Kurukshetra University, Kurukshetra

(Established by the State Legislature Act-XII of 1956)
("A++" Grade, NAAC Accredited)

Syllabus
for

Post Graduate Programme

M.Sc. Mathematics

as per NEP-2020
Curriculum and Credit Framework for Postgraduate Programme

With Multiple Entry-Exit, Internship and CBCS-LOCF
With effect from the session 2024-25 (in phased manner)

DEPARTMENT OF MATHEMATICS
FACULTY OF SCIENCES

KURUKSHETRA UNIVERSITY, KURUKSHETRA -136119

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Deptt. of Mathematics
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CC-1 REAL ANALYSIS

With effect from the Session: 2024-25			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	I		
Name of the Course	REAL ANALYSIS		
Course Code	M24-MAT-101		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Real Analysis up to the 299 level		
Course Objectives	The course aims to familiarize the learner with Riemann-Stieltjes integral, uniform convergence of sequences and series of functions, functions of several variables and Fourier series.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the concept of Riemann-Stieltjes integral along its properties; integration of vector-valued functions with application to rectifiable curves. CLO 2: Understand and handle convergence of sequences and series of functions; construct a continuous nowhere-differentiable function; demonstrate understanding of the statement and proof of Weierstrass approximation theorem. CLO 3: Understand the concepts of differentiability and continuity of functions of several variables and their relation to partial derivatives; apply the knowledge to prove inverse function theorem and implicit function theorem. CLO 4: To formulate convergence problems of Fourier series, know about the (C,1) summability of Fourier series and apply these notions to prove the well- known Fejer theorem, Bessel's inequality, Riesz-Fischer theorem, Parseval equality and Riemann-Lebesgue theorem.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Definition and existence of the Riemann-Stieltjes integral, properties of the integral, integration and differentiation, the fundamental theorem of calculus, integration of vector-valued functions, rectifiable curves. (Scope as in Chapter 6 of 'Principles of Mathematical Analysis' by Walter Rudin, Third Edition).	15
II	Sequences and series of functions: Pointwise and uniform convergence of sequences of functions, Cauchy criterion for uniform convergence, Dini's theorem, uniform convergence and continuity, uniform convergence and Riemann integration, uniform convergence and differentiation. (Scope as in Sections 9.1 to 9.3 of Chapter 9 'Methods of Real Analysis' by R.R. Goldberg). Convergence and uniform convergence of series of functions, Weierstrass M-test, integration and differentiation of series of functions, existence of a continuous nowhere-differentiable function, the Weierstrass approximation theorem (Scope as in Sections 9.4, 9.5, 9.7 of Chapter 9 & Section 10.2 of Chapter 10 of 'Methods of Real Analysis' by R.R. Goldberg).	15
III	Functions of several variables: Linear transformations, the space of linear transformations on R^n to R^m as a metric space, open sets, continuity, derivative in an open subset of R^n, chain rule, partial derivatives, continuously differentiable mappings, the contraction principle, the inverse function theorem, the implicit function theorem. (Scope as in relevant portions of Chapter 9 (up to 9.29) of 'Principles of Mathematical Analysis' by Walter Rudin, Third Edition)	15
IV	Fourier Series: Formulation of convergence problems, the necessary and sufficient condition for the Fouriesr series for f at x to converge to f(x), The (C,1) summability of Fourier series, Fejer theorem, The L^2 theory of	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	Fourier series, Bessel's inequality, Riesz Fischer theorem, Parseval's equality, convergence of Fourier series, Riemann-Lebesgue theorem, Orthonormal expansions in $L^2[a, b]$, Bessel's inequality for generalized Fourier series. (Scope as in Chapter 12 of 'Methods of Real Analysis' by R.R. Goldberg).	
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. Walter Rudin, Principles of Mathematical Analysis (3rd Edition) McGraw-Hill, 2013.

2. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 2020.

Reference Books:

1. T.M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi, 1985.

2. Gabriel Klambauer, Mathematical Analysis, Marcel Dekkar, Inc. New York, 1975.

3. A.J. White, Real Analysis; an introduction. Addison-Wesley Publishing Co., Inc., 1968.

4. E. Hewitt and K. Stromberg. Real and Abstract Analysis, Berlin, Springer, 1969.

5. Serge Lang, Analysis I & II, Addison-Wesley Publishing Company Inc., 1969.

6. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi, 4th Edition 2010.

7. D. Somasundaram and B. Choudhary, A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi, 1997

CC-2 COMPLEX ANALYSIS

With effect from the Session: 2024-25			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	I		
Name of the Course	COMPLEX ANALYSIS		
Course Code	M24-MAT-102		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Real Analysis up to the 299 level		
Course Objectives	The main objective of the course is to familiarize the learner with complex function theory, analytic functions theory, the Cauchy's theorems, integral formulas, singularities and contour integrations and finally provide a glimpse of Argument principle; Rouche's theorem; Schwarz Lemma.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the concepts of limit, continuity, differentiation and integration for functions defined over a complex plane as well as for the elementary functions. CLO 2: Solve the complex integrals of various kinds through the applications of relevant theorems, formulae and power series expansions. CLO 3: Analyse the complex functions with singularities for zeroes and residues at poles and apply the results to solve the improper integrals. CLO 4: Solve complex improper integrals through the indentation, transformation/mapping of integration paths so as to avoid singularities and branch points/cuts.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

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Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Analytic functions; Harmonic functions; Reflection principle; Elementary functions: Exponential, Logarithmic, Trigonometric, Hyperbolic, Inverse trigonometric , Inverse hyperbolic, Complex exponents; Complex Integration: Definite integral; Contours; Branch cuts. (Relevant portions from the book recommended at Sr. No. 1)	15
II	Cauchy-Goursat theorem; Simply/ multiply connected domains; Cauchy integral formula; Morera's theorem; Liouville's theorem; Fundamental theorem of algebra; Maximum modulus principle; Power series: Taylor series; Laurent series; Uniform/ absolute convergence. (Relevant portions from the book recommended at Sr. No. 1)	15
III	Differentiation, integration, multiplication, division of power series; Singularities; Poles; Residues; Cauchy's residue theorem; Zeros of an analytic function; Evaluation of improper integrals; Jordan's lemma. (Relevant portions from the book recommended at Sr. No. 1)	15
IV	Indented paths; Integration along a branch cut; Definite integrals involving sines and cosines; Winding number of closed curve; Argument principle; Rouche's theorem; Schwarz Lemma ; Transformations: linear, bilinear (Mobius), sine, z^2, $z^{1/2}$; Mapping: Isogonal; Conformal; Scale factors; Local inverses; harmonic conjugates. (Relevant portions from the book recommended at Sr. No. 1)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

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K.U. KURUKSHETRA

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. Churchill, R.V. and Brown, J.W., Complex Variables and Applications, Eighth edition; McGraw Hill International Edition, 2009.

Reference books:

1. Ahlfors, L.V., Complex Analysis. McGraw-Hill Book Company, 1979.
2. Conway, J.B., Functions of One complex variable, Narosa Publishing, 2000.
3. Priestly, H.A., Introduction to Complex Analysis, Claredon Press, Orford, 1990.
4. D.Sarason, Complex Function Theory, Hindustan Book Agency, Delhi, 1994.
5. Mark J.Ablewitz and A.S.Fokas, Complex Variables : Introduction & Applications, Cambridge University Press, South Asian Edition, 1998.
6. E.C.Titchmarsh, The Theory of Functions, Oxford University Press, London. 1939.
7. S.Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.

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Deptt. of Mathematics
K.U. KURUKSHETRA

CC-3 Theory of Ordinary Differential Equations

With effect from the Session: 2024-25	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	I
Name of the Course	Theory of Ordinary Differential Equations
Course Code	M24-MAT-103
Course Type	CC
Level of the course	400-499
Pre-requisite for the course (if any)	Courses on Differential Equation and Real Analysis up to the 299 level
Course Objectives	The objectives of this course are to study the existence and uniqueness theory of solutions of initial value problems, to study theory of homogeneous and non-homogeneous linear differential equations of higher order in detail, to learn about oscillations of second order differential equations, and solving boundary value problems. The aim of the course is to form a strong foundation in the theory of ordinary differential equations enabling a learner to apply towards problem solving.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of an initial value problem and its exact and approximate solutions, existence of solutions, uniqueness of solutions and continuation of solutions of an initial value problem of order one. Apply the knowledge to prove specified theorems and to solve relevant exercises CLO 2: Have deep understanding of theory of linear differential equations of higher order by getting knowledge of basic theory, Wronskian theory and fundamental sets, adjoint equations and standard theorems related to these topics. Apply methods of reduction of order and variation of parameters to solve linear and non-linear differential equations respectively and to solve higher order linear differential equations with constant coefficients. CLO 3: Understand preliminary, oscillation and Sturm' theory of second order ordinary differential equations and comparison theorems. Apply this knowledge to solve problems of checking second order ODEs for oscillatory, finding common zeros and applying Prüffer transformation. CLO 4: Have good understanding of boundary value problems of second order, their classification and solution. Appreciate

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	the concept of Green's function. Attain skills to solve boundary value problems which find great applications in areas of applied mathematics, science and engineering.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Existence and Uniqueness of Solutions: Existence of solutions; Initial value problem, ε-approximate solution, Equicontinuous set of functions, Ascoli lemma, Cauchy–Peano existence theorem and its corollary Uniqueness of solutions; Lipschitz condition, Gronwall's inequality, Inequality involving approximate solutions, Method of successive approximations, Picard-Lindelöf theorem. Continuation of solutions, Maximal interval of existence, Extension theorem.	15
II	Theory of linear differential equations: Linear Differential Equation (LDE) of order n, Basic theory of homogeneous linear equation, Wronskian theory: Definition, necessary and sufficient condition for linear dependence and linear independence of solutions of homogeneous LDE, Abel's Identity, Fundamental sets, More Wronskian theory, Reduction of order. Non-homogeneous linear differential equation of order n: Variation of parameters. Adjoint equations, Lagrange's Identity, Green's formula, Self adjoint equation of second order. Linear differential equation of order n with constant coefficients;	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	Characteristic roots, Fundamental set. (Relevant portions from the books ‘Theory of Ordinary Differential Equations’ by Coddington and Levinson and the book ‘Differential Equations’ by S.L. Ross)	
III	Linear second order equations: Preliminaries, Superposition principle, Riccati’s equation, Prüffer transformation. Oscillations of second order differential equations: Zero of a solution, Oscillatory and non-oscillatory equations, Abel’s formula, Common zeros of solutions and their linear dependence, Sturm separation theorem, Sturm fundamental comparison theorem and its corollaries, Elementary linear oscillations, Comparison theorem of Hille-Wintner, Oscillations of $x'' + a(t)x = 0$. (Relevant portions from the book ‘Differential Equations’ by S.L. Ross and the book ‘Textbook of Ordinary Differential Equations’ by Deo et al.)	15
IV	Second order boundary value problems (BVP): Linear problems; periodic boundary conditions, regular linear BVP, singular linear BVP; non-linear BVP, Sturm-Liouville BVP; Definition, Characteristic values and Characteristic functions. Orthogonality of characteristic functions. Green’s functions: Definition and Properties. Applications of boundary value problems, Picard’s theorem. (Relevant portions from the book ‘Differential Equations’ by S.L. Ross and the book ‘Textbook of Ordinary Differential Equations’ by Deo et al.)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. Earl A. Coddington and Norman Levinson, *Theory of Ordinary Differential Equations*, McGraw Hill Education , 2017.
2. Sheply L. Ross, *Differential Equations*, Wiley , 3rd Edition, 2007.
3. S.G. Deo, V. Raghavendra, Rasmita Kar, V. Lakshmikantham, *Textbook of Ordinary*

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

Differential Equations, Tata McGraw-Hill , 2006.

Reference books;

4. P. Hartman, *Ordinary Differential Equations*, John Wiley & Sons NY, 1971.
5. G. Birkhoff and G.C. Rota, *Ordinary Differential Equations*, John Wiley & Sons, 1978.
6. G.F. Simmons, *Differential Equations*, Tata McGraw-Hill , 1993.
7. I.G. Petrovski, *Ordinary Differential Equations*, Prentice-Hall, 1966.
8. D. Somasundaram, *Ordinary Differential Equations, A first Course*, Narosa Pub., 2001.

CC-4 MECHANICS OF SOLIDS

With effect from the Session: 2024-25	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	I
Name of the Course	Mechanics of Solids
Course Code	M24-MAT-104
Course Type	CC
Level of the course	400-499
Pre-requisite for the course (if any)	Courses having contents of Vector Calculus and Differential Equations up to the level 299
Course Objectives	In this course, basic theory of mechanics of solids is introduced. First, the laws of transformations and tensors will be introduced. Mathematical theory of deformations, analysis of strain and analysis of stress in elastic solids will be learnt next. A student will also learn basic equations of elasticity and variational methods. In this course, the students will be exposed to the mathematical theory of elasticity and other techniques which find applications in areas of civil, structural, and mechanical engineering, Earth Sciences and Material sciences. This course in Applied Mathematics will provide a sound base and open gates for doing research in the number of areas involving solid mechanics.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the concepts of tensors as a generalized form of directional entities and to know their properties through the operations of algebra and calculus. CLO 2: Understand affine transformation and infinitesimal deformation analysis of strain and stress tensors. Have a strong foundation to learn theory of elasticity to solve scientific problems. CLO 3: Relate strain tensor and stress tensor through anisotropic elastic moduli, subjected to reflection/rotational symmetries to define elastic isotropy, and using theorems/ principles to explore the role of these relations in strain energy, compatibility conditions and uniqueness of solution.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	CLO 4: Learn variational methods to solve boundary value problems in elasticity. Learn to prove standard theorems related to theory of variational problems and to apply these techniques/methods by minimizing the potential / strain / complementary energies to solve scientific problems in mechanics of solids and get exposed to research problems in the field of elasticity. Also to understand phenomenon of wave propagation in infinite elastic medium.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

<u>Instructions for Paper- Setter:</u> The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Tensor Algebra: Coordinate-transformation, Cartesian Tensors of different order. Properties of tensors. Isotropic tensors of different orders and relation between them. Symmetric and skew symmetric tensors. Tensor invariants. Deviatoric tensors. Eigen-values and eigen-vectors of a tensor. Tensor Analysis: Scalar, vector, tensor functions, Comma notation. Gradient, divergence and curl of a vector / tensor field. (Relevant portions of Chapters 2 and 3 of book by D.S. Chandrasekharaiah and L. Debnath)	15
II	Analysis of Strain: Affine transformation, Infinitesimal affine deformation. Strain tensor, Geometrical Interpretation of strain	17

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	components. Strain quadric of Cauchy. Principal strains, Invariants, General infinitesimal deformation. Examples of strain, Equations of compatibility. (Relevant portions of Chapter 1 of the book by I.S. Sokolnikoff). Analysis of Stress: Stress Vector, Stress tensor, Equations of equilibrium, Transformation of coordinates. Stress quadric of Cauchy, Principal stresses. Maximum normal and shear stresses. Mohr's circles. Examples of stress. (Relevant portions of Chapter 2 of the book by I.S. Sokolnikoff).	
III	Equations of Elasticity: Generalised Hooke's Law, Anisotropic symmetries, Homogeneous Isotropic media. Elasticity moduli for Isotropic media. Equilibrium and dynamic equations for an isotropic elastic solid. Strain energy function and its connection with Hooke's Law. Beltrami-Michell compatibility equations. Uniqueness of solution. Clapeyron's theorem. Saint-Venant's principle. (Relevant portions of Chapter 3 of book by I.S. Sokolnikoff).	14
IV	Variational Methods: Variational problems and Euler's Equations, Theorem of minimum potential energy. Theorem of minimum complementary energy. Reciprocal theorem of Betti and Rayleigh. Ritz method: one and two dimensional cases. Galerkin method. Method of Kantorovich. Wave propagation in infinite regions. Surface waves (Relevant portions of Chapters 6 and 7 of the book by I.S. Sokolnikoff).	14
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. I.S. Sokolnikoff, Mathematical Theory of Elasticity, Tata-McGraw Hill Publishing Company Ltd., New Delhi, 1977.
2. D.S. Chandrasekharaiah and Lokenath Debnath, Continuum Mechanics, Academic Press, 2014.

Reference books;

1. A.E.H. Love, A Treatise on the Mathematical Theory of Elasticity, Cambridge University Press, 2013.
2. Y.C. Fung. Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
3. Shanti Narayan, Text Book of Cartesian Tensor, S. Chand & Co., 1950.
4. S. Timeshenko and N. Goodier. Theory of Elasticity, McGraw Hill, New York, 1970.
5. I.H. Shames, Introduction to Solid Mechanics, Prentice Hall, New Delhi, 1975.
6. Robert J. Asaro and Vlado A. Lubarda, Mechanics of Solids and Materials, Cambridge University Press, 2006.
7. Lallit Anand and Sanjay Govindjee, Continuum Mechanics of Solids, Oxford University Press 2020.
8. L S. Srinath, Advanced Mechanics of Solids, McGraw Hill, 2008.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

CC-5 ABSTRACT ALGEBRA

With effect from the Session: 2024-25			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	I		
Name of the Course	ABSTRACT ALGEBRA		
Course Code	M24-MAT-105		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Algebra up to the level 299.		
Course Objectives	The concept of a group is surely one of the central ideas of Mathematics. The main aim of this course is to introduce Sylow theory and some of its applications to groups of smaller orders. An attempt has been made in this course to strike a balance between the different branches of group theory, abelian groups, nilpotent groups, finite groups, infinite groups and to stress the utility of the subject. A study of modules, submodules, quotient modules, finitely generated modules etc. is promised in this course. Similar linear transformations, Nilpotent transformations and related topics are also included in the course.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of normal subgroup, quotient group, isomorphism, automorphism, conjugacy, G-sets, normal series, composition series, solvable group, nilpotent group and refinement theorem. CLO 2: Learn about cyclic decomposition, alternating group A_n , simplicity of A_n for $n \geq 5$, Sylow's theorem and its applications. CLO 3: Understand concepts of modules, submodules, direct sum, R-homomorphism, quotient module, completely reducible modules, free modules, representation of linear mappings and their ranks. CLO 4: Learn about similar linear transformation, triangular form, nilpotent transformation, primary decomposition theorem, Jordan form, rational canonical form and elementary divisors.		
Credits	Theory	Practical	Total

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist of 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Normal subgroup, quotient group, normalizer and centralizer of a non-empty subset of a group G, commutator subgroups of a group. first, second and third isomorphism theorems, correspondence theorem, Aut(G), Inn(G), automorphism group of a cyclic group, G-sets, orbit of an element in group G, Cayley's theorem. conjugate elements and conjugacy classes, class equation of a finite group G and its applications, Burnside theorem. normal series, composition series, Jordan Holder theorem, Zassenhaus lemma, Scheier's refinement theorem, solvable group, nilpotent group. (Chapter 5 and 6 of recommended book at Sr. No. 1, Chapter 5 of recommended book at Sr. No. 2)	15
II	Cyclic decomposition, even and odd permutation, Alternation group A_n, simplicity of the Alternating group A_n ($n \geq 5$). Cauchy's theorem, Sylow's first, second and third theorems and its applications to group of smaller orders. groups of order p^2 and pq (q>p). (Chapter 7, 8.4 and 8.5 of recommended book at Sr. No 1)	15
III	Modules, submodules, direct sums, finitely generated modules, cyclic module. R-homomorphism, quotient module, completely reducible modules, Schur's lemma, free modules, representation of linear mapping, rank of linear mapping. (Chapter 14 of recommended book at Sr. No 1)	15
IV	Similar linear transformation, invariant subspaces of vector spaces, reduction of a linear transformation to triangular form, nilpotent transformation, index of nilpotency of a nilpotent transformation. Cyclic subspace with respect to a nilpotent transformations, uniqueness of the invariants of a nilpotent transformation. Primary decomposition theorem. Jordan blocks, Jordan canonical forms, cyclic module relative to a linear	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	transformation, rational canonical form of a linear transformation and its elementary divisors, uniqueness of elementary divisors. (6.4. to 6.7 of recommended book of Sr. No. 3).	
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1 P. B. Bhattacharya, S. K. Jain, S. R. Nagpaul, Basic Abstract Algebra (Second edition), Cambridge University Press, 2012.

2. Surjit Singh and Quazi Zameeruddin : Modern Algebra ,Vikas Publishing House, 2021.

3 I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

PC-1 PRACTICAL-1

With effect from the Session: 2024-25			
Part A - Introduction			
Name of the Programme	M.Sc. Mathematics		
Semester	I		
Name of the Course	Practical-1		
Course Code	M24-MAT-106		
Course Type	PC		
Level of the course	400-499		
Pre-requisite for the course (if any)			
Course objectives	This is a laboratory course and objective of this course is to acquaint the students with the coding skills in C programming language for problem solving. Also, some problem solving techniques based on papers M24-MAT-101 to M24-MAT-105 will be taught.		
Course Learning Outcomes (CLO) After completing this course, the learner will be able to:	CLO 1: Solve practical problems related to theory courses undertaken in the Semester-I from application point of view. CLO 2: Know syntax of expressions, statements, structures and to write source code for a program in C. CLO 3: Edit, compile and execute source programs for desired results. CLO 4: Debug, verify/check and to obtain output of results.		
Credits	Theory	Practical	Total
	0	4	4
Teaching Hours per week	0	8	8
Internal Assessment Marks	0	30	30
End Term Exam Marks	0	70	70
Max. Marks	0	100	100
Examination Time	0	4 hours	
Part B- Contents of the Course			
Practicals			**Contact Hours**
Practical course will consist of two components Part-A and Part-B. The examiner will set 5 questions at the time of practical examination asking 2 questions from the Part-A and 3 questions from the Part-B by taking course learning outcomes (CLO) into consideration. The examinee will be required to solve one problem from the Part-A and to write and execute 2 questions from			120

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

the Part-B.	
Part-A Problems based on the theory courses M24-MAT-101 to M24-MAT-105 will be solved in this part and their record will be maintained in the Practical Note Book. Direct results and theorems will not be asked rather exercises or numerical problems or applied problems based on the theory parts will be done, as identified or given by the teacher concerned.	30
Part-B The following practicals will be done using the programming language C and record of those will be maintained in the practical Note Book: 1. Use of nested *if.. .else* in finding the smallest of four or more numbers. 2. To find if a given 4-digit year is a leap year or not. 3. To compute AM, GM and HM of three given real values. 4. To invert the order of digits in a given positive integral value. 5. Use series sum to compute sin(x) and cos(x) for given angle x in degrees. Then, check error in verifying $\sin^2 x+\cos^2(x) = 1$ or other such T-identities. 6. Verify $\sum n^3 = \{\sum n\}^2$, (where n=1, 2,…, m) & check that prefix and postfix increment operator gives the same result. 7. Compute simple interest and compound interest for a given amount, time period, rate of interest and period of compounding. 8. Program to multiply two given matrices in a user defined function. 9. Calculate standard deviation for a set of values {x(j), j = l, 2,..., n} having the corresponding frequencies {f(j), j = l,2,...,n}. 10. Write the user-defined function to compute GCD of two given values and use it to compute the LCM of three given integer values. 11. Compute GCD of 2 positive integer values using recursion / pointer to pointer. 12. Check a given square matrix for its positive definite/ negative definite forms. 13. To find the inverse of a given non-singular square matrix. 14. To convert a decimal number to its binary representation and vice-versa. 15. To solve an algebraic or transcendental equation by Newton-Raphson and Regula-Falsi methods. 16. To solve initial value problems by Runge-Kutta methods. 17. To solve a system of linear equations by Gauss-Seidel method. 18. To solve a definite integral using Simpson rules. 19. Use array of pointers for alphabetic sorting of given list of English words. 20. To search a number in an array by binary search method.	90 (Lab hours include instructions for writing programs in C and demonstration by a teacher and for run the programs on computer by students.)
Suggested Evaluation Methods	

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Practicum**	**30**	➢ **Practicum**	**70**
• Class Participation:	5	Lab record, Viva-Voce, write-up and execution of the programs	
• Seminar/Demonstration/Viva-voce/Lab records etc.:	10		
• Mid-Term Examination:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

1. Amos Gilat, *MATLAB An Introduction With Applications* 5ed, Wiley, 2008.
2. Rudra Pratap, *Getting Started with MATLAB*, Oxford University Press, 2010.
3. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, K. R. Coombes, J. E. Osborn, and G. J. Stuck, *A Guide to MATLAB*, Second Edition, Cambridge University Press, 2006.

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K.U. KURUKSHETRA

SEMINAR

With effect from the Session: 2024-25	
Name of the Programme	M.Sc. Mathematics
Semester	I
Name of the Course	Seminar
Course Code	M24-MAT-107
Course Type: (CC/DEC/PC/SEM/CHM/OEC/EEC)	SEM
Level of the course	400-499
Course objectives	The objectives of this course are self-learning, understanding a topic in detail, exploring library and e-resources, comprehension of the subject/topic, investigating a problem, knowledge of ethics, effective communication and life-long learning.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Identify an area of interest and to select a topic therefrom realizing ethical issues related to one's work and unbiased truthful actions in all aspects of work and to develop research aptitude. CLO 2: Have deep knowledge and level of understanding of a particular topic in core or applied areas of Mathematics, imbibe research orientation and attain capacity of investigating a problem. CLO 3: Obtain capability to read and understand mathematical texts from books/journals/e-contents, to communicate through write up/report and oral presentation. CLO 4: Demonstrate knowledge, capacity of comprehension, precision, defence, capability to work independently and tendency towards life-long learning.
Credits	Seminar
	2
Teaching Hours per week	2
Max. Marks	50
Internal Assessment Marks	0

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

End Term Exam Marks	50
Examination Time	1 hour

Instructions for Examiner: Evaluation of the seminar will be done by the internal examiner(s) on the parameters as decided by staff council of the department. There will be no external examination/viva-voce examination.

Each student will select a topic of one's choice, will get approval from the concerned teacher incharge, give sittings in library so as to read different books and journals, and e-resources, prepare a seminar document, present before the group and its teacher incharge for one hour. The evaluation of the seminar will be done by the concerned teacher incharge by taking into account the following:

i. Subject knowledge.
ii. Degree of difficulty, research aptitude and knowledge updation in terms of choice of the topic.
iii. Contents of the seminar report.
iv. Presentation, Communication and. Language skills
v. Response to questions.

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Deptt. of Mathematics
K.U. KURUKSHETRA

CC-6 FIELD THEORY

With effect from the Session: 2024-25			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	II		
Name of the Course	FIELD THEORY		
Course Code	M24-MAT-201		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Algebra up to the level 299		
Course Objectives	As suggested by the name of the course itself, some of the advanced topics of abstract algebra will be taught to the students in this course including field extensions, finite fields, normal extensions, finite normal extensions and splitting fields. A study of Galois extensions, Galois groups of polynomials, Galois radical extensions will also be taught.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of irreducible polynomial, Eisenstein criterion, field extension, algebraic and transcendental extension, algebraically closed field. CLO 2: Have deep understanding of Splitting fields, normal extension, multiple roots, prime field, finite field and separable extension. CLO 3: Learn about automorphism groups, fixed field, Dedekind lemma, fundamental theorem of Galois theory, roots of unity, Cyclotomic polynomial and cyclic extension. CLO 4: Have deep understanding of polynomials solvable by radicals, symmetric functions, ruler and compass construction.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		
Part B- Contents of the Course			
Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each			

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist of 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Irreducible polynomials, Eisenstein criterion, Gauss lemma. Field extension, algebraic and transcendental extension, degree of extension, algebraic closure and algebraically closed field.	15
II	Splitting field, degree of extension of splitting field. Normal extension, multiple roots, prime field, characterization of prime field, finite field, separable extension.	15
III	Automorphism group, fixed field, Dedekind lemma, Galois groups of polynomials, Galois extension, fundamental theorem of Galois theory, fundamental theorem of algebra, roots of unity. Cylotomic polynomials, Klein's four group, cyclic extension, Frobenius automorphism of a finite field.	15
IV	Solvability of polynomials by radicals over Q. Symmetric functions and elementary symmetric functions. Construction with ruler and compass only.	15
Total Contact Hours		60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition, 2012.

Reference Books :

1. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.

2. Surjit Singh and Quazi Zameeruddin, Modern Algebra, Vikas Publishing House, 2021.

3. Patrick Morandi, Field and Galois Theory, Springer 1996.

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Deptt. of Mathematics
K.U. KURUKSHETRA

CC-7 MEASURE AND INTEGRATION

With effect from the Session: 2024-25			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	II		
Name of the Course	MEASURE AND INTEGRATION		
Course Code	M24-MAT-202		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Real Analysis up to the 299 level		
Course Objectives	The main objective is to familiarize the learner with Lebesgue outer measure, measurable sets, measurable functions, Lebesgue integration, fundamental integral convergence theorems, functions of bounded variation, differentiation of an integral, absolutely continuous functions and L^p-spaces.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the concepts of measurable sets and Lebesgue measure; construct a non-measurable set; apply the knowledge to solve relevant exercises. CLO 2: Know about Lebesgue measurable functions and their properties; and apply the knowledge to prove Egoroff's theorem, Lusin's theorem and F.Riesz theorem. CLO 3: Understand the requirement and the concept of the Lebesgue integral (as a generalization of the Riemann integration) along its properties and demonstrate understanding of the statements and proofs of the fundamental integral convergence theorems. CLO 4: Know about the concepts of differentiation of monotonic function, functions of bounded variations, differentiation of an integral, absolutely continuous functions; apply the knowledge to prove specified theorems and study L^p-spaces.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

<u>Instructions for Paper- Setter:</u> The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Lebesgue outer measure, elementary properties of outer measure, measurable sets and their properties, Lebesgue measure of sets of real numbers, algebra of measurable sets, Borel sets and their measurability, characterization of measurable sets in terms of open, closed, F_σ and G_δ sets, existence of a non-measurable set.	15
II	Lebesgue measurable functions and their properties, the almost everywhere concept, characteristic functions, simple functions, approximation of measurable functions by sequences of simple functions, Borel measurability of a function. Littlewood's three principles, measurable functions as nearly continuous functions. Lusin's theorem, almost uniform convergence, Egoroff's theorem, convergence in measure, F.Riesz theorem that every sequence which is convergent in measure has an almost everywhere convergent subsequence.	15
III	The Lebesgue Integral: Shortcomings of Riemann integral, Lebesgue integral of a bounded function over a set of finite measure and its properties, Lebsegue integral as a generalization of the Riemann integral, Bounded convergence theorem, Lebesgue theorem regarding points of discontinuities of Riemann integrable functions. Integral of a non-negative function, Fatou's lemma, Monotone convergence theorem, integration of series, the general Lebesgue integral, Lebesgue convergence theorem.	15
IV	Differentiation and Integration: Differentiation of monotone functions, Vitali's covering lemma, the four Dini derivatives, Lebesgue differentiation theorem, functions of bounded variation and their representation as difference of monotone functions. Differentiation of an integral, absolutely continuous functions and their	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	properties, convex functions, Jensen's inequality. L^p-spaces.	
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. H.L. Royden, Real Analysis (3rd Edition) Prentice-Hall of India, 2008.

Reference Books:

1. 1. G.de Barra, Measure theory and integration, New Age International, 2014.

2. P.R. Halmos, Measure Theory, Van Nostrans, Princeton, 1950.

3. I.P. Natanson, Theory of functions of a real variable, Vol. I, Frederick Ungar Publishing Co., 1961.

4. R.G. Bartle, The elements of integration, John Wiley & Sons, Inc.New York, 1966.

5. K.R. Parthsarthy, Introduction to Probability and measure, Macmillan Company of India Ltd.,Delhi, 1977.

6. P.K. Jain and V.P. Gupta, Lebesgue measure and integration, New Age International (P) Ltd., Publishers, New Delhi, 1986.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

CC-8 TOPOLOGY

With effect from the Session: 2024-25			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	II		
Name of the Course	TOPOLOGY		
Course Code	M24-MAT-203		
Course Type	CC		
Level of the course	400-499		
Pre-requisite for the course (if any)	Courses on Real Analysis up to the 299 level		
Course Objectives	The main objective of this course is to introduce basic concepts of point set topology, basis and sub-basis for a topology. Further, to study continuity, homeomorphisms, open and closed maps, product and quotient topologies, separation axioms and introduce the notion of connectedness of topological spaces.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Know about topological spaces, understand neighbourhood system of a point and its properties, interior, closure, boundary, limit points of subsets, and base and sub-base of topological spaces; apply the knowledge to solve relevant exercises. CLO 2: Learn alternate methods of defining a topology using properties of neighbourhood system, interior operator, closed sets, Kuratowski closure operator and know about first and second countable spaces, separable and Lindelof spaces, continuous functions and their characterizationss. CLO 3: Know about the Tychonoff product topology and its characterization as the smallest topology such that the projection maps are continuous; connectedness and its relation with continuity. CLO 4: Have understanding of the separation axioms and their properties; know about the quotient topology and demonstrate understanding of the statements and proofs of Embedding theorem and Urysohn's Lemma.		
Credits	Theory	Practical	Total

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

<u>Instructions for Paper- Setter:</u> The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Definition and examples of topological spaces, neighbourhoods, neighbourhood system of a point and its properties, interior point and interior of a set, interior as an operator and its properties, definition of a closed set as complement of an open set, limit point (accumulation point) of a set, derived set of a set, adherent point (closure point) of a set, closure of a set, closure as an operator and its properties, dense sets and separable spaces. Base for a topology and its characterization, base for neighbourhood system, sub-base for a topology. Relative (induced) topology and subspace of a topological space.	15
II	Alternate methods of defining a topology using properties of neighbourhood system, interior operator, closed sets, Kuratowski closure operator. comparison of topologies on a set, about intersection and union of topologies, the collection of all topologies on a set as a complete lattice. First countable, second countable, their relationships and hereditary property. countability of a collection of disjoint open sets in a separable and a second countable space, Lindelof theorem. Definition, examples and characterizations of continuous functions, composition of continuous functions, open and closed functions, homeomorphism.	15
III	Tychonoff product topology, projection maps, their continuity and openness, Characterization of product topology as the smallest topology such that the projections are continuous, continuity of a function from a space into a product of spaces.	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	Connectedness and its characterization, Connected subsets and their properties, Continuity and connectedness, Components, Locally connected spaces.	
IV	T_0, T_1, T_2 spaces, productive property of T_1 and T_2 spaces. Regular and T_3 separation axioms, their characterization and basic properties i.e. hereditary and productive properties. quotient topology w.r.t. a map, continuity of function with domain a space having quotient topology, about Hausdorffness of quotient space. Completely regular and Tychonoff ($T_{3\ 1/2}$), spaces, their hereditary and productive properties. Embedding lemma, Embedding theorem, normal and T_4 spaces, Urysohn's Lemma, complete regularity of a regular normal space, Tietze's extension theorem (statement only). (Scope of the course is as in relevant portions in the book 'General Topology' by J.L.Kelley).	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. J.L. Kelley: General Topology, Springer Verlag, New York, 2012.

Reference Books:

1. J. R. Munkres, Toplogy, Pearson Education Asia, 2002.
2. C.W. Patty, Foundation of Topology, Jones & Bertlett, 2009.
3. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.
4. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.
5. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi,2009.
6. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.
7. Khalil Ahmad, Introduction to Topology, Narosa Publishing House, 2019.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

CC-9 ADVANCED DIFFERENTIAL EQUATIONS

With effect from the Session: 2024-25	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	II
Name of the Course	Advanced Differential Equations
Course Code	M24-MAT-204
Course Type	CC
Level of the course	400-499
Pre-requisite for the course (if any)	Courses on Differential Equation and Real Analysis up to the 299 level
Course Objectives	The objectives of this course are to study the theory of system of linear and non-linear, homogeneous and non-homogeneous differential equations with constant and/or variable coefficients, to understand the dependence of solution on initial parameters, and to understand the critical points of linear and non-linear system of differential equations and to determine types and stability of those critical points and systems' solutions. This course is an advance course on system of differential equations to give a strong foundation for doing research in the areas of differential equations and dynamical system.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn about system of linear differential equations of first order and its preliminary concepts, homogeneous and non-homogeneous linear systems, existence and uniqueness theory, fundamental matrix, theory of adjoint systems, linear systems with constant coefficients and with periodic coefficients. Attain the skill to obtain fundamental matrix of such a given linear system to demonstrate problem solving. CLO 2: Understand system of differential equations and its existence theory, dependence of solution of an IVP on initial parameters, extremal solutions, upper and lower solutions so as to be able to develop research aptitude in this area. CLO 3: Know critical points of linear and non-linear system of differential equations, their types and stability. Understand concepts of potential energy function, limit cycles, semi orbit and limit sets. Apply the gained knowledge to determine type and stability of critical points and check for existence of limit cycles of given systems. Have a

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	foundation to understand area of non-linear analysis of dynamical systems where mathematics and space science connect to each other. CLO 4: Understand stability of linear, quasi-linear and non-linear systems. Learn to apply Lyapunov direct method to determine stability of such systems for investigating and solving problems.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	System of linear differential equations: Preliminary definitions and notations. Linear homogeneous systems; Definition, Existence and uniqueness theorem, Fundamental matrix, Liouville formula, Adjoint systems, Reduction of the order of a homogeneous system. Non-homogeneous linear systems; Variation of constants formula. Linear systems with constant coefficients. Linear systems with periodic coefficients, Floquet theory. (Relevant portions from the book 'Theory of Ordinary Differential Equations' by Coddington and Levinson)	15
II	System of differential equations; Preliminary concepts, Differential equation of order n and its equivalent system of differential equations, Existence and uniqueness of solutions of system of differential equations. Dependence of solutions on initial conditions and parameters: Preliminaries, continuity and differentiability of solution of a system of differential equations as a function of initial parameters. (Relevant portions from the book 'Theory of Ordinary Differential	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	Equations' by Coddington and Levinson) Extremal solutions: Maximal and Minimal solutions. Upper and Lower solutions, Comparison theorems, Existence via upper and lower solutions. (Relevant portions from the book 'Textbook of Ordinary Differential Equations' by Deo et al.)	
III	Autonomous systems; Phase plane, Paths and Critical points, Types of critical points; Node, Center, Saddle point, Spiral point, Stability of critical points, Critical points and paths of linear systems; Basic theorems and their applications. Critical points and paths of non-linear systems; Basic theorems and their applications. Non-linear conservative systems, Potential energy function, Dependence on a parameter. Limit Cycles and periodic solutions, Benedixson's non-existence criterion, Half-path, Limit set. (Relevant portions from the book 'Differential Equations' by S.L. Ross)	15
IV	Stability of linear and non-linear systems: System of equations with constant coefficients, linear equation with constant coefficients. Lyapunov Stability: Stability of solution of a differential system, Positive definite and semidefinite functions, Negative definite and semidefinite functions, Decrescent function, Lyapunov function, Lyapunov's theorems on stability. Stability of quasi-linear systems. Boundedness of solutions of a second order differential equations. (Relevant portions from the book 'Textbook of Ordinary Differential Equations' by Deo et al.)	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

• Mid-Term Exam:	15	

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. Earl A. Coddington and Norman Levinson, *Theory of Ordinary Differential Equations*, McGraw Hill Education , 2017.
2. Sheply L. Ross, *Differential Equations*, Wiley, 3^{rd} Edition, 2007.
3. S.G. Deo, V. Raghavendra, Rasmita Kar, V. Lakshmikantham, *Textbook of Ordinary Differential Equations*, Tata McGraw-Hill , 2006.

Reference books;

4. P. Hartman, *Ordinary Differential Equations*, John Wiley & Sons NY, 1971.
5. G. Birkhoff and G.C. Rota, *Ordinary Differential Equations*, John Wiley & Sons, 1978.
6. G.F. Simmons, *Differential Equations*, Tata McGraw-Hill , 1993.
7. I.G. Petrovski, *Ordinary Differential Equations*, Prentice-Hall, 1966.
8. D. Somasundaram, *Ordinary Differential Equations*, *A first Course*, Narosa Pub., 2001.
9. Mohan C Joshi, *Ordinary Differential Equations*, *Modern Perspective*, Narosa Publishing House, 2006.

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

CC-10 COMPUTER PROGRAMMING WITH MATLAB

With effect from the Session: 2024-25	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	II
Name of the Course	Computer Programming With MATLAB
Course Code	M24-MAT-205
Course Type	CC
Level of the course	400-499
Pre-requisite for the course (if any)	-
Course Objectives	This course is designed for the students to learn the computer programming. The objective of this course is to develop a skill of writing codes in MATLAB or equivalent Open Source software and using built-in tools for solving different types of mathematical problems which arise in the areas of Mathematical/Physical/Life/Social Sciences and Engineering.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Get familiar with the importance and working of MATLAB as computation platform through the knowledge of characters, variables, operators, functions and expressions as used for elementary operations in matrix algebra along with the editing, load/save data and compilation/execution/quitting of source programs. CLO 2: Learn the process of writing a source program in MATLAB as a programming language making use of the statements for input/output, conditional/non-sequential processing involving functions, arrays and structures. CLO 3: Learn the plotting of the curves and surfaces, which can be edited, modified, accumulated, handled, printed, exported. CLO 4: Write source programs with objects, variables, expressions, abstract functions, math functions in symbolic form and their subsequent use for the operations/ concepts/ problems in calculus, linear algebra and differential equations.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Introduction: Basics of programming; Anatomy of a program; Constants; Characters; Variables; Data types; Assignments; Operators; functions; Examples of expressions; Entering long statements; Command line editing. Good programming style. Working with vectors: Defining a Vector, Accessing elements within a vector, Basic operations on vectors; Mathematical functions; Strings; String functions; Cell array; Creating cell array; Concatenation. Working with Matrices: Generating matrices; Mathematical operations and functions; Deleting rows /columns; Linear algebra; Arrays; Multivariate data; Scalar expansion; Logical subscripting; Input and output: Save/Load functions, M-files, The find function; The format function; Suppressing output; (Relevant portions from the recommended text books 1-3).	15
II	Flow Control: if and else, switch and case, for loop, while loop, continue, break, try – catch, return. Data Structures: Multidimensional arrays; Cell arrays, Characters and text; Structures, Scripts and Functions: Scripts; Functions; Types of functions; Global variables; Passing string arguments to functions; The eval function; Function handles; Function functions; Vectorization; Preallocation. Linear differential equation of order n with constant coefficients; Characteristic roots, Fundamental set. (Relevant portions from the recommended text books 1-3).	15
III	Graphics: Plotting process; Graph components; Figure tools; Arranging	15

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K.U. KURUKSHETRA

	graphs within a figure; Selecting plot types; Plot editing mode, Using functions to edit graphs; Modifying a graph data source; Modify a graph to enhance the presentation; Printing a graph; Exporting a graph. Basic Plotting Functions: Creating a plot; Multiple data sets in one graph; Specifying line styles and colors; Plotting lines and markers; Imaginary and complex data; Adding plots to existing graph; Figure windows; Multiple plots in one figure; Controlling the axes; Axis labels and titles; Saving figures. Mesh and Surface Plots: Visualizing functions of two variables; Reading/writing images. Printing and Handle Graphics: Using the handle; Graphics object; Setting object Properties; Specifying the axes or figure, Finding the handles of existing objects. Animations: Erase mode method, Creating movies. (Relevant portions from the recommended text books 1-3).	
IV	Symbolic Math: Symbolic objects; Creating symbolic variables and expressions; The findsym Command; The default symbolic variable; Constructing real and complex variables; Creating abstract functions; Creating symbolic math functions; Creating an M-file. Calculus: Limits; Differentiation; Integration; Symbolic summation; Taylor series; Examples; Simplifications and substitutions, Variable-precision arithmetic examples. Linear Algebra: Basic algebraic operations; Linear algebraic operations; Eigenvalues; Jordan canonical form; Singular value decomposition; Eigenvalue trajectories. Solving Equations: System of algebraic equations, System of differential equations. (Relevant portions from the recommended text books 1-3).	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

• Seminar/presentation/assignment/quiz/class test etc.:	10	
• Mid-Term Exam:	15	

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. *Learning MATLAB*, COPYRIGHT 1984 - 2005 by The MathWorks, Inc.
2. Amos Gilat, *MATLAB An Introduction With Applications* 5ed, Wiley, 2008.
3. Rudra Pratap, *Getting Started with MATLAB*, Oxford University Press, 2010.

Reference books;

4. C. F. Van Loan and K.-Y. D. Fan., *Insight through Computing: A Matlab Introduction to Computational Science and Engineering*, SIAM Publication, 2009.
5. T. A. Davis and K. Sigmon, *MATLAB Primer* 7th Edition, CHAPMAN & HALL/CRC, 2005.
6. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, K. R. Coombes, J. E. Osborn, and G. J. Stuck, *A Guide to MATLAB*, Second Edition, Cambridge University Press, 2006.
7. Y.Kirani Singh, B.B. Chaudhari, *MATLAB Programming*, PHI Learning, 2007.
8. K. Ahlersten, *An Introduction to Matlab*, Bookboon.com.
9. C. Gomez, C. Bunks and J.-P. Chancelier, *Engineering and Scientific Computing with SCILAB*, Birkhäuser, 2012.
10. A. Quarteroni, F. Saleri and P. Gervasio, *Scientific Computing with MATLAB and Octave*, Springer Nature, 2014.

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PC-2 PRACTICAL-2

With effect from the Session: 2024-25			
Part A - Introduction			
Name of the Programme	M.Sc. Mathematics		
Semester	II		
Name of the Course	Practical-2		
Course Code	M24-MAT-206		
Course Type	PC		
Level of the course	400-499		
Pre-requisite for the course (if any)			
Course objectives	This course aims the students to learn the practical implementations of the features of MATLAB/SCILAB/Octave which they study as a theory course M24-MAT-204 and to write codes for problem solving. Also, implementation of some problem solving techniques, based on papers M24-MAT-201 to M24-MAT-205, would be learnt.		
Course Learning Outcomes (CLO) After completing this course, the learner will be able to:	CLO 1: Solve practical problems related to theory courses undertaken in the Semester-II from application point of view. CLO 2: Know syntax of expressions, statements, data types, structures, commands and to write source code for a program in MATLAB/SCILAB/Octave. CLO 3: Edit, compile/interpret and execute the source program for desired results. CLO 4: Debug, verify/check, to obtain and store output of results.		
Credits	Theory	Practical	Total
	0	4	4
Teaching Hours per week	0	8	8
Internal Assessment Marks	0	30	30
End Term Exam Marks	0	70	70
Max. Marks	0	100	100
Examination Time	0	4 hours	
Part B- Contents of the Course			
Practicals			**Contact Hours**
Practical course will consist of two components Part-A and Part-B. The			120

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examiner will set 5 questions at the time of practical examination asking 2 questions from the Part-A and 3 questions from the Part-B by taking course learning outcomes (CLO) into consideration. The examinee will be required to solve one problem from the Part-A and to write and execute 2 programs from the Part-B.	
Part-A Problems based on the theory courses M24-MAT-201 to M24-MAT-205 will be solved in this part and their record will be maintained in the Practical Note Book. Direct results and theorems will not be asked in this section rather exercises or numerical problems or applied problems based on the theory parts will be done, as identified or given by the teacher concerned.	30
Part-B The following practicals will be done using MATLAB/SCILAB/Octave and record of those will be maintained in the practical Note Book: 1. Create any 4 x 3 matrix A. Do the following steps: (a) Get those elements of A that are located in rows 3 to 4 and columns 2 to 3 (b) Add a fourth column to A and interchange that with the first column of A; replace the last 3 x 3 sub-matrix of A (rows 2 to 4, columns 2 to 4) by a 3 x 3 identity matrix; delete the first and third rows of A and then string out all elements of A in a row and transpose it at the end. 2. Use switch…case to calculate the income tax on a given income at the existing rates. 3. To compute the arithmetic mean, geometric mean and harmonic mean for the values {x(j), j=l,2,...,n} and the corresponding frequencies {f(j), j=l,2,...,n}. 4. Write a function file factorial to compute the factorial n! for any integer n. The input should be the number n and the output should be n!. 5. Write a function using for … loop or a while … loop to compute the sum of a geometric series $1 + r + r^2 + r^3 + \cdots + r^n$ for a given r and n. 6. Write function for the greatest common divisor (GCD) of two given positive integers and use it to find the least common multiple (LCM) of three given positive integer values and to find GCD of more than two integers. Get the result using built-in functions as well. 7. Write functions to calculate sin(x) and cos(x) as series sum of n terms. Use these functions to plot sin(x), cos(x), sin(x) +cos(x), x in [0, 2π], for n=2, 5, 10, 20. Display the deviation of curves so plotted from those which are obtained via built-in functions. 8. Plot log(x), exp(x), sin(x) and cos(x) in a single figure. Use different colours, markers, labels and title for the graph. Also display the legend. 9. Plot a circle for given centre and a point on the boundary. Find its perimeter and area. 10. Identify the location of a given point (x, y) in terms of (a) at origin, (b) on	90 (Lab hours include instructions for writing programs and demonstration by a teacher and for running the programs on computer by students.)

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

x-axis or y-axis, (c) in quadrants I, II, III or IV. Verify through x-y plot.

11. Plot (a) parametric curve using ezplot (b) polar curves using ezpolar. (c) contours using ezcontour.
12. For given coefficients (a, b, c, d, e), solve the equation $ax^2+by^2+2cx+2dy+e= 0$ to plot the corresponding conic, viz. parabola/ hyperbola/ ellipse/ circle or else.
13. For given perimeter and number of sides, plot the polygon and calculate its area.
14. Solve a cubic equation or quartic equation with given coefficients and verify the solution through built-in function.
15. (a) Use polar coordinates to plot 4 circles in a plot with common centre but of different radii.

    (b) For 4 spheres with given centre and radii, plot their surfaces as different subplots in a figure.
16. Given a function $f(x) = \sin(x)$, write a MATLAB script that computes the Taylor series expansion of the function around a point x_0 up to the n terms. Evaluate the Taylor series at a set of points. Plots the original function and its Taylor series approximation on the same graph for comparison.
17. For a given square matrix A, find the eigen-values and eigen-vectors and check the result with the use of built-in function.
18. Find the inverse of a given matrix and verify the result by using built-in function.
20. Given matrix A of order 4x3, Plot the bar diagram corresponding to matrix A for the following cases:
    (a) Display four groups of three bars, different bar corresponding to each entry of row in a group
    (b) Display one bar for each row of the matrix. The height of each bar is the sum of the elements in the row.
21. Given the three vectors X, Y, Z. Represent the data Y versus X and Z versus X in one graph by using the following routines:
    (a) Plot ( )
    (b) Scatter( )
    (c) Fill ( )
22. For given matrices X, Y and Z, demonstrate
    (a) Plot3 ( ).
    (b) Contour( )
    (c) Surf( )
    (d) Surfc( )
23. Represent the data given by vector X by using following routines:
    (a) bar( )
    (b) piechart( )
    (c) pie3( )
    (d) plot Histogram chart and Scatter chart using polar coordinates

Suggested Evaluation Methods	
Internal Assessment: 30	**End Term Examination: 70**

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

➢ **Practicum**	**30**	➢ **Practicum**	**70**
• Class Participation:	5	Lab record, Viva-Voce, write-up and execution of the programs	
• Seminar/Demonstration/Viva-voce/Lab records etc.:	10		
• Mid-Term Examination:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

1. Amos Gilat, *MATLAB An Introduction With Applications* 5ed, Wiley, 2008.
2. Rudra Pratap, *Getting Started with MATLAB*, Oxford University Press, 2010.
3. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, K. R. Coombes, J. E. Osborn, and G. J. Stuck, *A Guide to MATLAB,* Second Edition, Cambridge University Press, 2006.

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