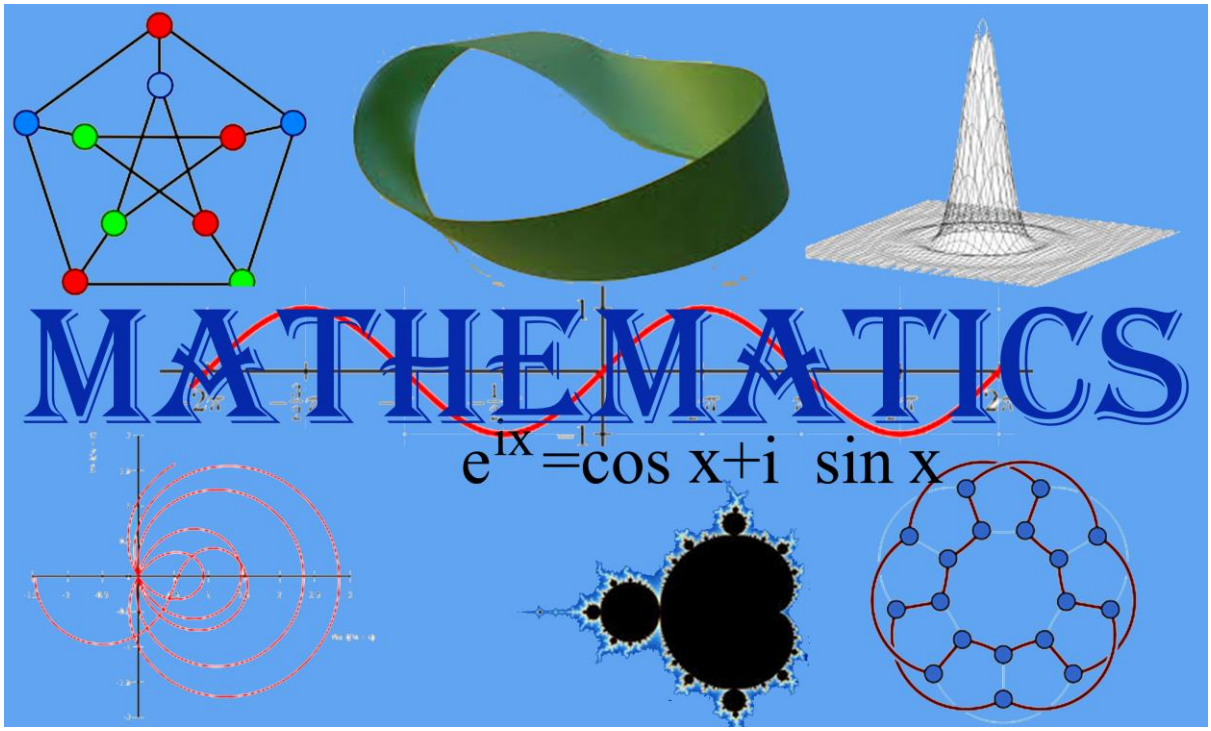
Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme



Name of the Programme:

M.Sc. Programme in Mathematics

(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 MSc Programme in Mathematics

Programme Specific Outcomes (PSO) for
MSc Programme in Mathematics

PSO 1 Solve problems in various fields of Mathematics.

PSO 2 Sharpening of mathematical concepts leading to research.

PSO 3 Knowledge about scientific method and skills in mathematical computation

PSO 4 Extension of domain knowledge to face real life problems

PSO 5 Enhancement of critical thinking skills and attitudes to become a thinker and professional

PSO 6 Creating academic excellence in mathematics and allied subjects

Programme Structure of MSc Mathematics

Semester	Course Code	Name of the course	Credits
I	**Core Courses (CC)**		
	MAT-CC-511	Linear Algebra	3
	MAT-CC-512	Real Analysis	3
	MAT-CC-513	Differential Equations	4
	MAT-CC-514	General Topology	4
	MAT-CC-515	Numerical Methods	4
II	**Core Courses (CC)**		
	MAT-CC-521	Abstract Algebra	4
	MAT-CC-522	Measure Theory	4
	MAT-CC-523	Algebraic Topology	4
	Discipline-Specific Elective (DE)		
	MAT-DE-524	Graph Theory	4
	MAT-DE-525	Theory of Wavelets	4
III	**Core Courses (CC)**		
	MAT-CC-531	Complex Analysis-I	4
	MAT-CC-532	Functional Analysis	4
	MAT-CC-533	Approximation Theory	4
	Discipline-Specific Elective (DE)		
	MAT-DE-534	Differential Geometry	4
	MAT-DE-535	Operations Research	4
	MAT-DE-536	Galois Theory	4
	Core Courses (CC)		
	MAT-CC-541	Complex Analysis-II	4
	MAT-CC-542	Theory of Linear Operators	4

IV	MAT-CC-543	Dissertation and Viva	6
	Discipline-Specific Elective (DE)		
	MAT-DE-544	Integral Equations and Calculus of Variations	4
	MAT-DE-545	Number Theory	4
	MAT-DE-546	Coding Theory	4
Any semester (I-IV)	**Generic Course (GC)**		
	MAT-GC-501	Complex Analysis	2
	MAT-GC-502	Finite State Machines	2
	Skill Enhancement Elective (SE)		
	MAT-SE-501	Fundamentals in Latex	2

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

SEMESTER I	Course Code: MAT-CC-511	Credits: 3

NAME OF THE COURSE: LINEAR ALGEBRA

Course Outcomes:

CO1: Understand basis of a vector space, invariant subspaces, diagonable matrices, Jordan form of a general matrix and the Cayley Hamilton theorem.
CO2: Solve problems related to change of basis and matrix of a linear transformation, computation of the dual basis for a given basis of a vector space, computation of the Eigenvalues and Eigenvectors of matrices.
CO3: Create nilpotent matrices, unitary similar matrices and normal matrices and to derive properties of Hermitian matrices and positive definite matrices.

COURSE CONTENT

Module I: Vector space, basis and coordinates, linear transformation, the matrices of linear transformation, change of basis and similarity, special type of matrices, sub matrices, partitioned matrices and block multiplication, invariant subspaces.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand about basis of a vector space and invariant subspaces.
M02: Solve problems related to change of basis and matrix of a linear transformation.

Module II: The inner product, length orthogonality and projection in C^n, orthogonal compliments and projection onto a subspace, linear functional and the dual space.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Analyze about subspaces and linear functional in an inner product space.
M02: Compute the dual basis for a given basis of a vector space.

Module III: Eigen values, algebraic and geometric multiplicities, diagonalizability, triangulation theorem, more about the characteristic polynomial, Eigen values of AB and BA
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand about diagonable matrices.
M02: Compute the Eigen values and Eigen vectors of matrices.

Module IV: The theorem of sylvester and reduction to block diagonal form, Nilpotent matrices, the Jordan form of a general matrices, the Cayley-Hamilton theorem and the minimal polynomial.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand about Jordan form of a general matrix and the Cayley Hamilton theorem.

M02: Find the minimal polynomial associated with a matrix.
M03: Create nilpotent matrices.
Module V: Unitary similarity, normal matrices, more about normal matrices, condition for unitary similarity.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Analyse unitary similar matrices and normal matrices.
M02: create unitary similar matrices and normal matrices.

Module VI: Conjugate bilinear forms, properties of Hermetion matrices, the Rayleigh-Ritz ratio and the Courant-Fisher theorem, Cauchy's interlacing theorem and other Eigen value inequalities, positive definite matrices.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand about Rayleigh-Ritz ratio.
M02: Derive properties of Hermitian matrices and positive definite matrices.

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]. Helence Shapiro, Linear Algebra and Matrices : Topic for a second course, American Mathematical Society, 2015.

Additional References

[1]. COHN. P. M., Elements of Linear Algebra, Chapman and Hall, London , 1994
[2]. HALMOS. P. R., Finite dimensional Vector spaces, Narosa Publishing House, New Delhi, 1980
[3]. HERSTEIN. N., Topics in Algebra, Wiley Eastern Ltd Reprint , 1991
[4]. Kenneth Hoffman and Ray Kunze, Linear Algebra, Prentice Hall of India , Second Edition, New Delhi, 1997
[5]. LANG. S., Linear Algebra, Addison Wesley Pub. Co. Reading, Mass, 1972

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: MAT-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: Riemann's 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.

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]. W. Rudin, Principles of mathematical analysis, 2017.
[6]. Strichartz. R.S., The way of Analysis, Jones and Barllel Publishers

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: MAT-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: Introduction, the 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]. Amaranath T., "An elementary course in partial differential equations", Jones & Bartlett Learning, 2009
[2]. Coddington E.A., "An introduction to ordinary differential equations", Dover publications, 1961
[3]. Simmons G.F., "Differential Equations with applications and historical notes", 3rd edition, CRS Press, 2017
[4]. Ian Sneddon, "Elements of partial differential equations", 2013
[5]. Stephen A Wirkus, Randall J Swift, Ryan S Szypowski, "A course in differential equations with boundary value problems", 2nd edition,CRS press, 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: MAT-CC-514	Credits: 4

NAME OF THE COURSE: GENERAL TOPOLOGY

Course Outcomes:

CO1: Understand the concepts and results in topology and apply these results to other branches of mathematics

CO2: Appreciate topology as an abstraction of real analysis

COURSE CONTENT

Module I: Metric spaces, The Definition and Some Examples, Open Sets and Closed Sets in Metric Spaces, Interior, Closure and Boundary, Continuous Functions, Equivalence of Metric Spaces, New Spaces from Old, Complete Metric Spaces.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Identify continuous functions.
M02: Find open and closed sets.
M03: Work on abstract metric spaces.

Module II: Topological Spaces, The Definition and Some Examples, Interior, Closure, and Boundary, Basis and Sub basis, Continuity and Topological Equivalence, Subspaces.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concept of topology.
M02: Find the interior and closure of a set.
M03: Work on continuous functions in a topological space.

Module III: Connectedness, Connected and Disconnected Spaces, Theorems on Connectedness, Connected Subsets of the Real Line, Applications of Connectedness, Path Connected Spaces.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Demonstrate the impact of connectedness on continuous functions.
M02: Identify connected topological spaces and path connected topological spaces.

Module IV: Compactness, Compact Spaces and Subspaces, Compactness and Continuity, Properties Related to Compactness, One-Point Compactification, The Cantor Set.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concept of compactness.
M02: Demonstrate the impact of compactness on continuous functions.

Module V: Product and Quotient Spaces, finite Products, Arbitrary Products, Comparison of Topologies, Quotient Spaces.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concept of product topology.
M02: Find quotient spaces.

Module VI: Separation Properties, T0, T1, and T2-Spaces, Regular Spaces , Normal Spaces, Separation by Continuous Functions.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Demonstrate Hausdorff space as a topological space in which every net has unique limit.
M02: Analyse normal space as a topological space in which every real valued continuous function defined on a closed subspace has a continuous extension.

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]. Croom F. H., *Principles of Topology*, Dover Publication Inc., 2016.

Additional References

[1]. Cain G., *Introduction to general topology*, Pearson, 2012.
[2]. Joshy K. D., I*ntroduction to general topology,* New Age International (P) Ltd., 2004.
[3]. Kelly J. L., *General topology*, Springer-Verlag, 1955.

[4]. Lynn Arther Steen, Seebatch J. A., *Counter examples in topology*, Dover Publication Inc. 1995.
[5]. Simmons G. F., *Introduction to modern analysis*, McGraw Hill, 1983.

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: MAT-CC-515	Credits: 4

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

COURSECONTENT

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, characterizing algorithms, rates of convergence,, the bisection method, the secant method, Newton's method, error analysis and accelerating convergence- order of convergence, Aitken's Δ^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, Spline interpolation- piecewise-polynomial approximation, cubic splines- cubic splines interpolation, construction of cubic splines, parametric curves.

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, five -point formulas, Round-off error instability.

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 determinants, matrix factorization- permutation matrices, techniques for special matrices- strict diagonal dominance, positive definite matrices, band matrices, tridiagonal matrices.

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, the steepest descent method-The gradient of a function, Homotopy and continuation methods.

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 II	Course Code: MAT-CC-521	Credits: 4

NAME OF THE COURSE: ABSTRACT 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 fundamental concepts in groups, homomorphism in group, quotient groups and group actions.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand quotient groups, p-groups, simple groups and isomorphism theorems in groups.
M02: Find the kernel of a group homomorphism, center of a group and the connection between orbits and stabilizers.
M03: Construct new groups from a given group.

Module II: A quick review of fundamental concepts in ring theory and polynomials, from arithmetic to polynomials, irreducibility, Euclidean rings and principal ideal domain.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand Euclidean rings and partial ideal domain.
M02: Analyze factorization of polynomials over a field.
M03: Solve problems related to irreducibility of polynomials.
Module III: Quotient rings and finite fields.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand extension field of a field and splitting field.
M02: Classify algebraic and transcendental elements over a field.

Module IV: Insolvability of the quintic.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand separable extension and normal extension.
M02: Compute Galois groups of polynomials over the field of rational numbers.

Module V: Finite Abelian group.

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

M01: Understand about direct sum of groups.
M02: Classify finite abelian groups.
M03: Construct the invariant factors of a finite abelian group from its elementary divisors.

Module VI: Sylow theorems, solvable groups (proof of Zassenhaus Lemma and Krull-Schmidt Theorem are omitted)

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand Sylow theorems and solvable groups.
M02: Find the Sylow p-subgroups of groups.
M03: Construct the composition series of certain cyclic 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]. Joseph J. Rotman, Advanced Morden Algebra, American Mathematical Society, Second edition, 2010.

Additional References

[1]. Gallian J.A., "Contemporary Abstract Algebra", 8th edition, Cengage learning,
[2]. Herstein I.N, "Topics in Algebra", Second edition, Wiley india Pvt. Ltd,
[3]. Garrett, Paul B., Abstract algebra, Chapman and Hall/CRC Taylor and Francis group, 2017.
[4]. Jacobson N., "Basic Algebra", Vol-1, Hindustan Pub. Corporation (India) 1993.
[5]. John B Fraleigh, "A first course in Abstract Algebra", Seventh edition Addison-Wesley pub, 2002.
[6]. Michael Artin, "Algebra", Second edition, pearson Educational Limited, 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 II	Course Code: MAT-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 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 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: MAT-CC-523	Credits: 4

NAME OF THE COURSE: ALGEBRAIC TOPOLOGY

Course Outcomes:

CO1: To familiarize with homotopy and homology theory so as to connect topological concepts with algebraic concepts.

CO2: Formulate complex problems using appropriate algebraic topology terminology.

CO3: Use sophisticated tools from algebraic topology in various areas of mathematics.

COURSE CONTENT

Module I: Geometric complexes and polyhedral, Orientation of geometric complexes, chains and cycles, Chains, cycles and homology groups.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand basic notations and terminologies such as complex, polyhedra, boundary.
M02: Demonstrate the relation between linearly independent and geometrically independent sets in $\mathbf{R}^n$.

Module II: Examples of homology groups, structure of homology groups, Euler-Poincare theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Compute the homology group of a cylinder, torus, Mobius strip. (Evaluate)
M02: Describe the structure of homology groups (Create)

Module III: Simplicial approximation, Induced homomorphisms on the homology groups, Brouwer fixed point theorem and related results.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Demonstrate the fact that homeomorphic spaces have isomorphic homology groups.
M02: Create applications of homology theory.

Module IV: Homotopic paths and the fundamental group.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concept of homotopy.
M02: Demonstrate that fundamental groups topological space with respect to two path-connected points are isomorphic.

Module V: Covering homotopy property for S1, Examples of fundamental groups.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Demonstrate the importance of covering path property and covering homotopy property.
M02: Compute the fundamental group of unit circle, cylinder.

Module VI: Basic properties of covering spaces, Classification of covering spaces, Universal covering spaces.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Demonstrate the equivalence of covering spaces of a space.
M02: Analyse the relation between the automorphism group of a universal covering space and fundamental group of its base space.

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]. Croom F. H., *Basic concepts in algebraic topology*, Springer-Verlag., 2016.

Additional References

[1]. Armstrong M. A., *Basic Topology*, Springer-Verlag, 1983.

[2]. Hatcher., *Algebraic Topology*, Cambridge University Press, 2002.
[3]. Munkers J. R., *Elements of Algebraic Topology*, Addison Wesley, 1984.
[4]. I. M. Singer and J. A. Thorpe, *Lectures on elementary topology and geometry*, Sringer, 1977.
[5]. Spanier E., Algebaic Topology, Springer Verlag, 1966.

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: MAT-DE-524	Credits: 4

NAME OF THE COURSE: GRAPH THEORY

Course Outcomes:

CO1: Understand the connection between mathematics and other branches of science and social sciences.
CO2: Analyse mathematical applications through graphs.
CO3: Analyse mathematical applications through graphs.
CO4: Solve several topological and geometrical problems by using graph theoretical parameters.

COURSE CONTENT

Module I: Introduction to graph models- graphs and digraphs, common families of graphs, graph modelling applications, walks and distance, paths, cycles and trees, vertex and edge attributes more applications.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand basic concepts and properties of graphs.
M02: Familiarise with graphical applications.
M03: Construct graph models.

Module II: Structure and representation- graph isomorphism, automorphisms and symmetry subgraphs, some graph operations, tests foe non-isomorphism, matrix representations, more graph operations.

Module Outcome:
After Completion of this module, the student should be able to:
M01:Obtain more knowledge about graphs in terms of algebraic properties.
M02:Identify non-isomorphic graphs.
M03:Analyse various graph theoretical operations.

Module III: Trees- characterization of properties of trees, rooted trees, ordered trees and binary trees, binary-tree traversals, binary search trees, counting binary trees: Catalan recursion, spanning trees- tree growing, depth-first and breadth-first search, minimum spanning trees and shortest paths .

Module Outcome:
After Completion of this module, the student should be able to:
M01:Acquire clear cut knowledge on classes of trees and their properties.
M02:Determine the number of binary trees in the given graphs.
M03:Write various tree-search algorithms.

Module IV: Connectivity- vertex and edge-connectivity, constructing reliable networks, block decompositions, Optimal graph traversals- Eulerian trails and tours, DeBruijn sequences and post man problems, Hamiltonian paths and cycles.

Module Outcome:
After Completion of this module, the student should be able to:
M01:Identify the Euler tours and Hamiltonian cycles of the given graph.
M02:Analyse different connectivity properties.
M03:Construct reliable networks.

Module V: Planarity and kuratowski's theorem- planar drawings and some basic surfaces, subdivision and homeomorphism, extending planar drawings, crossing numbers and thickness, Graph colourings- vertex-colourings, map-colorings, edge-colorings, factorization

Module Outcome:
After Completion of this module, the student should be able to:
M01:Understand planarity properties of graphs.
M02:Determine the factorability of graphs.
M03:Compute the crossing number and thickness of a graph.

Module VI: Special digraph models- directed paths, and mutual reachability, digraphs as models for relations, tournaments, Network flows and applications- flows and cuts in networks, solving the maximum-flow problem, flows and connectivity .
Module Outcome:
After Completion of this module, the student should be able to:
M01:Analyse network flows and its applications.
M02:Solve maximum-flow and connectivity problems.
M03:Construct different digraph models.

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]. Jonathan L. Gross, Jay Yellen, Mark Anderson, "GRAPH THEORY AND ITS APPLICATIONS", Third edition, CRC Press, 2019.

Additional References

[1]. Aleksander Mratinkovic, Hazen Shawky Fouda et.al., "Illustrated Handbook of Graph Theory", 3 G-learning, 2018.
[2]. Bondy J.A and Murthy U.S.R, "Graph Theory with Applications", The Macmillan Press limited.
[3]. Gary Chartrand and Ping Zhang, "Introduction to Graph Theory", Tata-McGraw-Hill Edition 2006.
[4]. Harary, "GRAPH THEORY", Addison-Wesley,1989.
[5]. Suresh Singh G., "Graph Theory" PHI Learning Private Limited.
[6]. 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 II	Course Code: MAT-DE-525	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 $[-\pi, \pi)$.
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 III	Course Code: MAT-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: MAT-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, uniform boundedness 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 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.
[4]. Simmons G. F., I*ntroduction to Topology and Modern Analysis, McGraw Hill-1983.*

[5]. Thamapan Nair. M., *Functional analysis: A first course*, 2001, P. H. I.

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 III	Course Code: MAT-CC-533	Credits: 4

NAME OF THE COURSE: APPROXIMATION THEORY

Course Outcomes:

CO1: Analyse the existence and characterization of best approximation for polynomials and rational functions.
CO2: Apply algorithms for finding an approximate solution for the approximation problems.
CO3: Construct polynomials for a given function at a certain finite number of given points.

COURSE CONTENT

Module I: Metric spaces- an existence theorem for best approximation from a compact subset ; Normed linear spaces, Inner product spaces

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concepts of Metric space, Normed space, Banach space and inner product space.
M02: Apply a method for constructing orthonormal sets from linearly independent set.
M03: Analyse the existence for approximation from compact set.

Module II: Convexity – Caratheodary's theorem – Theorem on linear inequalities – an existence theorem for best approximation from finite dimensional subspaces – uniform convexity – strict convexity.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the concepts of convex set, convex hull, uniform convexity and strict convexity.
M02: Apply the concept of best approximation from finite dimensional subspaces.
M03: Analyse the necessary and sufficient condition for the system of linear inequalities to be inconsistent.
M04: Find the relationship between uniformly convex space and strictly convex space.

Module III: The Tchebycheff solution of inconsistent linear equations – systems of equations with one unknown – three algebraic algorithms ; Characterization of best approximate solution for m equations in n unknowns – the special case m = n +1 ; Polya's algorithm.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Analyse the procedure for solving the Tchebycheff problem connected with system of equations with one unknown.
M02: Apply algorithms for finding an approximate solution.
M03: Compute the minimax solutions of a system of n+1 equations in n unknowns.
M04: Develop methods for locating minimum points of the functions.

Module IV: Interpolation – the Lagrange formula – Vandermonde's matrix – the error formula – Hermite interpolation ; The Weierstrass theorem – Bedrstein polynomials – Monotone operators – Fejer's theorem ; General linear families – characterization theorem – Haar conditions – alternation theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the characterization of best approximations for generalized polynomials.
M02: Analyse that there exist some sequence of polynomials converging to a prescribed continuous function, uniformly on a closed bounded interval.
M03: Construct polynomials that agree with a given function at a certain finite number of a given points.

Module V: Rational approximation – Conversion of rational functions to continued fractions; Existence of best rational approximation – extension of the classical theorem ; Generalized rational approximation – the characterization of best approximation – an alternation theorem – the special case of ordinary rational functions ; Unicity for generalized rational approximation.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Analyse the conversion of rational functions to continued fractions.
M02: Analyse the existence of best rational approximation
M03: Explain the characterization of best approximation for generalized rational approximations.

Module VI: The Stone Approximation Theorem; The Muntz Theorem – Gram's lemma; Approximation in the mean – Jackson's Unicity Theorem – Characterization theorem – Markoff's theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Trace a logical connection between fundamentality of $\{1, x, x^2,\ldots\}$ and the divergence of the series of reciprocal exponents, $1+1/2+1/3+\ldots$.
M02: Analyse the unicity of best approximation in the mean
M03: Understand the characterization for best approximation in the mean

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]. Cheney E.W., "Introduction to Approximation Theory" , MC Graw Hill, 1966

Additional Reference

[1]. Davis P. J, "Interpolation and Approximation", Blaisdell Pub., 1964.

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 III	Course Code: MAT-DE-534	Credits: 4

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

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 III	Course Code: MAT-DE-535	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: MAT-DE-536	Credits: 4

NAME OF THE COURSE: GALOIS THEORY

Course Outcomes:

CO1: Create wider knowledge about field extensions

CO2: Familiarize various results on algebraic structures.

CO3: Study properties of rings of polynomials, extension fields, splitting fields and their applications in real world problems.

COURSE CONTENT

Module I: Rings of polynomials over a field, evaluation homomorphism, zeros of polynomials, Division algorithm, Irreducible polynomial, Prime and maximal ideals, prime fields.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Learn rings of polynomials over a field, evaluation homomorphism, zeros of polynomials, division algorithm, irreducible polynomial, prime ideals, maximal ideals and prime fields.
M02: Appreciate how Galois Theory uses and unifies ideas from polynomials, fields and groups.

Module II: Extension field and zeros of polynomials, Irreducible polynomial for elements
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the definition and various properties of extension field, zeros of polynomials over a field and irreducible polynomials over a field.
M02: Apply the concept that every nonconstant polynomial has a zero.

Module III: Algebraic extensions, algebraically closed field, algebraic closure.
Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the algebraic extension of a field and algebraic closure of a field.
M02: Appreciate various important properties of algebraically closed fields.

Module IV: Automorphisms of splitting fields, separable extensions, perfect fields.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Learn the definition of splitting field, separable extensions and perfect fields.
M02: Understand various properties and theorems on automorphisms of splitting fields.

Module V: Galois group of a polynomial, Frobenius automorphism, primitive n^{th} roots of unity, solvability by radicals.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the Galois group of field extension.
M02: Apply the concept of how the Galois group takes account of there being a formula for the roots of a polynomial that involves only the field operations and taking square roots, cube roots, etc.
M03: Analyse Frobenius automorphism and the primitive nth roots of unity.
M04: Compute the Galois group of a polynomial.

Module VI: Galois extension and intermediate fields, The fundamental theorem of Galois theory, Applications.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the definition of Galois extension and intermediate fields.
M02: Use the fundamental theorem of Galois theory in various applications.

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. Fraleigh, A First Course in Abstract Algebra, AWL, 1999 (5^{th} Edition).
[2]. Joseph Rotman, Galois Theory, Springer, 1998.

Additional References

[1]. Hungerford T.W., Algebra, Springer, 1974
[2]. Patrick Morandi, Field and Galois theory, Springer, 1996

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 IV	Course Code: MAT-CC-541	Credits: 4

NAME OF THE COURSE: COMPLEX ANALYSIS-II

Course Outcomes:

CO1: Analyse the space of continuous analytic functions.
CO2: Approximate analytic function by a sequence of polynomials.
CO3: Solve problems related to finite products, harmonic functions and elliptic functions.

CO4: Use the results in complex analysis to solve problems in other branch of mathematics.

COURSE CONTENT

Module I: Compactness and Convergence in the space of Analytic functions, The space C(G,Ω), Space of Analytic functions, Riemann Mapping Theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Analyze the space of continuous functions and the space of analytic functions. (Analyse)
M02: Derive that all proper simply connected regions in the place are equivalent to the open unit disk (Create)

Module II: Weierstrass factorization Theorem, Factorization of sine function, The Gamma function.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Apply Weierstrass factorization theorem for finding the factorization of sine function.
M02: Solve problems related to the infinite product of sequence of complex numbers.
M03: Derive properties of Gamma functions.

Module III: Riemann Zeta function, Runge's Theorem, Simple connectedness, Mittag – Leffler's Theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Approximate an analytic function defined on a region by sequence of rational functions analytic on the region.
M02: Find the relationship between the Gamma function and the Riemann Zeta function.

Module IV: Analytic continuation and Riemann surfaces, Schwarz Reflection Principle, Analytic continuation along a path, Monodromy Theorem.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand about Schwarz Reflection Principle and germ of analytic functions.
M02: Redefine an analytic function so as to extend its domain of analyticity in a proper way.

Module V: Basic properties of Harmonic functions, Harmonic functions on a disc,

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the basis properties of harmonic functions.
M01: Analyse harmonic functions defined on the open unit disk and then interpret the result for arbitrary disks.

Module VI: Entire functions, Jensen's formula, The genus and order of an entire function, Hadamard factorization Theoerm.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand Jensen's Formula and Hadamard's Factorization Theorem.
M02: Solve problems related to finding of the genus and order of an entire function.

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 One Complex Variable", Springer – Verlag, New York, 1973. (Indian Edition : Narosa)

Additional References

[1]. Ahlfors L. V., Complex Analysis, Mc-Graw Hill (1966)

[2]. Rudin W., Real and Complex Analysis, Mc-Graw.

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: MAT-CC-542	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.
[2]. Simmons G. F., Topology and Modern Analysis, McGraw – Hill, Singapore.

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.
[4]. 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 IV	Course Code: MAT-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: MAT-DE- 544	Credits: 4

NAME OF THE COURSE: INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS

Course Outcomes:

CO1: Solve simple initial value problem and boundary value problem using calculus of several variable.
CO2: Solve integral equations of several types.
CO3: Understand the concepts, methods and structure of integral equations theory.
CO4: Formulate physical problems into integral equation and solve.
CO5: Solve mathematical problems using techniques from integral equations theory.

COURSE CONTENT

Module I: Introductory concepts, Definitions, classification of linear integral equation, solution of integral equation, converting Volterra integral equation to ODE, converting IVP to Volterra integral equation, converting BVP to Fredholm integral equation

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the basic concepts of integral equations.
M02: Distinguish between Volterra integral equation and Fredholm Integral equation.
M03: Convert Volterra integral equation to ODE.
M04: Convert IVP to Volterra integral equation.
M05: Convert BVP to Fredholm Integral equation.

Module II: Fredholm integral equations**,** introduction, the Adomian decomposition method, the variational iteration method, the direct computation method, the successive approximations method, the method of successive substitutions, comparison between alternative methods, homogeneous Fredholm integral equations, Fredholm integral equations of the first kind.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Solve the Fredholm Integral equation using various methods.

Module III: Volterra integral equations, introduction, the Adomian decomposition method, the variational iteration method, the series solution method, converting Volterra equation to IVP, successive approximations method, the method of successive substitutions, comparison between alternative methods, Volterra integral equations of the first kind

Module Outcome:
After Completion of this module, the student should be able to:
M01:Understand Volterra integral equations.
M02: Solve the Volterra integral equation using various methods.

Module IV: Fredholm Integro-Differential Equations, Introduction, Fredholm Integro-Differential Equations, The Direct Computation Method, The Adomian Decomposition Method, The Variational Iteration Method, Converting to Fredholm Integral Equations,
Volterra Integro-Differential Equations, Introduction, Volterra Integro-Differential Equations, The Series Solution Method, The Adomian Decomposition Method, The Variational Iteration Method, Converting to Volterra Integral Equation, Converting to Initial Value Problems, Volterra Integro-Differential Equations of the First Kind.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand Fredholm Integro-differential equation and Volterra Integro-differential equation.
M02:Solve Fredholm Integro-differential equation using various methods.
M03:Solve Volterra Integro-differential equation using various methods.

Module V: Calculus of Variations: Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum.

Module Outcome:
After Completion of this module, the student should be able to:
M01: Understand the basic concepts of calculus of variation.
M02: Solve simple variational problems.
M03: Describe the necessary conditions for an extremum.

Module VI: Euler`s equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler`s equations. Variational problem in parametric form

Module Outcome:
After Completion of this module, the student should be able to:
M01: Find out the Euler equation of a functional.
M02: Solve simple variable end point problems.

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]. Abdul-Majid Wazwaza, First Course in Integral Equations, World Scientific Publishing Co. Pte. Ltd., Second edition, 2015
[2]. Gelfand, Fomin , Calculus of variations, Dover books.

Additional References

[1]. Jerry A.J , Introduction to integral equations with Applications , Wiley publishers
[2]. Filip Rindler, Calculus of variations, Springer, 2018.
[3]. R.K. Sharma, Calculus of variations, MedTech, 2017.
[4]. Weinstock R, Calculus of variations with applications to Physics and engineering, Dover Publications.

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 IV	Course Code: MAT-DE-545	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

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 IV	Course Code: MAT-DE-546	Credits: 4

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.

COURSECONTENT

MODULE VI:

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 etal., 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)

ANY SEMESTER (I-IV)	Course Code: MAT-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: MAT-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: MAT-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)