduction using R", Wiley, ISBN 0-470-02297-3.
3. Phil Spector (2008): "Data Manipulation with R", Springer, New York, ISBN 978-0-387-74730-9.
4. Field A., "Discovering Statistics Using SPSS", Fourth Edition, SAGE, 2013.
5. Daniel j Denis (2018), "SPSS Data analysis for univariate bivariate and multivariate statistics" Wiley, ISBN: 9781119465775.

Examination Pattern

GMAH4B19P: STATISTICAL DATA ANALYSIS USING R

Marks: 100 [Internal: 20, External: 80 (Record: 20 & Practical Exam: 60)]
Pattern of External Practical Examination

Time: 3 Hours Max. Marks: 60

Section A (Each question carries 2 Marks) (5x2= 10 Marks)
I. Answer any 1 question out of 2 from Excel
II. Answer any 2 questions out of 3 from R programming
III. Answer any 2 questions out of 3 from SPSS

Section B (Each question carries 5 Marks) (6 x 5= 30 Marks)
IV. Answer any 2 questions out of 3 from Excel.
V. Answer any 2 questions out of 3 from R programming
VI. Answer any 2 questions out of 3 from SPSS

Section C (Each question carries 10 Marks) (2 x 10= 20 Marks)
VII. Answer any 1 question out of 2 from R programming
VIII. Answer any 1 question out of 2 from SPSS

SEMESTER V

GMAH5B20T: ALGEBRA I

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objective

- To learn several examples, are taught to check whether an algebraic system forms a group or not and are introduced to some fundamental results of group theory.
- To learn about the idea of structural similarity, the notion of cyclic group, permutation group, various examples and very fundamental results in the area of group theory.

Course Outcomes

- At the end of the course students explain the general way in which algebraic structures are introduced and studied in an abstract fashion.
- Students enjoy the construction of algebraic structures and they begin to develop new algebraic structures by generalizing the well-known examples.

Module I **(20 Hours)**
Binary operations; Isomorphic binary structures; Groups; Subgroups (Sections 2, 3, 4 & 5).

Module II **(20 Hours)**
Cyclic groups; Groups and permutations; Orbits, cycles, and Alternating groups (Sections 6, 8 & 9).

Module III **(20 Hours)**
Cosets and Theorem of Lahrange, Dierected products and finitely generated abelian groups, Homomorphisms (Sections 10, 11, & 12)

Module IV **(20 Hours)**
Factor Groups, Factor Group Computation, Simple Groups, Group Action (Sections 14, 15, &16)

Text

1. John B. Fraleigh: A First Course in Abstract Algebra, 7th Edition, Pearson.

References

1. Joseph A. Gallian: Contemporary Abstract Algebra. Narosa Pub. House.
2. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul: Basic Abstract Algebra, 2nd edition, Cambridge University Press.
3. Michael Artin: Algebra, 2nd edition, ISBN-13, 978-0132413770 PHI

SEMESTER V

GMAH5B21T: COMPLEX ANALYSIS

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- The course is aimed to provide a thorough understanding of complex function theory
- The focus of the course is on the study of analytic functions and their basic behavior with respect to the theory of complex calculus.

Course Outcomes

- To understand the difference between differentiability and analyticity of a complex function and construct examples.
- To understand necessary and sufficient condition for checking analyticity.
- To know of harmonic functions and their connection with analytic functions.
- To know a few elementary analytic functions of complex analysis and their properties.
- To understand definition of complex integral, its properties and evaluation.
- To know a few fundamental results on contour integration theory such as Cauchy's theorem, Cauchy- Goursat theorem and their applications.
- To understand and apply Cauchy's integral formula and a few consequences of it such as Liouville's theorem, Morera's theorem and so forth in various situations.
- To see the application of Cauchy's integral formula in the derivation of power series expansion of an analytic function.
- To see another application of residue theory in locating the region of zeros of an analytic function.

Module I: Complex Numbers **(20 Hours)**

2.1 Are complex numbers necessary?
2.2 Basic properties of complex numbers

Chapter 3: Prelude to complex analysis;
3.1 Why is complex analysis possible?
3.2 Some useful terminology;
3.3 Functions and continuity;

Chapter 4: Differentiation: Differentiability: Power series: Logarithms 4.5: Singularities

Module II: Complex Integration **(20 Hours)**

5.1 The Heine-Borel theorem

5.2 Parametric representation: Integration: Estimation: Uniform convergence

Module III: Cauchy's theorem **(20 Hours)**

Cauchy's theorem: A first approach: Cauchy's theorem: A more general version

6.3 Deformation

Chapter 7: Some consequences of Cauchy's theorem: Cauchy's integral formula: The fundamental theorem of algebra

7.3 Logarithms

7.4 Taylor series

Module IV: Laurent series and Residue theorem **(20 Hours)**

Laurent series: Classification of singularities

8.3 The residue theorem

Chapter 9: Applications of Contour Integration

9.1 Real integrals: Semicircular contours

9.2 Integrals involving circular functions

Text

1. Complex Analysis: John M. Howie, Springer InternationalEdition

References

1. James Ward Brown, Ruel Vance Churchill: Complex variables andapplications (8/e) McGraw-Hill Higher Education (2009).
2. John B. Conway, Functions of one complex variable (2nd edition), Springer international student edition, 1973.
3. Alan Jeffrey: Complex Analysis and Applications (2/e) Chapman and Hall/CRC Taylor Francis Group (2006).
4. Saminathan Ponnusamy, Herb Silverman: Complex Variables with Applications Birkhauser Boston (2006).
5. John H. Mathews & Russell W. Howell: Complex Analysis for Mathematics and Engineering (6 /e).
6. H A Priestly: Introduction to Complex Analysis (2/e) Oxford University Press (2003).
7. Jerrold E Marsden, Michael J Hoffman: Basic Complex Analysis (3/e) W.H Freeman, N.Y. (1999).

SEMESTER V

GMAH5B22T: LINEAR ALGEBRA

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- This course should enable the student to study the linear systems of equations, vector spaces, and linear transformations.
- A number of methods for solving a system of linear equations are discussed.
- The introduction of central topic of linear algebra namely the concept of a vector space.
- The idea of a subspace, spanning vectors, basis and dimension are discussed and fundamental results in these areas are explored.
- This enables the student to understand the relationship among the solutions of a given system of linear equations and some important subspaces associated with the coefficient matrix of the system.

Course Outcomes

- The student will come to understand the modern view of a matrix as a linear transformation.
- To find out the eigenvalues from the characteristic equation and the corresponding eigenvectors.
- To check whether diagonalization is possible and learn procedure for diagonalizing a given matrix
- To realize that there are matrices that cannot be diagonalized and even learn to check it.
- To learn that only symmetric matrices with real entries can be orthogonally diagonalized and using Gram-Schmidt process.

Module I **(17 Hours)**

1.1: Introduction to Systems of Linear Equations Linear equation in n variables, linear system of m equations in n variables, solution, Linear Systems in Two and Three Unknowns, solution by geometric analysis, consistent and inconsistent systems, linear system with no, one, and infinite number of solutions, augmented matrix and elementary row operations.

1.2: Gaussian elimination Considerations in Solving Linear Systems, Echelon Forms, reduced row echelon form, Elimination Methods, Gauss–Jordan elimination, Gaussian elimination, Homogeneous Linear Systems, Free Variables, Free Variable Theorem for Homogeneous Systems, Gaussian Elimination and Back Substitution, Some Facts about Echelon Forms.

1.3: Matrices and Matrix operations Matrix Notation and Terminology, row vector, column vector, square matrix of order n, Operations on Matrices, Partitioned Matrices, Matrix Multiplication by Columns and by Rows, Matrix Products as Linear Combinations, linear combination of column vectors, Column Row Expansion, Matrix Form of a Linear System, Transpose of a Matrix, Trace of a Matrix.

1.4: Inverses and algebraic properties of matrices Properties of Matrix Addition and Scalar Multiplication, Properties of Matrix Multiplication, Zero Matrices and Properties, Identity Matrices, Inverse of a Matrix, Properties of Inverses, Solution of a Linear System by Matrix Inversion, Powers of a Matrix, Matrix Polynomials, Properties of the Transpose.

1.5: Elementary matrices and a method for finding A^{-1} Equivalence, elementary matrix, Row Operations by Matrix Multiplication, invertibility of elementary matrices, invertibility and equivalent statements, A Method for Inverting Matrices, Inversion Algorithm, illustrations.

1.6: More on linear systems and invertible matrices Number of Solutions of a Linear System, Solving Linear Systems by Matrix Inversion, Linear Systems with a Common Coefficient Matrix, Properties of Invertible Matrices, equivalent statements for unique solution of $Ax= b$, determining consistency.

1.7: Diagonal, Triangular and Symmetric matrices Diagonal Matrices, Inverses and Powers of Diagonal Matrices, Triangular Matrices. Properties of Triangular Matrices, Symmetric Matrices, algebraic properties of symmetric matrices, Invertibility of Symmetric Matrices.

1.8: Matrix transformations Definition, Properties of Matrix Transformations, standard matrix, A Procedure for Finding Standard Matrices.

2.1: Determinants by cofactor expansion Minors, cofactors, cofactor expansion, Definition of a General Determinant, A Useful Technique for Evaluating 2 × 2 and 3×3 Determinants;

2.2: Evaluating determinants by row reduction Examples and problems to find determinant by row reduction (Theory omitted);

2.3 Properties of Determinants; Cramer's Rule Cramer's Rule (Only problems), Inverse of matrices using adjoint formula (Only problems).

Module II **(18 Hours)**

4.1: Real vector space Vector Space Axioms, examples, Some Properties of Vectors.

4.2: Subspaces Definition, criteria for a subset to be a subspace, examples, Building Subspaces, linear combination, spanning, Solution Spaces of Homogeneous Systems as subspace, The Linear Transformation Viewpoint, kernel, different set of vectors spanning the subspace.

4.3: Linear Independence Linear Independence and Dependence, illustrations, A Geometric Interpretation of Linear Independence, Wronskian, linear independence using Wronskian.

4.4: Coordinates and basis Coordinate Systems in Linear Algebra, Basis for a Vector Space, finite and infinite dimensional vector spaces, illustrations, Coordinates Relative to a Basis, Uniqueness of Basis Representation.

4.5: Dimension Number of Vectors in a Basis, dimension, Some Fundamental Theorems, dimension of subspaces.

Module III **(22 Hours)**

4.6: Change of Basis Coordinate Maps, Change of Basis, Transition Matrices, Invertibility of Transition Matrices, An Efficient Method for Computing Transition Matrices for $\mathbb{R}^n$, Transition to the Standard Basis for $\mathbb{R}^n$.

4.7: Row space, Column space and Null space Vector spaces associated with matrices, consistency of linear system, Bases for Row Spaces, Column Spaces, and Null Spaces, basis from row echelon form, Basis for the Column Space of a Matrix, row equivalent matrices and relationship between basis for column space, Bases Formed from Row and Column Vectors of a Matrix.

4.8 Rank, Nullity, and the Fundamental Matrix Spaces Equality of dimensions of row and column spaces, Rank and Nullity, Dimension Theorem for Matrices, The Fundamental Spaces of a Matrix, rank of a matrix and its transpose, A Geometric Link Between the Fundamental Spaces, orthogonal complement, invertibility and equivalent statements, Applications of Rank, Overdetermined and Underdetermined Systems.

4.9: Basic matrix transformations in $\mathbb{R}^2$ and $\mathbb{R}^3$ Reflection Operators, Projection Operators, Rotation Operators, Rotations in $\mathbb{R}^3$, Dilations and Contractions, Expansions and Compressions, Shears, Orthogonal Projections onto Lines Through the Origin, Reflections About Lines Through the Origin.

4.10: Properties of matrix transformations Compositions of Matrix Transformations, One to One Matrix Transformations, Kernel and Range, fundamental relationship between invertibility of a matrix and its matrix transformation, Inverse of a One-to-One Matrix Operator.

Module IV **(23 Hours)**

4.11: Geometry of matrix operators Transformations of Regions, Images of Lines Under Matrix Operators, Geometry of Invertible Matrix Operators, Elementary matrix and its matrix transformation, consequence.

5.1: Eigen values and Eigen Vectors Definition, Computing Eigenvalues and Eigenvectors, characteristic equation, alternative ways of describing eigen values, Finding Eigenvectors and Bases for Eigenspaces, Eigenvalues and Invertibility, Eigenvalues of General Linear Transformations.

5.2: Diagonalization The Matrix Diagonalization Problem, linear independence of eigen vectors and diagonalizability, Procedure for Diagonalizing a Matrix, Eigenvalues of Powers of a Matrix, Computing Powers of a Matrix, Geometric and Algebraic Multiplicity.

6.1: Inner Product Definition of General inner product, Euclidean inner product (or the standard inner product) on $\mathbb{R}n$, norm of a vector, properties (up to and including theorem 6.1.1), a few examples (only example7 and example 10) [rest of the section omitted].

6.2: Angle and orthogonality in Inner product spaces. Only the definition of orthogonality in a real inner product space (to be motivated by the relation in the definition (3) of section 3.2) and examples (2), (3) and (4).

6.3: Gram–Schmidt Process Definition of Orthogonal and Orthonormal Sets, examples, linear independence of orthogonal set, orthonormal basis, Coordinates Relative to Orthonormal Bases [‘Orthogonal Projections’ omitted] The Gram–Schmidt Process [only statement of Theorem 6.3.5 and the step-by-step construction technique are required; derivation omitted], illustrations examples 8 and 9, [rest of the section omitted].

7.1: Orthogonal Matrices Definition, characterisation of orthogonal matrices, properties of orthogonal matrices, Orthogonal Matrices as Linear Operators, a geometric interpretation [rest of the section omitted].

Text

1. Elementary Linear Algebra: Application Version(11/e): Howard Anton & Chris Rorres, Wiley (2014) ISBN 9781118434413

References

1. Linear Algebra Done Right: Sheldon Axler, Second Edition, Springer (2015) ISBN 978-3-319-11079-0.
2. Jim DeFranza, Daniel Gagliardi: Introduction to Linear Algebra with Applications Waveland Press, Inc. (2015) ISBN: 1478627778.
3. Otto Bretscher: Linear Algebra with Applications (5/e) Pearson Education, Inc. (2013) ISBN: 0321796977.
4. Ron Larson, Edwards, David C Falvo: Elementary Linear Algebra (6/e) Houghton Mifflin Harcourt Publishing Company (2009) ISBN: 0618783768.
5. David C. Lay, Steven R. Lay, Judi J. McDonald: Linear Algebra and its Application (5/e) Pearson Education, Inc. (2016) ISBN: 032198238X.
6. Martin Anthony, Michele Harvey: Linear Algebra: Concepts and Methods Cambridge University Press (2012) ISBN: 9780521279482.
7. Jeffrey Holt: Linear Algebra with Applications W. H. Freeman and Company (2013) ISBN: 071678667.

SEMESTER V

GMAH5B23T: OBJECT ORIENTED PROGRAMMING USING C++

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Introduces Object Oriented Programming concepts using the C++ language.
- Introduces the principles of data abstraction, inheritance and polymorphism.
- Introduces the principles of virtual functions and polymorphism.
- Introduces handling formatted I/O and unformatted I/O.
- Introduces exception handling.

Course Outcomes

- Able to develop programs with reusability, data abstraction and inheritance.
- Apply the principles of virtual functions and polymorphism.
- Handle exceptions in programming.
- Develop applications for a range of problems using object-oriented programming techniques.

Module I

Introduction to object-oriented programming, Characteristics of OOPS, Object oriented languages, comparison between Procedural and object-oriented programming, basic principles of Object Orientation-class, object, Abstraction, encapsulation, inheritance, polymorphism, modularity, and message passing. C++ Language Components: Primitive Data Types, Comments, Keywords, literals, Operators, Loops, The break and continue Statement.

Module II

Classes and Objects, Defining classes, Creating objects, Defining member function, Static class members, Friend functions, Passing and returning objects to and from functions, Constructors: Default constructors, Parameterized constructors, Constructor overloading, Constructors with default arguments, Copy constructors- Destructors.

Module III

Dynamic memory management, new and delete operators, Pointers to objects, Pointers to object members, Accessing members, this pointer, Operator overloading: Overloading unary and binary operators, Type conversion: Between objects and basic types and between objects of different classes, Inheritance: Single Inheritance, Overriding base class members, Abstract classes, Constructors and destructors in derived classes, Multilevel inheritance, Multiple Inheritance, Hierarchical Inheritance, Hybrid Inheritance, Virtual functions, Virtual base class.

Module IV

Polymorphism: Binding, Static binding, Dynamic binding, Static polymorphism: Function Overloading, Ambiguity in function overloading, Dynamic polymorphism: Base class pointer, object slicing, late binding, method overriding with virtual functions, pure virtual functions. Exception handling: Try, throw, and catch, exceptions and derived classes.

References

1. Object Oriented Programming with C++ by E. Balagurusamy, McGraw-Hill Education (India).
2. ANSI and Turbo C++ by Ashoke N. Kamthane, Pearson Education.
3. C++: The Complete Reference- Schildt, McGraw-Hill Education (India).
4. Bjarne Stroustrup, “The C++ Programming Language”, Pearson Education, 2004.

V SEMESTER ELECTIVES

SEMESTER V

Elective 1

GMAH5E01T: TOPOLOGY

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objective

- To demonstrate an understanding of the concepts of metric spaces and topological spaces, and their role in mathematics.
- To learn about the concepts of closed set, open set, closure of a set, neighborhoods, interior and accumulation points in a Topological space.

Course Outcomes

- Upon completing the course, students will be proficient in abstract notion of a toplogical space, where continuous function are defined in terms of open set not in the traditional $\varepsilon - \delta$ definition used in analysis.
- Upon completing the course, students will realize Intermediate value theorem is a statement about connectedness.

Module I **(20 Hours)**

(A quick review of metric spaces)

4.1 Definition of a Topological Space

4.2 Examples of Topological Spaces

Module II **(20 Hours)**

4.3 Bases and Sub-bases

4.4 Subspaces

Module III **(20 Hours)**

5.1 Closed sets and Closure

5.2 Neighbourhoods, Interior and Accumulation Points

Module IV **(20 Hours)**

5.3 Continuity and Related Concepts

6.1 Smallness conditions on a Space (Excluding the proof of Theorem 1.16)

6.2 Connectedness

Text

1. James R. Munkres- Topology A First Course, 2^{nd} edition- Prentice Hall of India.

References

1. C. Wayne Patty, Foundations of Topology, Second Edition- Jones & Bartlett India Pvt.Ltd., New Delhi, 2012.
2. K. D. Joshi, Introduction to General Topology, New Age International (P) Ltd. Publishers.
3. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill.
4. S. Willard, General Topology, Addison Wesley Publishing Compan.

SEMESTER V

Elective 2

GMAH5E02T: MATHEMATICAL FINANCE

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objective

- To learn the basics of Black-Scholes option pricing formula.
- To learn some applications of integration in various financial modeling situations

Course Outcomes

- To understand the role of risk neutral probability measures the use of some elements of stochastic calculus in mathematical finance.
- To understand the concepts of The Arbitrage theorem to form a pricing model for the stocks.

Module 1 **(20 Hours)**

2.3 Finance (2.3.1 - 2.3.5 of Text 1)
5.6 Some Applications of Integration (5.6.1 - 5.6.3 of Text 1)

Module II **(20 Hours)**

12.4 Linear difference equations (12.4.1 - 12.4.3 of Text 1)
10 Consumer Mathematics (10.1 - 10.4 of Text 2)

Module III **(20 Hours)**

6 The Arbitrage Theorem (6.1 - 6.3 of Text 3)
7 The Black- Scholes Formula (7.1 - 7.3 of Text 3)

Module IV **(20 Hours)**

10 Stochastic Order Relations (10.1 - 10.5 of Text 3)

Texts

1. Frank Verner and Yuri N. Sotskov, Mathematics of Economics and Business, Routledge Publications, 2006.
2. Timothy J. Biehler, The Mathematics of Money, The McGraw Hill Company, 2008.
3. Sheldon M. Ross. An elementary introduction to mathematical finance, Cambridge University Press 2011

SEMESTER V

Elective 3

GMAH5E03T: DIFFERENTIAL GEOMETRY

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objective

- This course should enable the student to understand the idea of orientable and non-orientable surfaces
- This course should enable the student develop arguments in the geometric description of curves and surfaces in order to establish basic properties of geodesic and parallel transport.

Course Outcomes

- To recognize the concept of curves and surfaces
- To understand the concept of curvature of a surface and able to compute the curvature of space curves.
- To understand geodesic as a distance minimizing curves on surfaces and find the geodesic of various surfaces.

Module I **(20 Hours)**

Chapter 1 Graphs and Level Sets

Chapter 2 Vector Fields

Module II **(20 Hours)**

Chapter 3 The Tangent Space

Chapter 4 Surfaces

Module III **(20 Hours)**

Chapter 5 Vector Fields on Surfaces; Orientation

Chapter 7 Geodesics

Module IV **(20 Hours)**

Chapter 8 Parallel Transport

Chapter 9 The Weingarten Map

Text

1. John A. Thorpe, Elementary Topics in Differential Geometry, Springer, 1979.

References

1. W.L. Burke: Applied Differential Geometry Cambridge University Press (1985)
2. M. de Carmo: Differential Geometry of Curves and Surfaces Prentice Hall Inc Englewood Cliffs NJ (1976).
3. V. Grilleman and A. Pollack: Differential Topology Prentice Hall Inc Englewood Cliffs NJ (1974).
4. B. O'Neil: Elementary Differential Geometry Academic Press NY (1966).
5. M. Spivak: A Comprehensive Introduction to Differential Geometry, (Volumes 1 to 5) Publish or Perish, Boston (1970, 75).
6. R. Millmen and G. Parker: Elements of Differential Geometry Prentice Hall Inc Englewood Cliffs NJ (1977).
7. I. Singer and J.A. Thorpe: Lecture Notes on Elementary Topology and Geometry UTM, Springer Verlag, NY (1967)

SEMESTER V

Elective 4

GMAH5E04P: MATHEMATICAL DOCUMENTATION USING LATEX

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objective

- To understand the basis of LaTeX.
- To learn how to apply LaTeX in plotting mathematical functions, mathematical symbols, multiline formulas, spacing and changing style in math mode.

Course Outcomes

- To install and use LaTeX.
- To understands typesetting using Latex and apply Latex in writing equations.

Module I: Getting Started with LaTeX

Introduction to TeX and LaTeX, Typesetting a simple document, Adding basic information to a document, Environments, Footnotes, Sectioning and displayed material.

Module II: Mathematical Typesetting with LaTeX

Accents and symbols, Mathematical typesetting (elementary and advanced): Subscript/ Superscript, Fractions, Roots, Ellipsis, Mathematical Symbols, Arrays, Delimiters, Multiline formulas, Spacing and changing style in math mode.

Module III: Graphics and Beamer Presentation in LaTeX

Graphics in LaTeX, Simple pictures using PSTricks, Plotting of functions, Beamer presentation.

Module IV: HTML

HTML basics, Creating simple web pages, Images and links, Design of web pages.

External Examination (Practical)

The external examination is a practical examination of 3 hr duration. The Practical Examinations will be conducted by 2 examiners (One External and One Internal). The Practical examination has 3 sections ; 2 LaTex (document/beamer) preparation and 1 web page designing (based on the syllabus).

References

1. Bindner, Donald & Erickson, Martin. (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group, LLC.
2. Lamport, Leslie (1994). LaTeX: A Document Preparation System, User's Guide and Reference Manual (2nd edition). Pearson Education. Indian Reprint.
3. Dongen, M. R. C. van (2012). LaTeX and Friends. Springer-Verlag.
4. Robbins, J. N. (2018). Learning Web Design: A Beginner's Guide to HTML (5th edition). O'Reilly Media Inc.

SEMESTER VI

GMAH6B24T: ALGEBRA II

Contact Hours : 80 (5 hrs./wk.)
Number of Credits : 4
Examination : 3 Hours
Course Evaluation : 100 (Internal: 20 + External: 80)

Course Objectives

- To learn several examples, are taught to check whether an algebraic system forms a ring (or field) or not and are introduced to some fundamental results of ring theory and field theory.
- To learn about the idea of structural similarity, the notion of factor rings, ideals, various examples and very fundamental results in the area of ring theory and field theory.

Course Outcomes

- At the end of the course students explain the general way in which algebraic structures are introduced and studied in an abstract fashion.
- Students enjoy the construction of algebraic structures and they begin to develop new algebraic structures by generalizing the well-known examples.

Module I **(20 Hours)**

Rings and Fields, Integral Domains (Sections 18&19)

Module II **(25 Hours)**

Fermat's and Euler's theorems, The field of quotients of an integral domain (Sections 20 & 21)

Module III **(25 Hours)**

Rings of Polynomials, Factorization of Polynomials over a Field (Sections 21 & 22)

Module IV **(20 Hours)**

Homomorphisms and factor rings, Prime and maximal ideal (Sections 26 & 27)

Text

1. Fraleigh, J.B.: A First Course in Abstract Algebra. (7^{th} Edition) Pearson (2003).

References

1. I.N. Herstein: Topics in Algebra Wiley Eastern (Reprint)
2. N.H. Mc Coy and R. Thomas: Algebra. Allyn & Bacon Inc. (1977).
3. J. Rotman: The Theory of Groups Allyn & Bacon Inc. (1973).
4. Hall, Marshall: The Theory of Groups. Chelsea Pub. Co. NY (1976).
5. Clark, Allan: Elements of Abstract Algebra Dover Publications (1984).
6. L.W. Shapiro: Introduction to Abstract Algebra McGraw Hill Book Co. NY (1975).

SEMESTER VI

GMAH6B25T: GRAPH THEORY

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- To analyze properties of graphs.
- To understand trees and their properties.
- To distinguish between Eulerian and Hamiltonian graphs.
- To analyze planar graphs.

Course Outcomes

- To understand and apply the fundamental concepts in graph theory.
- To apply graph theory based tools in solving practical problems.
- To improve the proof writing skills.

Module I **(24 Hours)**

An introduction to graph. Definition of a Graph, Graphs as models, More definitions, Vertex Degrees, Sub graphs, Paths and cycles The matrix representation of graphs (definition & example only) (Section 1.1 to 1.7).

Module II **(20 Hours)**

Trees and connectivity. Definitions and Simple properties, Bridges, Spanning trees, Cut vertices and connectivity (Section 2.1, 2.2, 2.3 & 2.6).

Module III **(20 Hours)**

Euler Tours and Hamiltonian Cycles .Euler’s Tours, The Chinese postman problem .Hamiltonian graphs, The travelling salesman problem, Matching and Augmenting paths, Hall`s Marriage Theorem- statement only, The personnel Assignment problem, The optimal Assignment problem, matching (Section 3.1, 3.2, 3.3, 3.4, 4.1, 4.2 4.3, 4.4).

Module IV **(20 Hours)**

Plane and Planar Graphs, Euler’s Formula, Kuratowski’s Theorem, Vertex Colouring, Critical Graphs (Section 5.1, 5.2, 5.4, 6.1, 6.3).

Text

1. John Clark Derek Allen Holton- A first look at graph theory, Allied Publishers.

References

1. Douglas B West Peter Grossman- Introduction to Graph Theory.

2. W.D. Wallis- A Biginner's Guide to Discrete Mathematics, Springer.
3. R. Balakrishnan, K. Ranganathan- A textbook of Graph Theory, Springer International Edition.
4. S. Arumugham, S. Ramachandran- Invitation to Graph Theory, Scitech. Peter Grossman.
5. J.K Sharma- Discrete Mathematics (2nd edition), (Macmillion).
6. S.A. Choudam- A First Course in Graph Theory (Macmillian).

SEMESTER VI

GMAH6B26T: DATA STRUCTURES USING C++

Contact Hours : **64 (4 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objectives

- To implement linear and non-linear data structure operations using C++ programs
- To solve problems implementing appropriate data structures
- To implement sorting and searching algorithms using relevant data structures

Course Outcomes

- Implement abstract data types using arrays and linked list.
- Apply the different linear data structures like stack and queue to various computing problems.
- Implement different types of trees and apply them to problem solutions.
- Discuss graph structure and understand various operations on graphs and their applicability.
- Analyse the various sorting and searching algorithms.
- Understand the hashing technique and hash functions.

Module I

Data structure- definition- types & operations, characteristics of data structures. Contiguous Data Structures: Arrays- Introduction, Linear arrays, Representation of linear array in memory, Operations on one dimensional array: Traversal, Insertions, Deletion, sorting in an array.

Module II

Linked List- Introduction, Representation of linked lists in memory, Traversal, Insertion, Deletion, Searching in a linked list, Circular linked list, Two-way linked list. Stack: primitive operation on stack, Representation of Stack in memory, Evaluation of arithmetic expressions, Queue- operations and its representation in memory- circular queue, doubly ended queue, priority queue.

Module III

Trees- Basic Terminology, representation, Binary Trees, Tree Representations using Array & Linked List, Basic operation on Binary tree: insertion, deletion and processing, Traversal of binary trees: In order, Pre-order & post-order. Introduction to graphs, Definition, Terminology, Directed, Undirected & Weighted graph, Representation of graphs, graph traversal- depth-first and breadth-first traversal of graphs.

Module IV

Searching and Sorting: Searching: Linear search, Binary search, Comparison of different methods, Sorting: Insertion, Bubble, Selection, Quick and Merge sort methods, Comparisons, Hashing: Different hashing functions, Methods for collision handling.

References

1. E. Horowitz & S. Sahni, Fundamentals of data structures.
2. Aron M., Tenenbaum, Data Structure Using C and C++.
3. Data structures, Algorithms, and applications in C++, Sartaj Sahni, Mc. Graw Hill, 2000.
4. “Fundamental of Data Structure” (Schaums Series) Tata-McGraw- Hill.

SEMESTER VI

GMAH6B27P: PRACTICAL (DATA STRUCTURES)

Contact Hours	**: 64 (4 hrs./wk.)**
Number of Credits	**: 3**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objectives

- Implement programs using classes and objects.
- Develop solutions using inheritance and polymorphism concepts.
- Utilize try and catch blocks to handle exceptions.
- Implement ADT using arrays and Linked list.
- Perform operations on Binary tree.
- Implement programs for Linear search, Binary search and different sorting methods.

Part A: C++ – Lab Questions

1. Write a C++ Program to display Names, Roll No., and grades of 3 students who have appeared in the examination. Declare the class of name, Roll No. and grade.
2. Create an array of class objects. Read and display the contents of the array.
3. Write a C++ program to declare Struct. Initialize and display contents of member variables.
4. Write a C++ program to declare a class. Declare pointer to class. Initialize and display the contents of the class member.
5. Given that an EMPLOYEE class contains following members: data members: Employee number, Employee name, Basic, DA, IT, Net Salary and print data members.
6. Write a C++ program to read the data of N employee and compute Net salary of each employee (DA=52% of Basic and Income Tax (IT) =30% of the gross salary).
7. Write a C++ to illustrate the concepts of console I/O operations.
8. Write a C++ program to use scope resolution operator. Display the various values of the same variables declared at different scope levels.
9. Write a C++ program to allocate memory using new operator.
10. Write a C++ program to create multilevel inheritance. (Hint: Classes A1, A2, A3).
11. Write a program that demonstrates function overloading, operator overloading.
12. Write a C++ program to create an array of pointers. Invoke functions using array objects.
13. Write a program that demonstrates friend functions, inline functions.
14. Write a C++ program to use pointer for both base and derived classes and call the member function. Use Virtual keyword.
15. a) Write a program that handles Exceptions. Use a Try Block to Throw it and a Catch Block to Handle it Properly.
    b) Write a Program to demonstrates user defined exceptions.

Part B: Data structure - Lab Questions

1. Write a program to merge two sorted array into one sorted array
2. Write a C++ programs to implement
   i) Linear search
   ii) Binary search
3. Write a C++ programs to implement
   i) Bubble sort
   ii) Selection sort
   iii) Guick sort
4. Write a C++ programs to implement **stack** using an array.
5. Write a C++ programs to implement **queue** using an array.
6. Write a C++ programs to implement list ADT to perform following operations
   a) Insert an element into a list
   b) Delete an element from list
   c) Search for a key element in list
   d) Count number of nodes in list
7. Write C++ programs to implement the **stack** using a singly linked list.
8. Write C++ programs to implement the **queue** using a singly linked list.
9. Write C++ programs to implement the deque (double ended queue) ADT using a doubly linked list and an array.
10. Write a C++ program to perform the following operations:
    a) Insert an element into a binary search tree.
    b) Delete an element from a binary tree.
11. Write C++ programs that use recursive functions to traverse the given binary tree in a) Preorder b) inorder and c) postorder.
12. Write a C++ program to implement all the functions of a dictionary (ADT) using hashing.

VI SEMESTER
ELECTIVES

SEMESTER VI
Elective 1
GMAH6E05T: MATHEMATICAL ECONOMICS

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objective

- To analyze properties of market equilibrium.
- To understand applications to Market and National Income Models.
- To understand applications of Integration.

Course Outcomes

- To understand equilibrium analysis in Economics.
- To understand some Economic Applications of Integrals.

Module I: Equilibrium Analysis in Economics **(20 Hours)**

3.1 The Meaning of Equilibrium
3.2 Partial Market Equilibrium- A linear Model
3.3 Partial Market Equilibrium- A non-linear Model
3.4 General Market Equilibrium
3.5 Equilibrium in National Income Analysis

Module II: Matrix Analysis **(20 Hours)**

5.6 Applications to Market and National Income Models
5.7 Leontif Input-Output Model

Module III: Further topics in Optimization **(20 Hours)**

13.1 Non-linear Programming and Kuhn-Tucker Conditions
13.2 The Constraint Qualification
13.3 Economic Applications
13.4 Sufficiency Theorems in Non-linear Programming

Module IV: Applications of Integration **(20 Hours)**

14.5 Some Economic Applications of Integrals
14.6 Domar Growth Model

Text

1. Alpha C. Chiang, Kevin Wainwright, Fundamental Methods of Mathematical Economics, 4^{th}Edition, 2005.

SEMESTER VI

Elective 2

GMAH6E06T: FUZZY MATHEMATICS

Contact Hours	**: 80 (5 hrs./wk.)**
Number of Credits	**: 4**
Examination	**: 3 Hours**
Course Evaluation	**: 100 (Internal: 20 + External: 80)**

Course Objective

- To understand the fundamental concepts of Fuzzy Mathematics.
- To understand the representations of Fuzzy Sets.
- To understand the types of Operations.

Course Outcomes

- To understand the basics of fuzzy mathematics.
- To apply fuzzy set theory in modeling and analyzing uncertainty in decision problem.

Module I **(20 Hours)**

1.3 Fuzzy Sets: Basic Types
1.4 Fuzzy Sets: Basic Concepts
1.5 Characteristics and Significance of the Paradigm Shift
2.1 Additional Properties of alpha-Cuts

Module II **(20 Hours)**

2.2 Representations of Fuzzy Sets
2.3 Extension Principle for Fuzzy Sets
3.1 Types of Operations
3.2 Fuzzy Complements
3.3 Fuzzy Intersections: t-Norms

Module III **(20 Hours)**

3.4 Fuzzy Unions: t-Conorms
3.5 Combinations of Operations
3.6 Aggregation Operations

Module IV **(25 Hours)**

4 1 Fuzzy Numbers

Module IV **(20 Hours)**

4.2 Linguistic Variables
4.3 Arithmetic Operations on Intervals
4.4 Arithmetic Operations on Fuzzy Numbers

Text

1. George J. Klir and Bo Yuan, Fuzzy Sets and Fuzzy Logic:Theory And Applications, Prentice Hall, 1995.

References

1. George J. Klir and Tina A Folger, Fuzzy sets, Uncertainty and Information, Prentice Hall of India,1988.
2. H. J. Zimmerman, Fuzzy Set theory and its Applications, 4th Edition, Kluwer AcademicPublishers, 2001.
3. Timothy J Ross, Fuzzy Logic with Engineering Applications, McGraw Hill International Editions, 1997.

SEMESTER VI

Elective 3

GMAH6E07P: PROGRAMMING USING SCILAB

Contact Hours : **80 (5 hrs./wk.)**
Number of Credits : **4**
Examination : **3 Hours**
Course Evaluation : **100 (Internal: 20 + External: 80)**

Course Objective

- To understand the Scilab and commands connected with matrices.
- To understand the Scilab commands for plotting functions.
- To understand Scilab commands for problems related with differential equations and integration.

Course Outcomes

- To understand the basics of Scilab and commands.

1. Introduction to Scilab and commands connected with matrices
2. Computations with matrices
3. Row reduced echelon form and normal form
4. Establishing consistency or otherwise and solving system of linear equations
5. Scilab commands for plotting functions.
6. Plotting of standard Cartesian curves using Scilab
7. Plotting of standard Cartesian curves using Scilab
8. Plotting of standard Polar curves using Scilab
9. Plotting of standard parametric curves using Scilab

LIST OF PROGRAMS

1. Creating a Scilab program (simple examples)
2. Verification of Euler's theorem, its extension and Jacobian
3. Scilab programs to illustrate left hand and right hand limits for discontinuous functions.
4. Scilab programs to illustrate continuity of a function
5. Scilab programs to illustrate differentiability of a function. Finding Taylor's series for a givenfunction.
6. Evaluation of limits by L' Hospital's rule using Scilab
7. Obtaining partial derivatives of some standard functions
8. Maxima commands for reduction formula with or without limits
9. Solution of Differential equation using Scilab and plotting the solution- I
10. Solution of Differential equation using Scilab and plotting the solution- II
11. Solution of Differential equation using Scilab and plotting the solution- III
12. Solution of Differential equations using Scilab and plotting the solution- IV
13. Finding complementary function and particular integral of constant coefficient second

and higher order ordinary differential equations

14. Solving second order linear partial differential equations in two variables with constant coefficient
15. Solutions to the problems on total and simultaneous differential equations
16. Solutions to the problems on different types of Partial differential equations
17. Evaluation of the line integral with constant limits
18. Evaluation of the line integral with variable limits
19. Evaluation of the double integral with constant limits
20. Evaluation of the double integral with variable limits
21. Evaluation of the triple integral with constant limits
22. Evaluation of the triple integral with variable limits
23. Scilab programs for area and volume

External Examination (Practical)

The external examination is a practical examination of 3 hr. duration. The Practical Examinations will be conducted by 2 examiners (One External and One Internal). The Practical examination has 3 sections with programmes from the list given above.

Text

1. C Bunks, J.- P. Chancelier, F. Delebecque, C. Gomez, M. Goursat, R. Nikoukhah, and S. Steer. Engineering and Scientific Computing With Scilab. Birkhauser Boston, 1999.

References

1. The Scilab Consortium. Scilab. http://www.scilab.org.
2. Introduction to Scilab