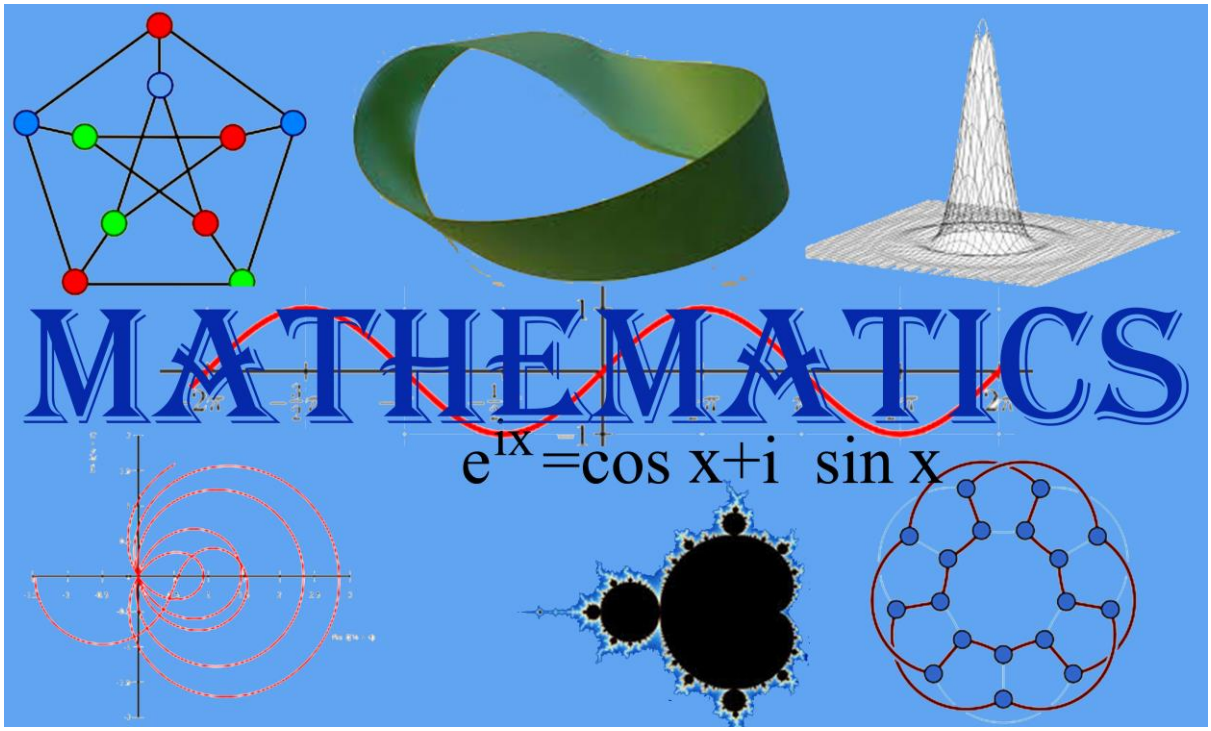
# Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme




**Name of the Programme: M.Sc. Programme in Mathematics with Specialisation in Finance and Computation**

(Syllabus effective from 2020 Admission onwards)

**UNIVERSITY OF KERALA**

**Department of Mathematics**

2020

## PREAMBLE

The role of higher education is vital in securing the gainful employment and providing further access to higher education comparable to the best available in the world-class institutions elsewhere. The improvement in the quality of higher education, therefore, deserves to be given top-most priority to enable the young generation of students to acquire skills, training and knowledge to enhance their thinking, comprehension and application abilities and prepare them to compete, succeed and excel globally. Sustained initiatives are required to reform the present higher education system for improving and upgrading the academic resources and learning environments by raising the quality of teaching and standards of achievements in learning outcomes across all undergraduate programs in science, humanities, commerce and professional streams of higher education.

One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes-based Curriculum Framework (LOCF), which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. The University Grants Commission (UGC) took the initiative of implementing the LOCF in the Colleges and the Universities of the country. Accordingly, the University of Kerala has decided to implement the LOCF in all its departments under the auspices of the Internal Quality Assurance Cell (IQAC). A series of teacher training workshops were organised by IQAC and the office of the Credit and Semester System (CSS), and the departments have revised the syllabus accordingly, through workshops and in consultation with academic experts in the field.

## GRADUATE ATTRIBUTES (GAs)

The Graduate Attributes (GAs) reflect particular qualities and abilities of an individual learner including knowledge, application of knowledge, professional and life skills, attitudes and human values that are required to be acquired by the graduates of University of Kerala. The graduate attributes include capabilities to strengthen one's professional abilities for widening current knowledge and industry-ready skills, undertaking future studies for global and local application, performing creatively and professionally, in a chosen career and ultimately playing a constructive role as a socially responsible global citizen. The Graduate Attributes define the characteristics of learners and describe a set of competencies that are beyond the study of a particular area and programme.

**The GAs of University of Kerala**

- Continue life-long learning as an autonomous learner
- Continuously strive for excellence in education
- Apply and nurture critical and creative thinking
- Promote sustainable development practices
- Promote co-operation over competition
- Balance rights with responsibilities
- Understand and respect diversity & difference
- Not be prejudiced by gender, age, caste, religion, or nationality.
- Use education as a tool for emancipation and empowerment of humanity.

# History of the Department of Mathematics

The Department of Mathematics came into existence as an independent unit in 1965 with the famous analyst Professor M. R. Parameswaran as the Head of the Department. Formerly the department of Mathematics was a part of the Department of Statistics and Mathematics. The Department of Statistics and Mathematics is one of the oldest teaching and research Departments of University of Kerala. Its functioning started in 1943 as part of the University of Travancore with Professor U. Sivaraman Nair as the head of the department. The eminent Mathematicians Dr Y Sitaraman, Professor K.S.S. Nambooripad, Professor V. Satyabhama, Professor M. I. Jinnah, Professor A. R. Rajan and Professor C. Jayasri served the department as heads. Currently Professor G. Suresh Singh is the head of the department.

The department of Mathematics is one of the prominent departments of the university which imparts quality education right from its inception. The department offers MSc, M Phil and PhD programmes in Mathematics which mainly focus on professional, technical and commercial upliftment of the students. The department is active in research in most areas of pure and applied mathematics covering graph theory, algebra, approximation theory, functional analysis, coding theory, cryptography, mathematical modelling, applied analysis and special functions. The department has produced a good number of M Phil and PhD scholars. The department conducts many programmes like national and international conferences, faculty development programmes, exhibitions and training programmes for the benefit of students, teachers and researchers. The department plays a key role in imparting mathematics awareness to school students in nearby locality and providing free UGC-CSIR NET coaching for aspirants. As a result of the recent appointments in the university, the department currently has 7 regular faculties.

# UNIVERSITY OF KERALA

## Syllabus for M.Sc. Programme in Mathematics with Specialisation in Finance and Computation

### Programme Specific Outcomes (PSO) for
### M.Sc. Programme in Mathematics with specialisation in Finance and Computation

**PSO 1** Solve problems in various fields of mathematics.

**PSO 2** Sharpening of mathematical concepts leading to research.

**PSO 3** Extension of domain knowledge to face real life problems.

**PSO 4** Knowledge about scientific method and skills in mathematical computation

**PSO 5** Understand concepts and skills related to financial and computational techniques.

**PSO 6** Enhancement of critical thinking skills and attitudes to become a thinker and professional.

**PSO 7** Creating academic excellence in mathematics and allied subjects.

## Programme Structure of M.Sc. Mathematics with Specialisation in Finance and Computation

| Semester | Course Code | Name of the course | Credits |
|---|---|---|---|
| I | **Core Courses (CC)** | | |
| | MATF-CC-511 | Algebra | 4 |
| | MATF-CC-512 | Real Analysis | 3 |
| | MATF-CC-513 | Differential Equations | 4 |
| | MATF-CC-514 | Financial Management | 3 |
| | **Discipline-Specific Elective (DE)** | | |
| | MATF-DE-515 | Data Structure and Management | 3 |
| | MATF-DE-516 | Graph Theory | 3 |
| | MATF-DE-517 | Difference Equation | 3 |
| | MATF-DE-518 | Coding Theory | 3 |
| II | **Core Courses (CC)** | | |
| | MATF-CC-521 | Topology | 4 |
| | MATF-CC-522 | Measure Theory | 4 |
| | MATF-CC-523 | Computing in Python and SageMath | 4 |
| | MATF-CC-524 | Risk Management | 3 |
| | **Discipline-Specific Elective (DE)** | | |
| | MATF-DE-525 | Combinatorics | 3 |
| | MATF-DE-526 | Advanced Graph Theory | 3 |
| III | **Core Courses (CC)** | | |
| | MATF-CC-531 | Complex Analysis-I | 4 |
| | MATF-CC-532 | Functional Analysis | 4 |
| | MATF-CC-533 | Operations Research | 4 |

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|---|---|---|---|
| | **Discipline-Specific Elective (DE)** | | |
| | MATF-DE-534 | Complex Networks | 3 |
| | MATF-DE-535 | Numerical Methods | 3 |
| | MATF-DE-536 | Differential Geometry | 3 |
| **IV** | **Core Courses (CC)** | | |
| | MATF-CC-541 | Theory of Linear Operators | 4 |
| | MATF-CC-542 | Number Theory | 4 |
| | MATF-CC-543 | Dissertation and Viva | 6 |
| | **Discipline-Specific Elective (DE)** | | |
| | MATF-DE-544 | Theory of Wavelets | 4 |
| | MATF-DE-545 | Business Mathematics | 3 |
| | MATF-DE-546 | Social Networks | 3 |
| | MATF-DE-547 | Representation Theory of Finite Groups | 3 |
| **Any semester (I-IV)** | **Generic Course (GC)** | | |
| | MATF-GC-501 | Complex Analysis | 2 |
| | MATF-GC-502 | Finite State Machines | 2 |
| | **Skill Enhancement Elective (SE)** | | |
| | MATF-SE-501 | Fundamentals in Latex | 2 |

*No of electives to be taken in each semester:
Semester I: **ONE**, Semester II: **ONE**, Semester III: **TWO**, Semester IV: **TWO**

| SEMESTER I | Course Code: MATF-CC-511 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** ALGEBRA

**Course Outcomes:**

**CO1**: Distinguish between group, ring and fields.
**CO2:** Analyse the role of group, ring and fields in solving problems other branches of mathematics.

## COURSE CONTENT

**Module I:** A quick review of vector space, basis and dimension, direct sum, the dimension formula, the matrix of a linear transformation, linear operators, Eigen vectors and the characteristic polynomials, triangular and diagonal form and Jordan form.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about basis and dimension of a vector space.
M02: Solve problems related to change of basis and the matrix of a linear transformation
M03: Compute Eigen vectors, characteristic polynomials and Jordan Form of a matrix.

**Module II:** Application of linear operators, orthogonal matrix and rotations, symmetry of plane figures, isometries, isometries of the plain, finite groups of orthogonal operators in the plane

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about orthogonal matrices and rotations
M02: Analyse isometries of the plane

**Module III:** More group theory, the class equation of the icosahedral group, conjugation in the symmetric group, normalizers, Sylows theorem, group of order 12.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about p-groups and simple groups
M02: Describe subgroups of prime power order of an arbitrary finite group.
M03: Classify group of order 12

**Module IV:** A quick review of rings, ideals and homeomorphisms, quotient rings, adding elements, product rings, fractions, maximal ideals.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand isomorphism in Rings, product rings ad quotient rings.
M02: Compute ideals and maximal ideals in rings

**Module V:** More about rings, factoring integers, unique factorization domains, Gauss's lemma, factoring integer polynomials.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Solve problems related to factorization of integer polynomials
M02: Understand about Euclidean domain, unique factorization domain and Principal Ideal domain

**Module VI:** Examples of fields, algebraic and transcendental elements, the degree of a field extension, irreducible polynomials, adjoining rools.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Classify algebraic and transcendental elements in Fields
M02: Compute the degree of a field extension and irreducible polynomials

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1] Michael Artin, "Algebra", Second edition, Pearson Educational Limited, 2017.

**Additional References**

[1] Herstein I.N, "Topics in Algebra", Second edition, Wiley India Pvt. Ltd, 1975
[2] Gallian J.A., "Contemporary Abstract Algebra", 8th edition, Cengage learning, 2013.
[3] Paul B Garrett, Abstract algebra, Chapman and Hall/CRC Taylor and Francis group, 2017.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).

60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-CC-512 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** REAL ANALYSIS

**Course Outcomes:**

**CO1**: Understand the concepts and results in analysis and apply these results to other branches of mathematics and real world applications.

**CO2:** Identify specific situation to which the fundamental results of real analysis apply and demonstrate advanced expertise in applying these results to said problems.

**CO3:** Determine the Riemann-Stieltjes integrability of a bounded function and prove a selection of results concerning integration.

**CO4:** Recognize the difference between pointwise and uniform convergence of a sequence of functions.

**CO5:** Illustrate the effect of uniform convergence on the limit function with respect to differentiability and integrability.

## COURSE CONTENT

**Module I:** Functions of bounded variation, total variation, additive property of total variations, total variation on [*a, x*] as a function of x, functions of bounded variations expressed as the difference of increasing functions, continuous functions of bounded variation, curves and paths, rectifiable paths and arcs, additive and continuity properties of arc length

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of bounded variation.
M02: Demonstrate the relation between monotonic functions and bounded variation.
M03: Find the arc length.

**Module II:** The Riemann-Stieltjes integral, the definition of the Riemann-Stieltjes integral, linear properties, integration by parts, change of variable in a Riemann-Stieltjes integral, reduction to a Riemann integral, step functions as integrators, reduction of a Riemann-Stieltjes integral to a finite sum, Euler's summation formula, monotonically increasing integrators, upper and lower integrals, addtive and linearity properties of upper and lower integrals.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic concepts in Reimann-Stieltjes integrals.

M02. Develop skills to identify integrable functions

**Module III:** Riemanns condition, comparison theorems, integrators of bounded variation, sufficient conditions for existence of Riemann-Stieltjes integrals, necessary conditions for existence of Riemann-Stieltjes integrals, mean value theorems for Riemann-Stieltjes integrals, the integral as a function of the interval, second fundamental theorem of integral calculus, change of variable in a Riemann integral, second mean value theorem for Riemann integrals, interchanging the order of integration.

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**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Apply first and second mean value theorems, second fundamental theorem of integral calculus for further studies.

M02: Demonstrate first and second mean value theorems, second fundamental theorem of integral calculus.

**Module IV:** Pointwise convergence of sequences of functions, examples of sequences of real valued functions, definitions of uniform convergence, uniform convergence and continuity, Cauchy condition for uniform convergence, uniform convergence of infinite series of functions, uniform convergence and Riemann-Stieltjes integration, uniform convergence and differentiation, sufficient conditions for uniform convergence of a series, power series.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Understand different notions of convergence.

M02: Demonstrate the impact of uniform convergence in the class of continuous, integrable and differentiable functions.

**Module V:** The directional derivative, the total derivative, the total derivative expressed in terms of partial derivatives, an application to complex valued functions, the Jacobian matrix, the chain rule, matrix form of the chain rule, the mean value theorem for differentiable functions.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Understand the concepts of directional derivative, total derivative and jacobian matrix.

M02: Demonstrate main results of this module.

**Module VI:** A sufficient condition for differentiability, a sufficient condition for equality of mixed partial derivatives, Taylor's formula for functions from Rn to R1, functions with nonzero Jacobian determinant.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01:Understand the concepts of Taylors formula.

M02: Demonstrate the importance of Taylors formula.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1] T. M. Apostol, Mathematical Analysis, Narosa Publishing House, 2nd edition, 2007.

**Additional References**

[1] S. Ghorpade and B. V. Limaye, A course in multivariate calculus and analysis, Springer Verlag, 2010.
[2] Krantz. S.G., Real Analysis and foundations, CRC Press, 2013.
[3] Malik. S.C., Mathematical Analysis, Wiley Eastern Ltd, 2017.
[4] Potter. M.H., C.B.Morrey, A first course in Real Analysis, Springer Verlag, 2000
[5] Strichartz. R.S., The way of Analysis, Jones and Barllel Publishers
[6] W. Rudin, Principles of mathematical analysis, 2017.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-CC- 513 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** DIFFERENTIAL EQUATIONS

**Course Outcomes:**

**CO1**: To understand the concepts of Ordinary and partial differential equations.
**CO2:** Tackle real world problems using techniques mastered in Differential equations

## COURSE CONTENT

**Module I:** Second order homogeneous differential equations, initial value problem, linear dependence and independence, second order nonhomogeneous differential equations, linear homogenous differential equations of order $n$, nonhomogeneous equations of order $n$,linear equations with variable coefficients.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Describe initial value problems and its solutions.
M02: Transform equations with variable coefficients into constant coefficients.
M03: Check the independence of functions using Wronskian.
M04: Identify second and higher order homogenous as well as non-homogenous equations.
M05: Solve homogenous and non-homogenous equations using various methods.

**Module II:** Legendre differential equation, Hermite differential equation, regular singular points, Laguerre differential equation, Chebyshev differential equation.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Define regular singular points and ordinary points of differential equations.
M02: Apply the orthogonality properties of various polynomials.
M03: Identify Legendre differential equation, Hermite differential equation, regular singular points, Laguerre differential equation, Chebyshev differential equation, Euler equation.
M04: Find the power series solutions of differential equations, recurrence relations and generating functions of various polynomials.
M05: Exemplify regular singular points and ordinary points of differential equations.

**Module III:** Bessel equation, solution by successive approximation, Lipschitz condition, convergence of successive approximations.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Identify the Bessel equation.
M02: Find the power series solutions of Bessel equation.
M03: Find the recurrence relations and generating functions of Bessel equation.
M04: Explain the orthogonality property of Bessel polynomial.

M05: Understand the method of successive approximations and solve problems using it.
M06: Describe the convergence of successive approximations and Picard's theorem.

**Module IV:** Linear system of ordinary differential equations, homogeneous linear system of differential equations, nonhomogeneous linear system.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Identify system of homogeneous and nonhomogeneous linear differential equations.
M02: Explain different types of solutions of homogeneous differential equations.
M03: Solve system of homogeneous linear differential equations.
M04: Solve system of nonhomogeneous linear differential equations using method of variations of parameters and method of undetermined coefficients.

**Module V:** Construction of first order partial differential equations, solution of first order partial differential equations, solution using Charpit's method, method of Cauchy's characteristics, method of separation of variables.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Construct partial differential equations by eliminating arbitrary constants / arbitrary functions from an equation of a function.
M02: Find solutions of first order partial differential equations using characteristic equation and Charpit's method.
M03: Identify and solve the special kinds of first order partial differential equations.
M04: Identify semi-linear quasi linear and non linear partial differential equations.
M05: Solve the first order PDE by using method of Cauchy characteristic.
M06: Solve PDE by using method of separation of variables.

**Module VI:** Origin of second order equations, linear partial differential equations with constant coefficients, equations with variable coefficients, canonical forms, classification of second order equations in n variables, modelling with second order equations.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the origin of second order PDE.
M02: Explain and solve linear PDE with constant coefficients and variable coefficients.
M03: Describe Canonical forms and reduce the given PDE into its Canonical form.
M04: Derive wave equation, heat equation and Laplace's equation.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz

- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. B J Gireesha, Rama S R Gorla, B C Prasannakumara, " Advanced Differential Equations", Studera Press, New Delhi, 2017.

**Additional References**

[1]. Stephen A Wirkus, Randall J Swift, Ryan S Szypowski, "A course in differential equations with boundary value problems", 2nd edition,CRS press, 2017.
[2]. Amaranath T., "An elementary course in partial differential equations", Jones & Bartlett Learning, 2009.
[3]. Simmons G.F., "Differential Equations with applications and historical notes", 3rd edition, CRS Press, 2017.
[4]. Somasundaram .D, "Ordinary differential equations-First Course".

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-CC-514 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** FINANCIAL MANAGEMENT

**Course Outcomes:**

**CO1**: Understand various financial functions in day to day life.
**CO2:** Analyse distinct cost properties.
**CO3:** Create several methods for dividend decisions.
**CO4:** Identify different properties of capital management.

## COURSE CONTENT

**MODULE I: Introduction to Finance**
Introduction; Scope of Finance; Financial Management System; Finance Functions; Role of a Finance Manager; Profit Maximization; Shareholders' Wealth Maximization (SWM); Sources of Finance: Short-term Finance; Long-term Funds; Concept of Time Value of Money

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Obtain knowledge on Financial Management System.
M02: Understand the role of a Finance Manager.
M03: Identify sources of different term funds.

**MODULE II: Cost of Capital**
Introduction; Cost of Capital; Cost of Debt; Cost of Preference Capital; Cost of Equity Capital; Approaches to Derive Cost of Equity; Weighted Average Cost of Capital and Weighted Marginal Cost of Capital; Financial and Operating Leverage.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the role of Capital cost in different aspects.
M02: Evaluate the relationship between weighted Average Capital cost and Weighted Marginal Capital cost.

**MODULE III: Capital Budgeting**
Introduction; Capital Budgeting Process; Methods to Evaluate Investment Proposals; Capital Rationing, Types of capital budgeting decisions, Preparation of capital budgeting proposal, estimating cash flows for project appraisal, Green capital budgeting; Non-discounted Cash Flow Techniques: Payback Period, ARR, Discounted Cash Flow Techniques: NPV, IRR, Modified IRR, PI and Capital Rationing

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Evaluate different kinds of investment methods.

M02: Understand typical cash flow systems.

**MODULE IV: Sources of Finance**
Debt: Term Loans, Debentures; Equity: Ordinary Shares; Hybrid: Preference, Warrants, Convertible securities, ADRs, GDRs. An introduction to leasing, Hire purchase, Leverage Buyouts and securitization.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Obtain clear cut knowledge in Debt and Term Loans.
M02: Familiar in shares and securities.
M03: Analyse leasing and Hire purchase.

**MODULE V: Dividend Decisions**
Dividend Decision – Theories – Modigliani and Miller Approach – Walter Model –Gordon Model – Dividend Policy and Share Valuation – Stock Splits – Bonus Shares - Practical Aspects of Dividend Policy – Corporate Dividend Behaviour

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Make decision on Dividend policies.
M02: Understand various concepts on stocks and Bonus Shares.
M03: Analyse properties of Corporate Dividend Behaviour.

**MODULE VI: Working Capital Management**
Factors influencing working capital requirement, estimating working capital requirement (numerical), Operating cycle analysis, Negative Working Capital. An introduction to Inventory Management. Objectives of Inventory management, EOQ Model (with numerical). Receivables management: An Introduction. Management of cash: Cash Planning, Managing the cash flows, Determining Optimum Cash Level (Baumol Model with numerical), Investing surplus cash.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand Factors of capital management.
M02: Estimate capital requirement.
M03: Create EOQ Model.
M04: Familiar in cash flow management system.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Pandey, I. M.., Financial Management (11th Ed), Vikas Publishing House Pvt. Ltd., 2015.

**ADDITIONAL REFERENCES**

[1]. Brearly R.A. and Myers, S.C. Eighth Edition Principles of Corporate Finance, Tata Mc-Graw Hill, 2008.

[2]. M.Y. Khan, P K Jain, Financial Management: Text, Problems and Cases, Tata Mc-Graw Hill, New Delhi, 2011.

[3]. Chandra, P. Fundamentals of Financial Management, Sixth Edition, Tata Mc-Graw Hill, 2014.

[4]. Horne. V. Tenth Edition, Financial Management and Policy, Prentice Hall of India, 2008.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-DE-515 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** DATA STRUCTURE AND MANAGEMENT

**Course Outcomes:**

**CO1**: Understand data structures and algorithms.
**CO2:** Understand static and dynamic memory allocation.

**CO3:** Implement stacks and Queues.

**CO4:** Represent network applications using Graphs and Binary trees.

**CO5:** Able to write database definition and manipulation statements.

**CO6:** Able to normalise database.

**CO7.** Understand database concurrency control and database recovery procedures.

**COURSE CONTENT**

**MODULE I:** Introduction to data and data structures. Algorithms and data structures. Classification – Linear and Nonlinear Data Structures, Arrays, Linked Lists.
**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Define Data structures and write Algorithms.
M02: Allocate memory either statically or dynamically based on the use case.

**MODULE II:** Stack – Array and Linked list implementation. Queue – Array and Linked list implementation. Types of Queue – Circular, Dqueue and Priority Queue, Applications of Stack and Queue.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Represent real life applications using stacks and queues.
M02: Understand how the computer operating systems are using stacks and queues for resource Management.

**MODULE III:** Introduction to graphs and its computing. Implementation of Graphs and searching – Depth first and Breadth first. Tree – Binary tree and implementation, Binary tree – traversals. Applications of Graph and Tree.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Represent Graphs and trees in computer memory and how these are used in real life applications.
M02: Traverse graphs and trees.

**MODULE IV:** Introduction to Database – Components of database and DBMS, File system and DBMS. Users of DBMS, Basics of Languages for database - DDL, SDL,VDL, DML and 4GL. Introduction to Schema and three level architecture of DBMS.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Differentiate File systems and DBMS.
M02: Know various Database Languages and Architecture.

**MODULE V:** Functional Dependency-keys, decompositions, introduction to Normalization and various forms. Structured Query Language - components. Basic methods for Data manipulation, data definition and data control through SQL.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Write SQL queries (DDL & DML) and set various integrity constraints.
M02: Eliminate Data Redundancy and Data Inconsistency.

**MODULE VI:** Introduction to Transactions - ACID properties. Concurrency control - introduction to different techniques and deadlock. Introduction to database recovery -log based, shadow paging. Introduction to Data warehouse and data mining - warehouse and mart, importance of data mining.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Handle control concurrency issues and database recovery.
M02: Understand the concept of Data warehouse and Data mining.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**


[1]. Data Structures and Algorithms using C,R. S. Salaria,Khanna Publishing; Fifth edition (2018), ISBN-10: 9789381068588

[2]. Introduction to Database Management System, Satinder Bal Gupta and Aditya Mittal, Laxmi Publications; First edition (2016), ISBN-10: 9381159319

**ADDITIONAL REFERENCES**


[1]. Thomas H Cormen, Charles E Leiserson, Ronald L Rivest, Clifford Stein, Introduction To Algorithms, MIT Press, 2001, ISBN 9780262032933

[2]. Alfred V. Aho, Data Structures and Algorithms, Addison-Wesley, ISBN 9780201000238

[3]. Peter Brass, Advanced Data Structures, Cambridge University Press, ISBN 9780511437533

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[6]. Database Management Systems (DBMS), Rajiv Chopra,S Chand Publishing; Fifth edition (2016), ISBN-10: 9385676342

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[8]. C.J. Date, Introduction to Database Systems, Pearson Education 8th ed., 2009 ISBN: 9780321197849.

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[10]. Building the DataWarehouse- W. H. Inmon, 4th ed.,Wiley Dreamtech India Pvt. Ltd 2009 ISBN: 9788126506453.


**On-line Sources**

www……..

**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-DE-516 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** GRAPH THEORY

**Course Outcomes:**

**CO1**: Understand the basic concepts of graphs.
**CO2:** Model real world problems using graph theory.

**COURSE CONTENT**

**MODULE I:** Basic concepts of graphs, bipartite graph, Euler's path, Euler's circuit, Euler's circuit theorems, Euler graph, Konigsberg bridge problem, Euler's cycle, Chinese postman problem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic concepts of graphs.
M02: Determine whether graphs are Eulerian.
M03: Analyse the properties of Eulerian graphs.

**MODULE II:** Hamiltonian graphs, Hamiltonian number, Hamiltonian path, Hamiltonian cycle.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Determine whether graphs are Hamiltonian.
M02: Understand the properties of Hamiltonian graphs.

**MODULE III:** Basic concepts of planar graphs, Euler's formula for planar graphs, polyhedrons and planar graphs, characterization of planar graphs, planarity tests.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand basic concepts of planar graphs.
M02: Analyse characterization of planar graphs.
M03: Apply algorithms to test planarity.

**MODULE IV:** Basics of tree, spanning trees, basic concept of independent sets, operation on sets.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Classify different types of trees.
M02: Understand different properties of independent sets and sets operations.

**MODULE V:** Vertex coloring, chromatic number, region coloring, coloring planar graphs, edge coloring, total coloring, application of graph coloring.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand basic concepts of vertex coloring and edge coloring of graphs.
M02: Find the chromatic number of a graph.
M03: Find the total coloring of a graph.

**MODULE VI:** Basic concept of directed graphs, traversal of digraph, tournaments

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Distinguish directed graphs and undirected graphs.
M02: Create applications on digraph.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Aleksander Mratinkovic, Hazen Shawky Fouda Et.al, "Illustrated Handbook of Graph Theory", 3G-learning, 2018.

**ADDITIONAL REFERENCES**

[1]. Bondy J.A and Murthy U.S.R, "Graph Theory with Applications", The Macmillan Press limited.
[2]. Gary Chartrand and Ping Zhang, "Introduction to Graph Theory", Tata-McGraw-Hill Edition 2006.
[3]. Harary, "Graph Theory", Addison-Wesley, 1989.
[4]. Suresh Singh G., "Graph Theory" PHI Learning Private Limited, 2010.
[5]. Khee Meng Koh EDt.al., Graph Theory, World scientific publishing, 2015.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-DE-517 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** DIFFERENCE EQUATION

**Course Outcomes:**

**CO1**: Solve Linear Difference Equations of Higher Order

**CO2:** Understand Linear non-homogeneous equations

**CO3:** Obtain techniques of Z-Transform Method

**CO4:** Create tools for approximation

**COURSE CONTENT**

**MODULE I: Linear Difference Equations of Higher Order**

Difference calculus – General theory of linear difference equations – Linear homogeneous equations with constant coefficients

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Familiar with the basic concepts in Difference calculus.

M02: Understand theories of Difference equations.

M03: Determine Linear homogeneous equations.

**MODULE II :** Linear non-homogeneous equations – Method of undetermined coefficients.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Analyse Linear non-homogeneous equations.

M02: Understand the logic in undetermined coefficients method.

**MODULE III: System of Linear Difference Equation**

Autonomous (time invariant) systems –The basic theory –The Jordan form: Autonomous (time-invariant) systems - Linear Periodic Systems.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Analyse Autonomous systems.

M02: Determine Linear Periodic Systems.

**MODULE IV: The Z-Transform Method**

Definitions and examples – Properties of Z-Transform – The inverse Z-Transform and solutions of difference equations - Power series method - Partial fraction method – Inversion integral method.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Understand Properties of Z-Transform.
M02: Convert the ideas to inverse Z-Transform.
M03: Solve difference equations by using Power series method, Partial fraction method and Inversion integral method.

**MODULE V: Oscillation Theory**
Three-term difference equations – Self-adjoint second order equations –Nonlinear difference

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Create facts in Oscillation Theory in terms of linear and Nonlinear difference equations

**MODULE VI:** Tools of approximations - Poincare's theorem – Asymptotically diagonal systems.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the significance of Poincare's theorem
M02: Deal with Asymptotically diagonal systems.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**REFERENCE**

[1]. Saber N.Elaydi, An Introduction to Difference Equations, Third Edition, Springer International Edition, First Indian Reprint, New Delhi, 2008.

**ADDITIONAL REFERENCES**

[1]. S.Goldberg, Introduction to Difference Equations, Dover Publications, 1986.
[2]. Walter G.Kelley, Allan C.Peterson, Difference Equations An Introduction with Applications, Academic Press, Indian Reprint, New Delhi, 2006.
[3]. V.Lakshmikantham, DonatoTrigiante, Theory of Difference Equations: Numerical Methods and Applications, Second Edition, Marcel Dekker, Inc, New York, 2002.

[4]. Ronald E.Mickens, Difference Equations, Van Nostrand Reinhold Company, New York, 1987.
[5]. Sudhir K.Pundir, Rimple Pundir, Difference Equations (UGC Model Curriculum), Pragati Prakashan, First Edition, Meerut, 2006.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER I | Course Code: MATF-DE-518 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** CODING THEORY

**Course Outcomes:**

**CO1**: Understand the importance of error detection and correction in communication systems
**CO2:** Apply the concepts of coding theory to detect and correct errors in communication.

**CO3:** Analyse various codes and its application in real life problems.

**CO4:** Develop new codes for practical situation using the expertise in coding theory.

## COURSE CONTENT

**Module I:** Detecting and correcting error patterns, Information rate, The effects of error detection and correction, Finding the most likely code word transmitted, Weight and distance, MLD, Error detecting and Correcting codes.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concepts of error detection, correction and information rate.
M02: Apply the properties of error patterns.
M03: Distinguish between MLD and IMLD.
M04: Evaluate the most likely code word send, weight of code and distance between codes.
M05: Create MLD table.

**Module II:** Linear codes, bases for $C = \langle S \rangle$ and $C^{\perp}$, generating and parity check matrices, Equivalent codes, Distance of a linear code, MLD for a linear code, Reliability of IMLD for linear codes.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of linear codes, bases, parity check matrices.
M02: Apply the properties of linear codes in MLD and IMLD.
M03: Interpret generating matrices and parity check matrices.
M04: Find the generating matrices and parity check matrices for $C = \langle S \rangle$ and $C^{\perp}$.
M05: Create generating matrices and parity check matrices.

**Module III:** Perfect codes, Hamming code, Extended codes,

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of perfect codes, Hamming codes and extended codes.
M02: Apply the properties of Hamming and extended codes.
M03: Distinguish between Hamming codes and extended codes.

M04: Obtain the Encoding and Decoding of Hamming codes an extended codes.
M05: Create examples of Hamming codes and extended codes.

**Module IV:** Golay code and extended Golay code, Red Hulles Codes

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concepts of Golay code, extended Golay code and Red Hulles Codes.
M02: Apply the properties of Golay code and extended Golay code.
M03: Identify the error patterns of Golay code, extended Golay code and Red Hulles Codes.
M04: Find the generating and parity check matrices for Golay code, extended Golay code and Red Hulles Codes.

**Module V:** Cyclic linear codes, Polynomial encoding and decoding, Dual cyclic codes

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concepts of cyclic linear codes, polynomial encoding and decoding.
M02: Apply the properties of cyclic linear codes and dual cyclic codes.
M03: Distinguish between generator matrices and generator polynomials.
M04: Find the generator matrix, parity check matrix, generator polynomials, syndrome polynomials for cyclic linear codes and dual cyclic codes.
M05: Create examples for cyclic codes.

**Module VI:** BCH Codes, Cyclic Hamming Code, Decoding 2 error correcting BCH codes

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of BCH codes, Cyclic Hamming codes.
M02: Apply the properties of linear codes, generator matrices, parity check matrices to BCH codes, Cyclic Hamming codes.
M03: Distinguish between irreducible polynomials and minimal polynomials.
M04: Finding the party check matrices for BCH codes, Cyclic Hamming codes.
M05: Create multiplication table for polynomials.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**

**References**

[1]. Hoffman D.J et al., Coding Theory The Essentials, Published by Marcel Dekker Inc 1991

**Additional References**

[1]. Berlekamp E.R, Algebriac Coding Theory, Mc Graw-Hill, 1968

[2]. Cameron P.J and Van Lint J.H, Graphs, Coded and Designs CUP, 1980

[3]. Hill H., A First Course in Coding Theory, OUP 1986.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**

(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-CC-521 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** TOPOLOGY

**Course Outcomes:**

**CO1**: Posses knowledge about the concepts and results in topology and apply these results to other branches of mathematics and real world applications.

**CO2**: Appreciate topology as an abstraction of real analysis.

## COURSE CONTENT

**MODULE I :** Topological Spaces, basis for a topology, the order topology, the product topology on $X \times Y$ the subspace toplogy.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of topology.
M02: Find a basis for a topology.
M03: Demonstrate different topologies on $R^2$ .

**MODULE II :** Closed sets and limit points, continuous functions, the metric topology, the quotient topology.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Identify continuous functions.
M02: Demonstrate that the product topology on $R^n$ is matrizable.

**MODULE III :** Connected spaces, connected subspaces of the real line, connected and local connectedness.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Identify connected subsets of the real line.
M02: Demonstrate the impact of connectedness on continuous functions.

**MODULE IV:** Compact spaces, compact subspaces of the real line, limit point compactness.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate the impact of compactness on continuous functions.
M02: Identify compact subsets of $R^n$

**MODULE V :** The countability axiom, Hausdorff spaces, regular spaces, normal spaces, the Urysohn lemma, the Tietze extension theorem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: demonstrate the impact of countability on convergence.
M02: demonstrate normal space as a topological space in which every real valued continuous function defined on a closed subspace has a continuous extension.

**MODULE VI :** The product topology, the Tychnoff theorem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate different topologies on product of topological spaces.
M02: Demonstrate their compactness.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Munkres J. R., *Topology*, PHI Learning, Second Edition, 2009.

**ADDITIONAL REFERENCES**

[1]. Adams, Fransoza, Introduction to topology: Pure and applied, PHI, 2012.
[2]. Cain G., Introduction to general topology, Person, 2012.
[3]. Croom F.H., Principles of topology, Dover publications, 2016.
[4]. Dugundji J., Topology, Allyn and Bacon Inc., 1978.
[5]. Joshi K. D., Introduction to General Topology, New Age International (P) Ltd, New Delhi, 2004.
[6]. Kelley J. L., General Topology, Springer-Verlag, Newyork, 1955.
Simmons G. F., Introduction to Topology and Modern Analysis.

**On-line Sources**

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**ASSESSMENT**
40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-CC-522 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** MEASURE THEORY

**Course Outcomes:**

**CO1**: Formulate complex problems using appropriate measure theory techniques.
**CO2:** Use sophisticated tools from measure theory in various areas of mathematics.
**CO3:** Identify specific situation to which the fundamental results of measure theory apply and demonstrate expertise in applying these results to said problems.

## COURSE CONTENT

**MODULE I:** Lebesgue outer measure, measurable sets, regularity, measurable functions, Borel and Lebesgue measurability.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concepts like Lebesgue outer measure, regularity and Lebesgue measurability.
M02: Find the Lebesgue outer measure of a set.

**MODULE II:** Integration of non-negative functions, the general integral, Riemann and Lebesgue integrals.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of Lebesgue integrability.
M02: Find the Lebesgue integral of a measurable function.

**MODULE III:** Differentiations, continuous non-differentiable functions, Lebesgues differentiation theorem, differentiation and integration.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of differentiation.
M02: Demonstrate existence of continuous non-differentiable functions.
M03: Demonstrate the importance of bounded variation in differentiation theory.

**Module IV:** Measures and outer measures, extension of a measure, uniqueness of the extension, completion of a measure, measure spaces, integration with respect to a measure (definition and Theorem 18 only).

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concepts like abstract measure space, measurable space, measure and integration.
M02: Develop skills to work on abstract measure spaces.

**MODULE V**: The $L^p$spaces, convex functions, Jensens Holders and Minkowskis inequalities, completeness of $L^p$ spaces, conver-gence in measure, almost uniform convergence, counter examples.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the properties of convex functions.
M02: Develop skills to work on the subspaces of $L^p$-spaces.

**MODULE VI**: Signed measures and the Hahn decomposition, Jordan decomposition, Radon-Nikodym theorem, measurability in a product space, product measures, Fubinis theorem (statement and examples only), Lebesgue measure in Euclidean space

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate the importance of Hahn decomposition, Jordan decomposition, Radon-Nikodym and Fubini's theorems.
M02: Develop skills to apply these results for further study.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. De Barra G., Measure Theory and Integration, New Age International (P) Ltd. Publishers, New Delhi, second edition, 2013.

**Additional References**
[1]. Athreya K. B. and Lahiri S. N., Measure Theory, Hindustan Book Agency, New Delhi, 2006.
[2]. Bartle R. G., The Element of Integration, John Wiley, 1964.
[3]. Berberian S. K., Measure and Integration, The McMillan Company, New York, 1965.
[4]. Halmos P. R., Measure Theory, Springer Verlag, 2014.
[5]. Rana K., An Introduction to Measure and Integration, Narosa Publishing company, New York, 1965.
[6]. Royden H. L., Real Analysis, Prentice Hall India, 1988 (3rd edition).
[7]. Rudin W., Real and Complex Analysis, Tata McGraw Hill, New Delhi, 2006.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-CC-523 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** COMPUTING IN PYTHON AND SAGEMATH

**Course Outcomes:**

**CO1**: Understand one of the most popular and robust general purpose programming language Python.
**C02**: Understand how scientific programming can be performed using Python and SageMath using various open source mathematics libraries and tools available.
**C03**: Visualize mathematics concepts and get the ability to demonstrate mathematical ideas through graphics.
**C04**: Solve any concrete mathematics or general science problem programmatically using numerical methods.

## COURSE CONTENT

**MODULE I:** Fundamentals of Python : Basic Mathematical operators, variables, different types of numbers including fractions and complex numbers, accepting user input as fractions, complex numbers etc. while running the programme, handling exceptions and invalid inputs

Writing basic programs with elementary mathematics concepts like calculating the factors of an integer, generating multiplication tables, converting units of measurement, finding the roots of a quadratic equation, finding gcd directly and using Euclidean algorithm

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand basic concepts of the programming language python.
M02: Learn how to perform basic mathematics operations in Python.
M03: See how to handle various number systems like integers and real numbers via problems like factorization, root finding etc.

**MODULE II:** Understanding the Cartesian Coordinate Plane, working with lists and tuples, dictionaries, range, and len commands, iterating over a list or tuple, conditional statements (if-else-elif), looping statements (for, while), writing programs using these concepts

Creating graphs with matplotlib, marking points on the graph, plotting points of average on graphs, customizing graphs, saving the plots, plotting with formulas, plotting multiple functions on the same graph.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Get a deeper understanding of various data types in Python.
M02: Know how to use programming to perform repeated computations easily.
M03: See how to plot mathematics functions and formulae.

**MODULE III:** Defining symbols and symbolic operations using sympy, working with expressions, factorizing and expanding expressions, substituting values in the place of variables/symbols, converting strings to mathematical expressions, solving general equations of higher degree, solving for one variable in terms of others, solving a system of linear equations, Defining functions like factorial function.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Learn advanced features of Python like using scientific libraries.
M02: Understand basic concepts of symbolic computing.
M03: Learn how to use Python for problems in Linear algebra.
M04: Learn how to define own functions in Python.

**MODULE IV:** Introduction to SageMath programming through examples, basic mathematical functions, working with arrays
Plotting Graphs in SageMath – 2D and 3D plots, Plot Options
Differential calculus using SageMath: Evaluating Limits, Limits Involving Trigonometric Functions, Limits Involving Infinity, Continuity, Differentiation, Derivative as a Function, Higher-Order Derivatives, Chain Rule and Implicit Differentiation

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: See how to extend the power of Python through the specialized math software SageMath.
M02: Learn advanced plotting techniques including those for 3D plotting.
M03: Understand various techniques available in SageMath to solve basic calculus problems.

**MODULE V:** Matrix Algebra: Adding, multiplying two matrices, row reduced echelon forms to solve linear system of equations, finding inverses of square matrices, determinants, exponentiation of matrices, computing the kernel of a matrix. Eigen values and Eigen vectors of a matrix.

Numerical Methods in Linear Algebra: Linear Systems: Gauss Elimination, Linear Systems: LU-Factorization and Matrix Inversion, Cholesky's Method, Gauss-Jordan Elimination and Matrix Inversion. Linear Systems: Solution by Iteration, Gauss-Seidel Iteration Method, Jacobi Iteration

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Learn how to perform matrix computations using SageMath.
M02: How to compute Eigen values and Eigen vectors to solve physical and mathematical problems.
M03: Understand various numerical methods to solve Linear Algebra problems using SageMath.

**MODULE VI** : Solving nonlinear equations**,** bisection method, Newton–Raphson Method, Secant Method, Fixed-Point Iteration

Numerical Integration**,** Trapezoidal Rule, Simpson's Rule, using the method of undetermined coefficients, Gauss quadrature formula

Numerical Methods for Differential Equations**,** Euler's Method, Taylor Series Method, Runge–Kutta's Method of order 3 and 4, Systems of Ordinary Differential Equations, Higher-Order Ordinary Differential Equations, Systems of Higher-Order Differential Equations

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Get the ability to solve various equations via the numerical functions available in SageMath.
M02: Solve differential equations of various orders numerically.
M03: Solve systems of differential equations numerically.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**


[1]. Amit Saha, "Doing Math with Python", no starch press, 2015.
[2]. Tuan A. Le, Hieu D. Nguyen, "SageMath Advice For Calculus", 2016.
[3]. Paul Zimmermann et.al., "Computational Mathematics with SageMath", 2018.
[4]. George A. Anastassiou, Razvan A. Mezei, 'Numerical Analysis Using Sage', Springer, 2015.


**ADDITIONALREFERENCE**


[1]. Vernon L. Ceder, "The Quick Python Book", Second Edition, Manning.
[2]. "NumPy Reference Release 1.12.0", Written by the NumPy community. (available for free download at https://docs.scipy.org/doc/numpy- dev/numpy-ref.pdf).
[3]. S.S. Sastry, "Introductory Methods of Numerical Analysis", Fifth Edition, PHI.


**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-CC-524 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** RISK MANAGEMENT

**Course Outcomes:**

**CO1**: Become expert in financial risk management.
**CO2:** Understand marketing management.

**CO3: A**nalyse different techniques in risk management.

**CO4:** Estimate Interest Rate and Currency Risk.

**CO5:** Familiar in Commodity Risk Management.

## COURSE CONTENT

**MODULE I:** Financial Risk – Definition and evolving styles of risk management. Organizing for Financial Risk Management - Role of risk manager- policies-decision making and execution

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand evolving styles of risk management.
M02: Organize Financial Risk Management.
M03: Create policies in decision making and execution.

**MODULE II**: Exposure to Risk and Diversification - specific and market risk- forecasting market movements. Forwards and Futures: market volatility; concepts of forwards, futures and swaps. Options: option pay-off profiles-option strategies-option pricing and hedge ratios-Black-Scholes option valuation model - arbitraging- speculating

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Acquire knowledge on forecasting market movements.
M02: Analyse concepts of forwards, futures and swaps.
M03: Create various types of options.

**MODULE III**: Managing Equity Risk: specific risks- managing market risk-Markowitz and Sharpe Single Index models. Managing Bond Risk - market conventions and yields-bonds with special features- yield curves hedging with futures and options.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Manage various classes of risk.
M02: Understand the role of different types of bonds.

**MODULE IV**: Managing Interest Rate and Currency Risk - one period forwards and futures- interest options - currency options and hedging longer term interest rate and currency exposures

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Obtain good knowledge in interest options and currency risk.
M02: Understand the concepts of currency options and currency exposures.

**MODULE V:** Foreign Exchange Risk Management - various foreign exchange rate risk management strategies - foreign exchange market in India.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Acquire better logic Foreign exchange risk management.
M02: Create a feasible foreign exchange market in India.

**MODULE VI:** Emergence of Commodity Risk Management - basic understanding of commodities-investment opportunities in commodities in India-working of commodity exchanges- importance of risk management in commodity derivatives- future of commodity derivatives.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand commodities-investment opportunities in India.
M02: Analyse the role of risk management in commodity derivatives.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. John C. Hull, Risk Management and Financial Institutions, Wiley Finance Series, 2012.

**Additional References**

[1]. Donald R. van Deventer, Kenji Imai, Mark Mesler, Advanced Financial Risk Management (2nd Ed.), Wiley Finance Series, 2013.
[2]. Brain A. Eales Financial Risk Management. London:Mc Graw – Hill, 1995.
[3]. N.D. Vohra & B.R. Bagri Futures and Options. New Delhi: Tata Mc Graw Hill, 2003.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-DE-525 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** COMBINATORICS

**Course Outcomes:**

**CO1**: Understand the basic principles of counting using different techniques and solve counting problems.
**CO2:** Solve counting problems using group actions.

## COURSE CONTENT

**MODULE I :** Counting words and permutations, counting subsets, counting anagrams, counting rule for set operations, counting functions, counting lattice paths, geometric series formula, binomial theorem, multinomial theorem, sum of powers of integers, recursions, recursions for multisets and anagrams, recursions for lattice paths.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Develops the basic counting techniques that form the foundation of enumerative combinatorics.
M02: Apply the basic counting techniques to study fundamental combinatorial objects such as words, permutations, subsets, functions and lattice paths.
M03: Apply combinatorics to probability theory.

**MODULE II :** Graphs and digraphs, walk and matrices, directed acyclic graphs and nilpotent matrix, vertex degrees, functional digraphs, cyclic structure of permutation, counting rooted trees, connectedness and components, forest , trees, counting trees.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Discuss some enumeration problems that arise in graph theory.
M02: Understand the basic concepts in graph theory.
M03: Understand various counting problems involving different kinds of trees.

**MODULE III :** Inclusion-exclusion formula, surjection and stirling numbers, Euler $\varphi$ function, derangements, involution, involution related to Inclusion-exclusion, generalized Inclusion-exclusion formulas.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand combinatorial techniques that are related to the arithmetic operation of subtraction, Inclusion-exclusion formula and involution.
M02: Analyse Inclusion-exclusion formula and exemplify.
M03: Analyse surjection formula.
M04: Understand a special class of permutations called derangements.
M05: Derive summation formula for derangements.

M06: Generalize Inclusion-exclusion formulas.

**MODULE IV :** Convergence of power series, examples of analytic power series, operations on power series, recursion with generating function, generating function for derangements, counting rule for weighted sets, product rule for weighted sets, generating function for trees, tree bijections.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept of generating functions, a powerful tool for solving many combinatorial problems.
M02: Apply generating functions to solve recursions.
M03: Analyse the exponential generating function for derangements.
M04: Understand the counting rule for weighted sets.
M05: Exemplify the sum rule and product rule for weighted sets by deriving the generating functions for various kinks of trees.

**MODULE V :** Bijective sum rule, bijective product rule for two sets, , bijective product rule, ranking words, ranking anagrams, ranking integer partition, ranking set partition, ranking trees.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic bijective sum rule and product rule to build ranking and unranking maps.
M02: Exemplify bijective sum rule and product rule.

**MODULE VI :** Basic operations of groups, notations for permutation, inversion and sign of a permutation, subgroups, automorphism group of graphs, group homomorphism, group action, permutation representations, stable subsets and orbits.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the initial concepts of group theory and some fundamental properties of permutations.
M02: Construct examples of subgroups of symmetric groups using graphs.
M03: Construct examples of subgroups using group homomorphism.
M04: Analyse that group actions and permutation representations are same.
M05: Understand the concepts of stable subsets and orbits and analyse orbit decomposition of a G-set.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics

- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Nicholas A Lochr, *Combinatorics,* CRC press, Second edition, 2018.

**ADDITIONAL REFERENCES**

[1]. Martin J Erickson, *Introduction to Combinatorics,* John Wiley and sons, Second edition, 2013.
[2]. Peter J Cameron, *Combinatorics Topic, Technique, Algorithams,* Cambridge University press, 1994.
[3]. Terence Tao, Van H Vu, *Additive Combinatorics,* Cambridge University press, 2006.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER II | Course Code: MATF-DE-526 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** ADVANCED GRAPH THEORY

**Course Outcomes:**

**CO1**: To understand and apply the fundamental concepts in graph theory
**CO2:** To apply graph theory based tools in solving practical problems

## COURSE CONTENT

**Module I:**
**Graphs:** Graphs as Models, Graph Classes and Graph Operations, Polynomial Algorithms and NP-Completeness.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the fundamental concepts in graph theory.
M02: Illustrate how graphs are used as models.
M03: Understand and apply graph operations to combine graphs and produce new graphs.
M04: Understand the order of magnitude and complexity function of an algorithm.
M05: Analyse a class of problems for which there is no polynomial time algorithm.

**Module II:**
The Center and Eccentricity, Self Centered Graphs, The Median, Central Paths, Path Algorith ms and Spanning Trees, Centers.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand various kinds of center and its properties.
M02: Analyse the characterization of Self Centered Graphs.
M03: Analyse that median of a tree consist of either a single node or pair of adjacent nodes.
M04: Apply depth first and breadth first search algorithms to find a spanning tree.
M05 Apply algorithms to find eccentricity

**Module III:**
**External Distance Problems:** Radius, Small Diameter, Diameter, Long Paths and Long Cycles

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand distance related parameters Radius, Diameter, Long Paths and Cycles of a graph.
M02: Analyse the characterization of radius minimal and r- critical graphs.
M03: Understand the concept of diameter minimal and diameter critical graphs.
M04: Find the trail number of a graph, maximum length of a longest induced path.

**Module IV:**
**Convexity:** Closure in variants, Metrics on Graphs, Geodetic Graphs, Distance Hereditary Graphs.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand distance related closure operations on graphs and analyse its properties.
M02: Determine geodetic iteration number, geodetic number, hull number of a graph.
M03: Analyse embedding problems for graphs.
M04: Analyse characterization of Geodetic Graphs and Distance Hereditary Graphs.

**Module V: Diagraphs:** Diagraphs and Connectedness, Acyclic digraphs.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the necessary and sufficient condition for a digraph to be strong, unilateral and weak.
M02: Analyse the characterization of graphs that have strongly connected orientation.
M03: Analyse the characterization of digraphs.

**Module VI:**
**Distance Sequences:** The eccentric sequences, Distance sequence, The Distance distribution.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand distance related sequences of a graph.
M02: Apply algorithm for constructing graph with degree sequence, if exists.
M03: Understand the distance degree sequence and status sequence of a graph and its properties.
M04: Find distance distribution of a graph.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**

**References**

[1]. Fred Buckley, Frank Harary, *Distance in Graphs,* AddisonWesley Publishing Company, 1990.

**ADDITIONAL REFERENCES**

[1]. Bondy and Murthy, *Graph Theory with Applications,* The Macmillan Press Limited,1976
[2]. Chartrand G and L.Lesniak, *Graphs and Diagraphs,* Prindle, Weber and Schmidt, Boston 1986
[3]. Garey M.R, D.S Johnson, *Computers and Intractability,* A Guide to the Theory of NP-Completeness, Freeman, San Francisco 1979.
[4]. Khee Meng Koh Et.al., Graph Theory, World scientific publishing, 2015.

[5]. K.R Parthasarathy, *Basic Graph Theory,* Tata Mc Graw-Hill, Publishing Co, New Delhi, 1994.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-CC-531 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** COMPLEX ANALYSIS-I

**Course Outcomes:**

**CO1**: Establish relationship between analytic functions and power series and to evaluate certain definite integrals which cannot be calculated by traditional method.
**CO2:** Solve problems related to power series and integrals.
**CO3:** Classify singularities and to find residues.
**CO4:** Solve problems using Mobius transformation.

## COURSE CONTENT

**MODULE I :** The extended plane and its spherical representation, Power Series, Analytic Function

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Analyse convergence of power series.
M02: Solve problems related to power series and analytic functions.
M03: Establish the relationship between analytic functions and power series.

**MODULE II :** Riemann – Stieltjes Integrals, Power Series representation of an analytic Function.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Establish the relationship between analytic functions and power series.
M02: Compute integrals of functions defined on rectifiable paths.

**MODULE III :** Zeros of an analytic Function, The index of a closed curve, Cauchy's Theorem and Integral Formula

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Establish an analogy between analytic functions and polynomials.
M02: Evaluate index of a closed rectifiable curve.
M03: Evaluate certain definite integrals that cannot be evaluated by traditional methods.

**MODULE IV :** Homotopic Version of Cauchy's Theorem, Simple Connectivity, Counting Zeros , The open mapping theorem, Goursat's Theorem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Evaluate certain definite integrals that cannot be evaluated by traditional methods.
M02: Count the number of zeros inside a curve.

**MODULE V :** Singularities ; Classification, Residues, The argument principles.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Classify singularities.
M02: Find residues and thereby to find the value of certain definite integrals.

**MODULE VI :** Analytic functions as mappings, Mobius transformations, the maximum principle, Schwarz's lemma.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Solve problems like finding the fixed points of a Mobius transformation and evaluating the cross ratio.
M02: Apply Schwarz's lemma to characterize the conformal maps of the open unit disk onto itself.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. John. B. Conway, Functions of Complex Variables, Springer – Verlag , New York, 1973. (Indian Edition ; Narosa).

**ADDITIONAL REFERENCES**

[1]. Ahlfors L. V., Complex analysis, Mc – Graw Hill (1966).

[2]. Lang S., Complex analysis, Mc – Graw Hill (1998).

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-CC-532 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** FUNCTIONAL ANALYSIS

**Course Outcomes:**

**CO1**: Appreciate how functional analysis uses and unifies the ideas from linear spaces and metric spaces.

**CO2**: Familiar with several techniques associated with transformations between two spaces.

**CO3**: Understand the basic properties of normed spaces and Banach spaces and some fundamental results of functional analysis.

**CO4**: Understand and apply fundamental theorems from the theory of normed spaces and Banach spaces including Hahn-Banach theorem, uniformboundedness principle, closed graph and open mapping theorems.

**CO5**: Appreciate the use of algebraic and topological structures in studying spaces of functions.

## COURSE CONTENT

**MODULE I :** Normed spaces, Riesz lemma, continuity of linear maps, operator norm.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Understand the definition of normed space, continuity of linear maps between normed spaces and the operator norm.

M02: Appreciate how the paper Functional Analysis uses and unifies ideas from vectorspaces, the theory of metrics, and complex analysis.

**MODULE II:** Hahn Banach theorems, Hahn Banach separation theorem, Hahn Banach extension theorem, Banach spaces.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Understand and apply the fundamental theorems, namely the Hahn-Banach separation theorem and the Hahn-Banach extension theorem, from the theory of normed spaces.

M02: Understand the definition of Banach spaces.

**MODULE III:** Bounded linear maps on Banach spaces, Uniform boundedness principle, closed graph theorem and open mapping theorem.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Report on fundamental properties of Banach spaces.

M02: Understand and apply the fundamental theorems, namely the Uniform boundedness principle, the resonance theorem, the closed graph theorem and the open mapping theorem.

**MODULE IV:** Spectrum of bounded operator, Gelfand Mazur theorem, Spectral radius formula.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the fundamentals of spectral theory of bounded linear operators on Banach spaces.

**MODULE V:** Duals and transposes, reflexivity.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the dual and the transpose of a bounded linear operator on a Banach space, the closed range theorem, the weak and weak *-convergences, the BolzanoWeierstrass property and the reflexivity.
M02: Solve problems involving the weak topology and the weak *-topology.

**MODULE VI:** Compact linear maps, spectrum of a compact operator

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the definition of a compact linear operator on a Banach space.
M02: Understand and apply the spectral theory of compact linear operators of Banach spaces.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Limaye B.V., Functional Analysis, New Age International (P) Limited publishers, Revised Third edition, 2017.

**Additional References**

[1]. Eidelmann Y., Milman V., Tsolomitis A., Functional analysis an introduction, Graduate studies in mathematics, American Mathematical Society, 2004.
[2]. Kreyszig E., Introductory Functional analysis with applications, John Wiley, 1978.
[3]. Maddox I. J., Elements of Functional analysis, Universal book stall, New Delhi, 1989.
[4]. Simmons G. F., Introduction to Topology and Modern Analysis, McGraw Hill-1983.
[5]. Thamapan Nair. M., Functional analysis: A first course, 2001, P. H. I.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-CC-533 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** OPERATIONS RESEARCH

**Course Outcomes:**

**CO1**: Analyze the role of Linear Programming and nonlinear programming, Network Analysis, Integer Programming, Queuing Models and decision theory.
**CO2**: Find the solutions of LPP using various techniques.
**CO3:** Solve transportation network problems and assignment problems.
**CO4:** Solve nonlinear programming.
**CO5:** Acquire clear cut knowledge in both theory and application.

## COURSE CONTENT

**MODULE I:** The Linear Programming model, art and skill of problem formulation- Integer and non-linear models, , graphical solution of linear programming solution- general definitions, graphical solutions, multiple optimal solutions, No optimal solutions, no feasible solutions, general solution method , Preparation for the simplex method- standard form of an LPP, Solutions of linear system.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Identify the characteristics of a linear programming problem.
M02: Formulate linear programming problems.
M03: Explain the types of solutions of an LPP.
M04: Understand slack and surplus variables.
M05: Write the standard form of an LPP.
M06: Solve the LPP graphically.

**MODULE II:** The simplex method, initial solution for general constraints- artificial variable, the two phase method, multiple optimal solution, unbounded solution, degenerate solution, the dual problem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the steps in simplex method.
M02: Solve LPP using simplex method.
M03: Understand the use of artificial variables in an LPP.
M04: Solve LPPs using artificial variable techniques such as Big-M method and Two-phase method.
M05: Articulate and exemplify multiple optimal solutions, unbounded solutions and degenerate solutions.
M06: Explain the relation between an LPP and its dual.
M07: Write the dual of a given LPP.

**MODULE III**: Graphs and networks- preliminary definitions, transportation network- northwest corner rule, minimum cost method, minimum row cost method, transportation simplex method, transportation simplex, assignment problem and stable matching- stable matching, capacitated transhipment problem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Describe networks and the basic concepts associated with it.
M02: Formulate transportation model.
M03: Determine the initial basic feasible solutions using various methods.
M04: Perform transportation simplex method.
M05: Formulate assignment model.
M06: Solve assignment model using Hungarian method.
M07: Describe stable matching and capacitated transhipment problem.

**MODULE IV:** Fundamental concepts of integer programming, typical integer programming problems- general integer problems, (0-1) problems, mixed integer problems, (0-1) model formulation- travelling sales man model, Knapsack model, branch and bound- example algorithm.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Describe the fundamental concepts of integer programming.
M02: Differentiate between general integer problems,0-1 problems and mixed integer Problems.
M03: Formulate various 0-1 models.
M04: Explain branch and bound algorithm.
M05: Solve problems using branch and bound algorithm.

**MODULE V:** Preliminary notation and concepts of nonlinear optimization, unconstraint optimization- one dimensional search algorithm, multi variable gradient search, Newton's method, quasi- Newton method, constraint optimization- Lagrange multipliers, Karush-Kuhn-Tucker conditions quadratic programming.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic concepts and notations of nonlinear optimization.
M02: Understand unconstrained optimization.
M03: Use one dimensional search and multivariable search algorithms.
M04: Explain Newton's method and quasi-newton method.
M05: Understand constrained optimization.
M06: Apply Lagrange multiplier method and Karush-Kuhn-Tucker conditions.
M07: Describe quadratic programming problem.

**MODULE VI:** Basic element of queueing systems, arrival and service patterns-the exponential distribution, birth and death processes, Analysis of simple queueing systems-

notations and definitions, steady state performance measures, practical limits of queueing models, the decision making process, an introduction to game theory- maximin strategy, maximax strategy, Laplace principle, Hurwicz principle. Savage minimax regret, decision tree

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Define the basic elements of a queueing system.
M02: Explain arrival and service patterns, birth-death processes.
M03: Understand the notations and definitions of simple queueing system.
M04: Derive steady state performance measures.
M05: Describe practical limits of queueing models.
M06: Understand the concepts of a game.
M07: Grasp the assumptions in the theory of games.
M08: Understand the key concept in the theory of games.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Michael W.Carter, Camille C.Price, Ghaith Rabadi, "Operations Research- A practical introduction", 2018.

**ADDITIONAL REFERENCES**

[1]. Goel B.S and Mittal S.K "Operations Research" Pragati Prakashan, Meerut 1973
[2]. Hardly G, "Linear Programming" Addison Wesley, Reading. Mass. 1962.
[3]. Hamdy A. Taha, "OPERATIONS RESEARCH", Seventh edition, Pearson Education (Singapore) Pte.Ltd.
[4]. Kapoor V.K, "Operations Research" Sultan chand and sons, New Delhi 1985.
[5]. Nita H.Shah, Ravi M.Gor, Hardik Soni, "Operations Research", Prentice Hall of India, New Delhi, 2007.
[6]. Ravindran A, Don.T. Phillips, James.J.Solberg, "Operations research-Principles and Practice", Second edition, John Wiley and Sons (Asia) Pvt.Ltd., Singapore-2000

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-DE-534 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** COMPLEX NETWORKS

**Course Outcomes:**

**CO1**: Articulate and exemplify the basic knowledge in network science, its evolution and motivation, and associated challenges.

**CO2:** Compute various properties of a network.

**CO3:** Explain the mathematics of networks.

**CO4:** Explain and generate random graphs and its properties.

**CO5:** Explain and generate random graphs with general degree distributions and its properties.

**CO6:** Explain the different model of netwrok formation and generate network according these models using software packages.

**COURSE CONTENT**

**MODULE I :** Introduction, Overview of Network science, Motivation, Large scale dynamic networks, Challenges of graph theory.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Articulate and exemplify the basic knowledge in network theory.
M02: Articulate challenges of handling large graphs.
M03: Exemplify occurrence of large scale networks in real world applications.
M04: Differentiate dynamic networks from static networks.
M05: Discuss the computational aspects of graphs.
M06: Discus overview of network science.

**MODULE II :** Basic Concepts related to Networks, Small world effect, transitivity and clustering, degree distribution, scale free networks, maximum degree; network resilience; mixing patterns; degree correlations; community structures; network navigation.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Articulate and exemplify small world networks and its importance.
M02: Articulate and exemplify transitivity and clustering and their importance.
M03: Discuss why scale free networks are important in network science.
M04: Articulate what is network resilience.
M05: Articulate community structures and navigation within a network.
M06: Compute the above for a given network using software packages.

**MODULE III:** Mathematics of networks: Networks and their representation, The adjacency matrix, Weighted networks, Directed networks, Hypergraphs, Bipartite networks, Trees, Planar networks, Degree, Paths, Components, Independent paths, connectivity, and cut sets, The graph Laplacian, Random walks.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Illustrate how networks can be represented.
M02: Articulate what is weighted networks and its applications.
M03: Define directed networks.
M04: Define hypergraphs.
M05: Articulate the concept of bipartite networks and their applications.
M06: Define different types of networks and their sub-structures.

**MODULE IV:** Random Graphs: Mean number of edges and mean degree, Degree distribution, Clustering coefficient, Giant component, Small components, Path lengths, Problems with the random graph.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Articulate and exemplify the concept of random graphs.
M02: Articulate the typical features of network parameters of random graphs.
M03: Define clustering coefficient.
M04: Define giant component of a network.
M05: Articulate the main problems related to random graphs.
M06: Generate different types of random graphs and compute it structural properties using software.

**MODULE V :** Random graphs with general degree distributions: Generating functions , The configuration model , Excess degree distribution, Clustering coefficient, Generating functions for degree distributions, Number of second neighbors of a vertex, Generating functions for the small components, Giant component, Size distribution for small components, Power-law degree distributions, Directed random graphs.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Articulate the features of random graphs with general degree distribution.
M02: Discuss configurational model.
M03: Discuss the characteristics of random graphs with general degree distributions.
M04: Explain the generating functions for small components.
M05: Discuss power-law distributions and how is it connected to random graphs.
M06: Articulate the concept of directed random networks and its occurrence.

**MODULE VI :** Models of network formation: Preferential attachment, The model of

Barabasi and Albert, Further properties of preferential attachment models, Extensions of preferential attachment models, Vertex copying models, Network optimization models.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Discuss various models for generating networks.
M02: Explain the model of Barabasi and Alberts.
M03: Explain the properties of preferential attachment models.
M04: Explain Vertex copying models.
M05: Explain Network optimization models.
M06: Generate networks using models of Barabasi and albert using software packages.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Newman M. E. J., Networks: An Introduction, Oxford University Press, Oxford, 2010.
[2]. The structure and function of complex networks, SIAM Review 45, 167-256, 2003.

**ADDITIONAL REFERENCES**

[1]. Evolution of Networks, Oxford University Press, Oxford, 2003.

[2]. Statistical mechanics of complex networks, Rev. Mod. Phys., 74(1), 2002.

[3]. Papers from the ACM and IEEE digital libraries.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).

60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-DE-535 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** NUMERICAL METHODS

**Course Outcomes:**

**CO1**: To develop the mathematical skills of the students in the areas of numerical methods.

**CO2:** To teach theory and applications of numerical methods in a large number of engineering subjects which require solutions of linear systems, finding eigenvalues, eigenvectors, interpolation and applications.

## COURSE CONTENT

**MODULE I:** Mathematical Preliminaries and Error Analysis- round-off error and computer arithmetic- binary machine numbers, decimal machine numbers, finite digit arithmetic, errors in scientific computation-nested arithmetic, rates of convergence,, the bisection method, the secant method, Newton's method, Aitken's $\Delta^2$ method, Muller's method.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Find error and can round off it.
M02: Understand different machine numbers.
M03: Identify applications.

**MODULE II:** Interpolation and polynomial approximation- Lagrange polynomials- Lagrange interpolating polynomials, Lagrange polynomial error formula, Neville's method, recursively generated Lagrange polynomials, divided differences- Newton's interpolatory divided differences formula, Newton's forward divided differences formula, Newton's backward divided differences formula, centered difference, Hermite interpolation- Hermite polynomials, Hermite polynomials error formula, Hermite polynomials using divided differences

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Approximate error through polynomials.
M02: Analyse various divided differences formula.
M03: Understand the role of Hermite polynomials.

**MODULE III**: Numerical integration and differentiation- basic quadrature rules- midpoint rule, Trapezoidal rule, Simpson's rule, composite quadrature rules- composite Simpson's rule, composite midpoint rule, composite Trapezoidal rule, Round-off error stability, Romberg integration- Extrapolation, Extrapolation with the composite Trapezoidal rule,

multiple integrals- Gaussian quadrature for double integral approximation, non-rectangular regions, double integral using Gaussian quadrature, triple integral approximation , improper integrals- left endpoint singularity, right endpoint singularity, infinite singularity, numerical differentiation- two-point formula, three-point formula

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Extend their knowledge in Numerical integration and differentiation.
M02: Analyse several rules on finding and Round-off error.
M03: Understand varieties of singularities.

**MODULE IV:** Numerical solution of initial value problems- Taylor methods- Euler's method, error bounds for Euler's method, higher order Taylor method, Approximate intermediate results, Runge-Kutta methods- Runge-Kutta methods of order two, higher-order Runge-Kutta methods, computational comparisons, predictor-corrector methods- Adams-Bashforth explicit methods, Adams-Moulton implicit methods, predictor-corrector methods, extrapolation methods .

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Solve initial value problems by using many methods.
M02: Develop knowledge on Runge-Kutta method.
M03: Develop several methods for getting numerical solution.

**MODULE V:** Direct methods for solving linear systems- Gaussian elimination- matrices and vectors, operation counts, linear algebra and matrix inversion- Matrix arithmetic, Matrix-Matrix products, square matrix, inverse matrices, transpose of a Matrix, Matrix seterminants, matrix factorization- permutation matrices, techniques for special matrices- strict diagonal dominance.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Analyse linear systems.
M02: Familiarise various matrix methods to solve problems in linear systems.

**MODULE VI:** Systems of nonlinear equations- Newton's method for systems-Jacobian matrix, Quasi-Newton methods-Sherman-Morrison formula

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Develop ideas on nonlinear systems.
M02: Understand techniques on solving systems of nonlinear equations.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. J.Douglas Faires, Richard Burden," Numerical Methods", Fourth edition, International Edition, 2013.

**ADDITIONAL REFERENCES**

[1]. John H Mathews, "Numerical Methods For Mathematics", Science and Engineering, Second Edition, Perentice-Hallof index pvt.ltd. New Delhi, 1998.
[2]. Curtis F Gerald, Patrick O Wheatley, "Applied Numerical Analysis", Sixth Edition, Pearson education pte.ltd, Delhi 2002.
[3]. Radhey S Gupta, "Elements of Numerical Analysis", Second edition, Cambridge University Press, 2015.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER III | Course Code: MATF-DE-536 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** DIFFERENTIAL GEOMETRY

**Course Outcomes:**

**CO1**: Compute quantities of geometric interest such as curvature, as well as develop a facility to compute in various specialized systems, such as semi geodesic coordinates or ones representing asymptotic lines or principal curvatures.
**CO2**: Introduced to the method of the moving frame and over determined systems of differential equations as they arise in surface theory.
**CO3**: Develop arguments in the geometric description of curves and surfaces in order to establish basic properties of geodesics, parallel transport, evolutes

## COURSE CONTENT

**MODULE I:** Graphs and level sets, Vector fields.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the graph and level set, associated with a real valued function of several variables.
M02: Understand the geometry of level sets from the calculus of vector fields.

**MODULE II:** Tangent Spaces, Surfaces, Vector fields on surfaces.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand tangent to the level set and gradient of a real valued function of several variables.
M02: Understand level curves in $R^2$, surface in $R^3$ and hypersurface in $R^{n+1}$ through various examples.
M03: Understand vector fields on a surface and various topological properties on the same.

**MODULE III:** Orientation, The Gauss map.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand orientation on a plane curve and orientation on the 2-sphere.
M02: Understand various properties of Gauss map associated with oriented n-surface.

**MODULE IV:** Geodesics, Parallel transport.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand curves appearing in n-surfaces namely geodesics.
M02: Understood that geodesics in n-surfaces play the same role that straight lines do in $R^n$
M03: Develop arguments in the geometric description of curves and surfaces in order to

establish basic properties of geodesics and parallel transport.

**MODULE V:** The Weingarten map, Curvature of plane curve.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the Weingarten map, the local behavior of curvature of plane curve and the local behavior curvature on an n-surface.

**MODULE VI:** Arc length, Line integral, Curvature of surfaces.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand how parameterizations of plane curves can be used to evaluate integrals over the curve.
M02: Find the length of the given arc.
M03: Understand the local behaviour of the curvature of surfaces.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

**[1].** John. A. Thorpe, Elementary Topics in Differential Geometry, Springer-Verlag

**Additional References**

[1]. Singer I and Thorpe J.A, Lecture notes on Elementary Topology and Geometry, Springer-Verlag.

[2]. Spivak M, Comprehensive Introduction to Differential Geometry (Vol. s 1 to 5), Publish or Perish Boston.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-CC-541 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** THEORY OF LINEAR OPERATORS

**Course Outcomes:**

**CO1**: Appreciate how functional analysis uses and unifies the ideas from linear spaces and metric spaces.

**CO2:** Apply ideas from theory of Hilbert spaces to other areas including Fourier series and related approximation techniques.

**CO3**: Create a working knowledge of the basic properties of Hilbert spaces and Banach algebras.

**CO4**: Demonstrate significant applications of the theory of functional analysis.

## COURSE CONTENT

**MODULE I**: Inner product spaces, orthonormal sets.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the definition of inner product spaces, Hilbert spaces and orthonormal sets.
M02: Report on fundamental properties of Hilbert spaces.

**MODULE II**: Projection and Riesz representation theorems, bounded operators and adjoints.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the definition of a bounded operator and the adjoint of a bounded operator on a Hilbert space.
M02: Understand and apply the fundamental theorems, namely the projection theorem and the Riesz representation theorem.

**MODULE III :** Normal, unitary and self adjoint operators

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Report on normal, unitary and self-adjoint operators on a Hilbert space.
M02: Understand the fundamentals of spectral theory and numerical range of bounded operators on a Hilbert spaces.

**MODULE IV:** Spectrum and numerical range.

**Module Outcome:**
*After Completion of this module, the student should be able to:*

M01: An insightful of compact self-adjoint operators from the characterization of the compact self-adjoint operators from its spectrum, and one also appreciate the importance of the spectrum.

**MODULE V:** Compact self adjoint operators, Projections.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: An insightful of one of the simple self-adjoint bounded operator on a Hilbert space namely the orthogonal projections.

**MODULE VI** : General preliminaries of Banach Algebras and the structure of commutative Banach algebras.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the general preliminaries of Banach algebras and the structure of commutative Banach algebras.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Limaye V., Functional Analysis, New Age International (P) Limited Publishers, Revised Third edition, 2017.
[2]. Simmons G. F., Topology and Modern Analysis, McGraw – Hill, Singapore, 2017.

**ADDITIONAL REFERENCES**

[1]. Eidelmann Y., Milman V., Tsolomitis A., *Functional analysis an introduction*, Graduate studies in mathematics, American Mathematical Society, 2004.
[2]. Kreyszig E., *Introductory Functional analysis with applications*, John Wiley, 1978.
[3]. Maddox I. J., *Elements of Functional analysis*, Universal book stall, New Delhi, 1989.
[4]. Thamapan Nair. M., *Functional analysis: A first course*, PHI, 2001,

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-CC-542 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** NUMBER THEORY

**Course Outcomes:**

**CO1**: Understand the connections between number theory and other branches of mathematics including algebra, analysis and combinatorics.
**CO2:** Analyse various properties of number theoretic functions.

**CO3:** Apply the properties and concepts in number theory to solve real world problems.

**CO4:** Create expertise in number theory leading to research.

## COURSE CONTENT

**Module I:** Arithmetical functions and Dirichlet Multiplication.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01:Understand basic concepts about Arithmetical functions and Dirichlet multiplication.
M02:Apply the properties of Mobius functions and Euler totient function.
M03:Compare Dirichlet inverses and Mobius inversion formulae.
M04:Evaluate Mobius functions and Euler totient function.
M05:Create tables of Mobius function, Euler totient function and Mangoldt function.

**Module II:** Multiplicative functions and completely multiplicative functions, Bell series.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01:Understand various multiplicative functions.
M02:Apply the properties of multiplicative functions.
M03:Compare multiplicative functions and Dirichlet multiplication.
M04:Evaluate Liouville's function and divisor function.

**Module III:** Congruences, Chinese Remainder theorem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01:Understand the basic concepts of congruence.
M02: Apply the properties of congruence and Chinese reminder theorem.
M03: Analyse residue classes and complete residue classes.
M04: Solve linear and polynomial congruence.
M05:Create example of various congruence.

**Module IV:** Periodic Arithmetic functions, Gauss sums.

**Module Outcome:**
*After Completion of this module, the student should be able to:*

M01:Understand the concept of periodic arithmetic functions.
M02:Apply the properties of Ramanujan's sum and Gauss's sum.
M03:Recognize the induced modulus and primitive characters.
M04:Evaluate Ramanujan's sum and Gauss's sum.
M05:Construct Dirichlet character table.

**Module V:** Quadratic residues, Reciprocity law, Jacobi symbol.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01:Understand quadratic residues and reciprocity law.
M02:Apply the properties of Legendre's symbol, reciprocity law and Jacobi symbols.
M03:Determine quadratic residues and nonresidues.
M04:Evaluate quadratic residues.
M05:Create table of quadratic residues and nonresidues.

**Module VI:** Primitive roots, existence and number of primitive roots.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01:Understand the concept of primitive roots.
M02:Apply the properties of primitive roots.
M03:Compare primitive roots and quadratic residues.
M04:Identify the non-existence of primitive roots.
M05:Evaluate primitive roots.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**
[1]. Apostol T.M., Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi, 1990.

**Additional Reference**

[1]. Rose H. E., A Course in Number Theory (Second Edition), Clarendon press, Oxford, 1994.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-CC-543 | Credits: 6 |
|---|---|---|

**NAME OF THE COURSE:** DISSERTATION AND VIVA

**Course Outcomes:**

**CO1**: Understanding the importance of dissertation in mathematical research.

**CO2:** Enhancement of critical thinking skills and attitudes to become a thinker and professional.

**CO3:** Sharpening of mathematical concepts leading to research.

**CO4:** Creating theoretical and practical knowledge in mathematics and allied subjects.

| SEMESTER IV | Course Code: MATF-DE-544 | Credits: 4 |
|---|---|---|

**NAME OF THE COURSE:** THEORY OF WAVELETS

**Course Outcomes:**

**CO1**: Understand the applied structure through wavelets.
**CO2:** Familiarize the knowledge on applications of Fourier transforms.

## COURSE CONTENT

**Module I:** Construction of Wavelets on $Z_n$ the first stage.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basics of wavelet theory in the finite dimensional space $l^2\ (Z_n\ )$.
M02: Solve problems involving wavelets in the finite dimensional space $l^2\ (Z_n\ )$.

**Module II:** Construction of Wavelets on $Z_n$ the iteration sets, Examples - Shamon, Daubiehie and Haar.
**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand Daubechiess wavelets and elementary compressions.
M02: Apply wavelet theory in the finite dimensional context to various applications.
M03: Give examples of Daubechiess wavelets and elementary compressions with the help of MatLab, Maple, or Mathematica.

**Module III:** $l^2\ (Z\ )$, Complete Orthonormal sets, $L^2[-\pi,\pi]$ and Fourier Series.
**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basics of wavelet theory in the infinite dimensional but discrete setting $l^2\ (Z\ )$, the square summable sequences on the integers.
M02: Apply Fourier series expansion of square integrable functions on the interval [−π, π).
M03: Analyse the general properties of complete orthonormal sets in inner product spaces.

**Module IV:** Fourier Transforms and convolution on $l^2\ (Z\ )$
**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand more properties of Fourier transform and convolution on $l^2\ (Z\ )$.
M02: Analyse the connection between $l^2\ (Z\ )$ and $L^2[-\pi,\pi]$ through Fourier transform.
**Module V:** First stage wavelets on Z

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the construction of first stage wavelets on the integers.

**Module VI:** The iteration step for wavelets on Z, Examples, Shamon Haar and Daubiehie.

**Module Outcome:**
*After Completion of this module, the student should be able to:*

M01: Apply wavelet theory in the infinite dimensional context $l^2\ (Z\ )$ to various applications.
M02: Compute of wavelets in the context of $l^2\ (Z\ )$ which includes the construction of Daubechiess wavelets and Shannon Haar wavelets on Z.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Michael Frazier, An Introduction to Wavelets through Linear Algebra, Springer

**Additional References**

[1]. Chui. C( 1992), An Introduction to Wavelets, Academic Press, Boston 29
[2]. Mayor (1993), Wavelets and Operators, Cambridge University Press

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-DE-545 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** BUSINESS MATHEMATICS

**Course Outcomes:**

**CO1**: Understand the basic connection between percentage and decimals.
**CO2:** Analyse the properties of sales and purchase for principals.

**CO3:** Enhance banking transaction procedures.

**CO4:** Create various tax calculation methods.

**CO5:** Update banking computation.

**COURSE CONTENT**

**MODULE I :** Changing percentage to decimals, changing fraction and decimals to percentage, determining base rate and percentage, computing amounts of increase and decrease, percents to allocate overhead expenses.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Convert percentage into decimals and vice-versa.
M02: Determine base rate and percentage.
M03: Analyse percents and overhead expenses.

**MODULE II :** Computation of sales commissions and gross pay, computation of graduated sales commissions, computation of sales and purchase for principals, computation of trade discounts, computation of series of trade discounts, computation of equvalant single discount rates, computation of cash discounts for fully paid invoice, computation of cash discounts for partially paid invoice.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Analyse sales commissions and graduated sales commissions.
M02: Compute sales and purchase.
M03: Evaluate different kinds of discounts.

**MODULE III :** Computation of markup variables, computation of markup based on cost, computation of markup percent based on cost, computation of markup based on selling prize, computation of markup percent based on selling prize.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Determine markup variable.
M02: Compute markup with respect to various parameters.

**MODULE IV :** Banking using deposit slip and bank checks, checkbooks and check registers, reconciling bank statement, preparation of payroll register, computation of federal

income tax withholding amounts, computation of social security, Medicare and other withholdings.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand banking methods.
M02: Analyse bank statements.
M03: Create payroll register.
M04: Compute income tax and social security.

**MODULE V :** Computation of sales tax as percent of prize, sales tax as an amount per unit, excise tax as an amount per unit, computation of assessed valuation and property tax, computation of tax rates, determination of taxable income.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Compute sales tax.
M02: Determine excise tax and property tax.
M03: Create norms for income tax.

**MODULE VI :** Computation of simple interest, Computation of ordinary interest, Computation of exact interest, comparison between ordinary interest and exact interest, computation of the interest variables of future values, computation of the interest variables of present values.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Do simple interest and ordinary interest calculations.
M02: Analyse the relation between ordinary interest and exact interest.
M03: Compute interest variables of future and current values.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**

**References**

*[1].* J. E. Deitz, J. L.Southam, *Contemporary Business Mathematics,* Cengage learning, 17th Edition, 2016.

**ADDITIONAL REFERENCES**

*[1].* Anderson, Sweeney, et.al., *Quantitative Methods for Business,* Cengage learning, 12th Edition, 2013.

**[2].** C.D. Miller, S.A. Salzman, G. Clendenan, *Business Mathematics,* Addison Wesley, seventh Edition, 1997

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-DE-546 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** SOCIAL NETWORKS

**Course Outcomes:**

**CO1**: Articulate the basic knowledge in social network analysis.

**CO2:** Carry carry out basic network operations in R and GEPHI.

**CO3:** Compute structural properties of a network using software packages .

**CO4:** Compute centrality measures of a network .

**CO5:** Demonstrate the ability to analyse large scale networks in computer.

**CO6:** Carry out percolation studies on given network.

**CO7:** Carry out diffusion studies on a network using popular epidemic models.

## COURSE CONTENT

**MODULE I:** Introduction to Social Network Analysis, Steps in social network analysis: network definition, manipulation, calculation, visualization. Graph terminology. Social networks. Technological networks. Sampling and data characteristics.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Articulate the basic knowledge in social network analysis.
M02: Define a social network.
M03: Explain various terminologies associated with the social network analysis.
M04: Explain technological networks.
M05: Explain graph visualization and articulate visualization methods.

**MODULE II:** Introduction to R / Lab, The R environment. statnet package for social network analysis. Basic transformation and visualization tools. Lab: Loading, manipulating, visualizing and saving network data in R.
Graph Properties / Visualization, Networks and representations. Adjacency matrix and properties. Weighted, directed, bipartite networks. Trees. Node degree. Paths, components, connectivity and cut sets. Graph Laplacian. Random walks. Levels of analysis: node, dyad, triad, subgroup. Best practices for graph visualization. Layout algorithms.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Install and statnet package in R.
M02: Carry carry out basic network operations in R.
M03: Articulate different representations of a network for loading into R packages.
M04: Articulate and carry out the best practices for graph visualization in R.
M05: Articulate the basic knowledge of layout algorithms.

**MODULE III:** Metrics / Lab**,** Measures of centrality. Page Rank, Hubs and Authorities. Betweenness. Transitivity, Reciprocity. Structural balance. Homophily and assortativity. Lab: Computing and displaying graph metrics in R and GEPHI software

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Install GEPHI software in computer.
M02: Articulate various measures of centralities of a network and compute them in R and GHEPHI.
M03: Define Hubs and Authorities.
M04: Explain Homophily and assortativity.
M05: Explain transitivity.
M06: Explain reciprocity and structural balance.

**MODULE IV:** Large-scale structure of networks / Algorithms, Shortest-paths and the small-world effect. Degree distributions, Power laws and scale-free networks. Clustering coefficients, Basic graph algorithms: computing properties of nodes and dyads. Maximum flow.

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Articulate and exemplify the basic knowledge about large scale structures of networks.
M02: Explain shortest paths.
M03: Explain small-world effect.
M04: Articulate and compute degree distributions of a network.
M05: Articulate and compute clustering coefficients.
M06: Discuss maximum flows.

**MODULE V:** Processes on networks, Percolation: Uniform random removal of vertices, Non-uniform removal of vertices , Percolation in real-world networks, Computer algorithms for percolation

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01 Articulate on the basic knowledge on process on networks.
M02: Discuss the effects of uniform removal nodes in networks.
M03: Discuss the effects of non-uniform removal nodes in networks.
M04: Analyse percolation in real-world networks.
M05: Analyse computer algorithms for percolation.
M06: Carry out percolation studies on network using software packages.

**MODULE VI :**Epidemics on networks:, Models of the spread of disease: The SI model, The SIR model, The SIS model, The SIRS model, Epidemic models on networks

**Module Outcome:**

*After Completion of this module, the student should be able to:*

M01: Articulate the basic knowledge of epidemics on networks.

M02: Explain disease spreading employing networks.
M03: Explain SI, SIS and SIR models.
M04: Analyse the spreading of epidemic according to these models in given network using software packages.

## ACTIVITIES, LEARNING RESOURCES & ASSESSMENT

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

## LEARNING RESOURCES

**References**


[1]. Newman, M.E.J. Networks: An Introduction. Oxford University Press. 2010.

[2]. Chen, X., & Yang, C. Z. Visualization of social networks. In *Handbook of social network technologies and applications* (pp. 585-610). Springer, Boston, MA, 2010.

[3]. https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf.


## ADDITIONAL REFERENCES


[1]. The structure and function of complex networks, SIAM Review 45, 167-256, 2003.

[2]. Statistical mechanics of complex networks, Rev. Mod. Phys., 74(1), 2002.

[3]. https://cran.r-project.org/web/packages/igraph/igraph.pdf.


**On-line Sources**

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## ASSESSMENT

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| SEMESTER IV | Course Code: MATF-DE-547 | Credits: 3 |
|---|---|---|

**NAME OF THE COURSE:** REPRESENTATION THEORY OF FINITE GROUPS

**Course Outcomes:**

**CO1**: Understand the concept of representation theory and its applications.
**CO2:** Analyse the properties of abstract groups using concrete groups.
**CO3:** Reduce problems in abstract algebra to problems in linear algebra.
**CO4:** Represent an abstract algebraic object, more concrete by describing its elements by matrices and the algebraic operations in terms of matrix addition and matrix multiplication.

## COURSE CONTENT

**MODULE I:** Introduction , G-modules, Characters, Reducibility, Permutation representations, Complete reducibility, Schur's lemma.

**Module Outcome:**

*After Completion of this module, the student should be able to:*
M01: Understand representation of a group.
M02: Describe different types of representation of a group.
M03: Articulate and exemplify G-modules.
M04: Explain character of a representation, reducibility, irreducibility, complete reducibility, natural characters and their properties.
M05: Find the natural representation of a permutation group.

**MODULE II :** The commutant (endomorphism) algebra, Orthogonality relations.

**Module Outcome:**

*After Completion of this module, the student should be able to:*
M01: Understand commutant algebra of a matrix representation.
M02: Relate commutant algebras of equivalent representations.
M03: Find the centre of the commutant algebra of a representation.
M04: Describe the commutant algebra of a representation taking account of the exact number of mutually inequivalent representations of different multiplicities.
M05: Derive the character relations of the first kind.
M06: Define the group algebra and show it is a G-module.

**MODULE III** : The character table, Finite abelian groups, The lifting process, Linear characters.

**Module Outcome:**

*After Completion of this module, the student should be able to:*
M01: Understand the structure of character tables.
M02: Derive the character relations of the second kind.
M03: Find the character tables of $S_3$ and various abelian groups.
M04: Describe the lifting process.
M05: Apply lifting process to construct the character tables of certain groups.
M06: Explain the linear characters of a group.

**MODULE IV :** Induced representations, The reciprocity law, The alternating group $A_{5.}$

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand induced representation of a group and induced characters.
M02: Derive expression for the induced characters.
M03: Explain the reciprocity theorem of Frobenius.
M04: Construct the character table of $A_{5.}$

**MODULE V :** Transitive groups, The symmetric group, Induced characters of $S_{n.}$

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Articulate and exemplify transitive groups and doubly transitive groups.
M02: Explain various properties of transitive groups and doubly transitive groups.
M03: Construct the character table of $S_{4.}$
M04: Explain the induced characters of $S_{n.}$

**MODULE VI :** Algebraic numbers, Representation of the group algebra, Burnside's (p,q) theorem.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the concept algebraic numbers.
M02: Describe the properties of algebraic numbers.
M03: Explain Burnside's-(p,q) theorem.
M04: Articulate and exemplify Frobenius groups.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

**[1].** Walter Ledermann, Introduction To Group Characters (second edition), 1987.

**Additional References**

[1]. Faulton- The Representation Theory of Finite groups, Lecture notes in Maths No.682, Springer 1978.
[2]. Kurtis W. and Reiner I. -Representation theory of finite groups and Associative algebras, John Wiley & sons, New York 1962.
[3]. Musli C.- Representations of Finite groups,Hindustan Book Agency, New Delhi 1993.
[4]. Schur I.-Theory of Group Characters, Academic Press, London 1977.
[5]. Serre J.P.- Linear Representations of Finite Groups, Graduate text in Maths,Vol 42,Springer 1977.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| ANY SEMESTER (I-IV) | Course Code: MATF-GC-501 | Credits: 2 |
|---|---|---|

**NAME OF THE COURSE:** COMPLEX ANALYSIS

**Course Outcomes:**

**CO1**: Understand the need of complex analysis in solving problems in other subjects.

**CO2:** Apply various techniques in complex analysis in real life problems.

**CO3:** Analyze functions of a complex variable using series expansions, using contour integrals, and using partial differential equations.

**CO4:** Develop expertise in complex analysis leading to research findings.

## COURSE CONTENT

**Module I:** Functions of a complex variable, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulas.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Define limits and continuity for functions of a complex variable.
M02: Understand functions of a complex variable.
M03: Apply differentiation formulae.
M04: Analyse limits and continuity for functions of a complex variable.
M05: Determine derivatives of functions of functions of complex variables.

**Module II:** Cauchy Riemann equations, sufficient condition for differentiability, Polar coordinates, Analytic functions and examples, Harmonic functions.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about the Cauchy-Riemann equations and polar coordinates.
M02: Apply the Cauchy-Riemann equations in polar form.
M03: Analyse the sufficient condition for differentiability.
M04: Find the harmonic conjugate of a given harmonic function.
M05: Articulate and exemplify analytic functions, singularity, entire functions and harmonic functions.

**Module III:** Derivatives of functions $\omega(t)$, Definite integrals of functions $\omega(t)$, Contours, Contour integrals and some examples.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand derivatives of complex valued functions of a real variable, Definite integrals of complex valued functions of a real variable.
M02: Evaluate contour integrals.

**Module IV:** Antiderivative, Cauchy-Goursat theorem, Simply connected domain, Multiply connected domains,Cauchy integral formula, An extension of Cauchy's integral formula(Proof of theorems are omitted), Liouville's Theorem and Fundamental theorem of Algebra.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: State Cauchy's integral formula, Liouville's theorem and fundamental theorem of algebra.
M02: Understand the concept anti-derivative and simply connected domain, multiply connected domain.
M03: Apply Cauchy- Goursat theorem.
M04: Evaluate complex contour integrals by applying Cauchy's integral formula and Cauchy- Goursat theorem.

**Module V:** Taylor Series, Laurent's series(Proof of the theorems in these two sections are omitted), Isolated singular points, Residues, Cauchy's residue theorem, Residue at infinity, Types of isolated singular points, Residue at poles, Examples.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand Taylor's series and Laurent's series.
M02: Apply residue theorem to find complex integrals.
M03: Classify singularities and poles.
M04: Determine residues.
M05: Represent analytic functions as Taylor's series and Laurent's series.

**Module VI:** Zeros of analytic functions, zeros and poles, Behaviour of functions near isolated singular points, Evaluation of improper integrals.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand zeros of analytic functions.
M02: Apply the concept of zeros and poles.
M03 :Analyse the behaviour of functions near isolated singularities.
M04: Evaluate improper integrals.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments

- Field work and survey

**LEARNING RESOURCES**

**References**

[1]. Complex variables and Applications, James Ward Brown,Ruel V. Churchill, 8th edition, McGRAW Hill International Edition.

**Additional References**

[1]. Ahlfors L. V., Complex analysis, Mc – Graw Hill (1966).

**[2].** John. B. Conway, Functions of Complex Variables, Springer – Verlag , New York, 1973. (Indian Edition ; Narosa).

[3]. Lang S., Complex analysis, Mc – Graw Hill (1998).

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**

(For each course include one model question paper based on OBE pattern)

| ANY SEMESTER (I-IV) | Course Code: MATF-GC-502 | Credits: 2 |
|---|---|---|

**NAME OF THE COURSE:** FINITE STATE MACHINES

**Course Outcomes:**

**CO1**: Students will be able to understand the basic concepts in formal language theory.

**CO2:** Students will be able to apply finite state machines to other fields.

**COURSE CONTENT**

**Module I:** Graphs, languages, grammars and automata.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic notations and terminologies needed for the course.
M02: Compute the language corresponding to a grammar and automata.

**Module II:** Deterministic finite acceptors and their transition graphs, languages and deterministic finite acceptors, regular languages.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understandthe language accepted by a deterministic finite accepter.
M02: Find the language accepted by a deterministic finite accepter and acceptor accepting a regular language.

**Module III:** Nondeterministic finite acceptors, equivalence of deterministic and nondeterministic finite acceptors, minimal automata.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate the equivalence of non-deterministic finite acceptor and deterministic acceptor.
M02: Find a minimal deterministic finite state machine for a regular language.

**Module IV:** Regular expressions, languages associated with regular expressions, equivalence of regular expressions and regular languages.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate the equivalence of regular expressions and regular languages.
M02: Find a minimal deterministic finite state machine for a regular expression.
**Module V:** Regular grammars, equivalence of regular grammars and regular languages.

**Module Outcome:**
*After Completion of this module, the student should be able to:*

M01: Understand the regular language generated by a regular grammar.
M02: Find the regular language generated by a regular grammar and a regular grammar for a regular language.

**Module VI:** Closure properties of regular languages, elementary questions about regular languages, Pumping lemma.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Demonstrate the power of pumping lemma.
M02: Create research output in the decision problems in formal language theory.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Linz P., An introduction to formal languages and automata, Jones and Bartlet student edition, 2012.

**Additional References**

[1]. Anderson J. A., Automata Theory with Modern Applications, Cambridge University Press, 2006.
[2]. Hopcroft J. E., Motwani R., Ullman J. D, Introduction to Automata Theory, languages and computation, Pearson, 2013.
[3]. Sisper M., Introduction to the Theory of Computation, CENGAGE Learning, 2012.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)

| ANY SEMESTER (I-IV) | Course Code: MATF-SE-501 | Credits: 2 |
|---|---|---|

**NAME OF THE COURSE:** FUNDAMENTALS IN LATEX

**Course Outcomes:**

**CO1**: The students will be able to typeset documents which involve accents of foreign languages, mathematical symbols, long tables pictures etc according to international standards.

**COURSE CONTENT**

**Module I:** Introduction to LATEX, Preparing an input file in LATEX, The Input, Running LATEX.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand the basic commands to prepare an input file in LATEX.

**Module II:** Changing the Type style, Symbols from other Language, Figures and other floating bodies, Lining it up in columns.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Change the type style of a document.
M02: Typeset symbols from other languages, figures and other floating bodies.

**Module III:** Typing Mathematical formulas, Fine points of Mathematics typing, Defining commands and Environments, Packages in LATEX.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand fine points of mathematics typing.
M02: Create commands and environments for specific purposes.

**Module IV:** The Table of contents, Cross References, Bibliography and citation, Making an index or Glossary.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about creation of bibliography using LATEX.
M02: Develop the table of contents and index for a document.

**Module V:** Pictures and Colors, The graphics Package, Colors.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about the graphic package in LATEX.
M02: Include pictures in a document.

**Module VI:** Other Document classes: Books, slides and letters, Presentation Tools in LATEX.

**Module Outcome:**
*After Completion of this module, the student should be able to:*
M01: Understand about the various document classes in LATEX.
M02: Prepare presentation slides using LATEX.

**ACTIVITIES, LEARNING RESOURCES & ASSESSMENT**

**Suggested Class Room Activities:**

- Assignments
- Seminar Presentation on selected topics
- Debates
- Quiz
- Demonstration of simple experiments
- Field work and survey

**LEARNING RESOURCES**
**References**

[1]. Leslie Lamport , *LATEX A Document Preparation System* , Addison _Wesley, 2000.

**Additional References**

[1]. Goosens, Mittelbach and Samari, *The LATEX Companion*, Addison _Wesley, 2004.
[2]. Donald Knuth, *The TEX Book*, Addison _Wesley, 1986.
[3]. E. Krishnan, *LATEX TUTORIALS – A PRIMER*, Indian TEX users group, 2003.

**On-line Sources**

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**ASSESSMENT**

40% Continuous / Formative Assessment (see PG Regulations).
60% End-semester/Summative Assessment: 3 hour written Exam.

**MODEL QUESTION BASED ON OBE FORMAT**
(For each course include one model question paper based on OBE pattern)