MASTER OF SCIENCE

IN

MATHEMATICS

CURRICULUM AND SYLLABUS

(For students admitted from academic year 2018-2019 onwards)

UNDER CHOICE BASED CREDIT SYSTEM

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

DEPARTMENT OF MATHEMATICS

FACULTY OF SCIENCE AND HUMANITIES

SRM UNIVERSITY

SRM NAGAR, KATTANKULATHUR – 603 203.

M.Sc. MATHEMATICS (For students admitted from the academic year 2018-2019 onwards)

CURRICULUM AND SYLLABUS

Objectives:

1. To develop strong student competencies in Mathematics and its applications in a technology-rich and interactive environment.
2. To develop strong student expertise in the research, analysis and interpretation of complex information related to the areas of finance, data analysis or computational fluid dynamics.
3. To prepare the students to successfully compete for current employment opportunities.
4. To give rigor mathematical training so that the students can easily go for higher studies in India or abroad.

Eligibility:

B. Sc. with Mathematics as a major subject (or) B. Sc. Triple Major with Mathematics as one of the major subjects.

Duration:

2 Years (4 semesters)

Contents

CURRICULUM

M. Sc. (Mathematics) **Total credits: 82**

As per UGC Regulation 2016 (Credit Framework for Online Learning Courses through SWAYAM), SRMIST strongly encourages the use of SWAYAM (Study Web of Active Learning by Young and Aspiring Minds) platform.

1. Students shall be allowed to choose one SWAYAM course per semester on the recommendation of the faculty advisor and the credits will be transferred.
2. Based on the curriculum, students shall be allowed to choose one major core course from SWAYAM.
3. Suitable courses available on SWAYAM can also be chosen as an elective (major/non-major).

SEMESTER - I

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	18PMA101	Real Analysis	3	1	-	1	4	4
Major Core	18PMA102	Linear Algebra	3	1	-	1	4	4
Major Core	18PMA103	Ordinary Differential Equations	3	1	-	1	4	4
Major Core	18PMA104	Numerical Analysis	3	1	-	1	4	4
Major Core	18PMA105	Introduction to Scientific Programming in C/Matlab/Python	2	-	6	-	8	5
Total			**14**	**4**	**6**	**4**	**24**	**21**

SEMESTER - II

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	18PMA201	Algebra	3	1	-	1	4	4
Major Core	18PMA202	Complex Analysis	3	1	-	1	4	4
Major Core	18PMA203	Partial Differential Equations	3	1	-	1	4	4
Major Core	18PMA204	Probability and Statistics	3	1	-	1	4	4
Non Major Elective-I		Open Elective-I	2	-	-	-	2	2
Seminar	18PMA205	Seminar*(Based on recent research articles)	-	-	2	-	2	1
Total			**14**	**4**	**2**	**4**	**20**	**19**

SEMESTER - III

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	18PMA301	Topology	3	1	-	1	4	4
Major Core	18PMA302	Operations Research	3	1	-	1	4	4
Major Core	18PMA303	Calculus of Variations and Mechanics	3	1	-	1	4	4
Project Work -1	18PMA304	Project Phase I* (Research and seminar)	-	-	8	-	8	4
Major Elective -I	18PMA3EA	Multivariate Calculus	3	1	-	1	4	4
	18PMA3EB	Fuzzy Sets and Applications						
	18PMA3EC	Fluid Dynamics						
	18PMA3ED	Discrete Mathematics						
	18PMA3EE	Numerical Solutions to Partial Differential Equations						
	18PMA3EF	Introduction to Statistical Learning						
	18PMA3EG	Introduction to Mathematical Finance						
Non Major Elective-II		Open Elective-II	2	-	-	-	2	2
Total			**14**	**4**	**8**	**4**	**26**	**22**

SEMESTER - IV

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	18PMA401	Functional Analysis	3	1	-	1	4	4
Major Core	18PMA402	Integral Equations and Transformation Techniques	3	1	-	1	4	4
Project Work-2	18PMA403	Project Phase-II (Research and seminar)	-	-	16	-	16	8
Major Elective-II	18PMA4EA	Dynamical Systems	3	1	-	1	4	4
	18PMA4EB	Applied Functional Analysis						
	18PMA4EC	Non-Linear Partial Differential Equations						
	18PMA4ED	Graph Theory						
	18PMA4EE	Introduction to Functional Data Analysis						
	18PMA4EF	Formal Languages and Automata Theory						
Total			**9**	**3**	**16**	**3**	**28**	**20**
Total number of credits to be earned for the award of degree			**82**					

Note:
*** Continuous assessment [Full Internal]**
L=Lecture hours, T=Tutorial hours, P= Practical hours, O= Outside class and C=Credits

Guidelines for selecting course				
Category	**No. of Courses**			
	I Semester	**II Semester**	**III Semester**	**IV Semester**
Major Core Courses	5	4	3	2
Major Electives	-	-	1	1
Non-Major Electives	-	1	1	-
Seminar-Research Initiative	-	1	-	-
Project Work-Phase I	-	-	1	-
Project Work-Phase-II	-	-	-	1
Total number of credits				**82**

Non Major Electives (Offered to the other departments)

1. **18PMA2NA**: Numerical Methods using C++
2. **18PMA2NB**: Introduction to Differential Equations
3. **18PMA3NA**: Applied Mathematics
4. **18PMA3NB**: Bio-Mathematics

SEMESTER - I

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA101	Real Analysis	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Introduction to real number system, sequence and series	a				
2.	Familiarity with function of several variables	a				
3.	Exposure to Riemann integration and Improper integrals	a				

Unit-I: Basic Topology
Finite, countable and uncountable sets, real number system as a complete ordered field, Archimedean property, supremum, infimum, Bolzano-Weierstrass theorem, Heine Borel theorem.

Unit-II: Numerical Sequence and Series
Convergence of sequences, subsequences, Cauchy sequences, upper and lower limits, some special sequences, Series, Series of nonnegative terms, the number e, Root and Ratio tests, Power series, summation by parts, Absolute convergence.

Unit III: Continuity and Differentiation
Limits of functions, continuous functions, continuity and compactness, connectedness and type of discontinuities, monotonic functions, infinite limits and limit at infinity, the derivative of real function, mean value theorems,

Unit-IV: Riemann-Stieltjes integral and Sequences and Series of Functions
Riemann sums and Riemann integral, Riemann-Stieltjes integral and its properties, improper integrals**,** Sequences and series of functions, uniform convergence and continuity, integration, differentiations, equicontinuous family of functions, Stone Weierstrass theorem.

Unit-V: Multi-variable calculus
Functions of several variables, directional derivatives, partial derivatives, derivative as a linear transformation, inverse and implicit function theorems, maxima and minima.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:
1. W. Rudin, *Principles of Mathematical Analysis*, Mc-Graw Hill, 1976.
2. E. Kreyszig , *Introductory Functional Analysis with Applications*, John Wiley and Sons, 2010.
   - Unit-I: Chapter 2 [Rudin].
   - Unit-II: Chapter 3 [Rudin]
   - Unit-III: Chapter 4, 5 [Rudin]
   - Unit-IV: Chapter 6, 7 [Rudin]
   - Unit-V: Chapter 9[Rudin]

References:

1. H. L. Royden, *Real Analysis*, Macmillan Publishing Company, 1998.
2. T. Tao, *Analysis I*, Hindustan Book Agency, 2006.
3. T. Tao, *Analysis II*, Hindustan Book Agency, Springer, 2015.
4. T. M. Apostol, *Mathematical Analysis*, Addison-Wesley, 1974.
5. G. F. Simmons, *Topology and Modern Analysis*, Kreiger, 2003.
6. C. C. Pugh, *Real Mathematical Analysis*, Springer, 2002.
7. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, Wiley, 2000.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50%
End Semester Weightage							50%
Total							100%

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA102	**Linear Algebra**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To be thorough with the fundamental concepts of matrices and determinants	**a**				
2.	Familiarity with the operators in the finite dimensional inner product spaces	**a**				
3.	To understand the different canonical forms	**a**				

Unit-I: Linear systems and vector spaces
Systems of linear equations, matrices and elementary row operations, row-reduced Echelon matrices, finite dimensional vector spaces, subspaces, linear dependence, basis, dimension.

Unit-II: Linear transformations
Linear transformations and their matrix representations, change of basis, isomorphism, rank and determinant of matrices,Rank-Nullity theorem, linear functional and dual space, annihilator, double dual, transpose of a linear transformation.

Unit-III: Matrices and its properties
Eigenvalues and eigenvectors, minimal polynomial, Cayley-Hamilton theorem, invariant subspaces, diagonal forms, triangular forms, Hermitian, skew-Hermitian and unitary matrices, direct-sum decompositions, invariant direct sums, primary decomposition theorem.

Unit-IV: Canonical forms
Cyclic subspaces and annihilators, cyclic decomposition and rational forms, Jordan-canonical form.

Unit-V: Inner product spaces
Finite dimensional inner product spaces, linear operators on inner product spaces, orthonormal basis, Gram-Schmidt ortho normalization process, self- adjoint operators, quadratic forms.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. G.Strang, *Introduction to Linear Algebra*, Wellesley-Cambridge Press, 1993.
2. K. Hoffman and R. Kunze, *Linear Algebra*, 2nd Ed., Prentice Hall of India, 2005.
    - Unit-I: Chapter 1: Chapter 2: Sec. 2.1-2.4 [Hoffman]
    - Unit-II: Chapter 3: Sec. 3.1-3.7 [Hoffman]
    - Unit-III: Chapter 6: Sec. 6.1-6.8 [Hoffman]
    - Unit-IV: Chapter 7: Sec. 7.1, 7.2 [Hoffman]
    - Unit-V: Chapter 8 [Hoffman]

References:

1. S. Kumaresan, *Linear Algebra: A Geometric Approach*, Prentice-Hall of India, 2004.
2. S. Axler, *Linear Algebra Done Right*, 2nd Ed., Springer UTM, 1997.
3. S. Lang, *Linear Algebra*, Springer Undergraduate Texts in Mathematics, 1989.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA103	**Ordinary Differential Equations**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To understand the concept of well posed differential equation (DE).	**a**				
2.	To study Green's functions, Sturm-Liouville type problems	**a**	**e**			
3.	Exposure to solve system of ordinary differential equations (ODE).	**a**	**e**			

Unit-I: Existence and uniqueness of solutions
Geometric view of an ODE, Review of separable ODEs, Homogeneous and reducible to homogeneous ODEs, and exact solutions of first order ODEs, method of successive approximations, Lipschitz condition, convergence of successive approximations, existence and uniqueness of solutions of initial value problems (IVP), non-local existence of solutions.

Unit-II: Second order equations
General solution of homogeneous equations, non-homogeneous equations, Wronskian, method of undetermined coefficients, method of variation of parameters.

Unit-III: Boundary value problems
Sturm comparison theorem, Sturm separation theorem, boundary value problems, Sturm-Liouville problems, Green's functions.

Unit-IV: Series solutions
Series solution of second order linear equations: ordinary points, regular singular points, Legendre polynomials and properties, Bessel functions and properties.

Unit-V: System of differential equations
Algebraic properties of solutions of linear systems, eigenvalue-eigenvector method of finding solutions, complex eigenvalues, equal eigenvalues.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.
Textbooks:
1. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, McGraw-Hill, 1955.
2. G.F. Simmons, *Differential Equations with Applications and Historical Notes*, 2nd Ed,McGraw- Hill, 1991.
3. R.P. Agarwal and D. O'Regan, *An Introduction to Ordinary Differential Equations*, Springer- Verlag, 2008.
   - Unit-I: Lecture 1 of "Haynes Miller, and Arthur Mattuck. 18.03 Differential Equations. Spring 2010. Massachusetts Institute of Technology: MIT Open Course Ware, https://ocw.mit.edu. License: Creative Commons BY-NC-SA."
     Chapter 1: Sec. 1-3, Chapter 2: Sec. 7-11 [Simmons]; Chapter 1: Sec 1-4 [Coddington and Levinson]
   - Unit-II: Chapter 3: Sec. 14-19 [Simmons]
   - Unit-III: Chapter 4, Chapter 7: Sec-43 [Simmons], Lecture33 [Agarwal and O'Regan]
   - Unit-IV: Chapter 5: Sec. 26-31, Chapter 8: Sec. 44-47 [Simmons]
   - Unit-V: Chapters 25, 26 [Agarwal and O'Regan]

References:

1. G. Birkh off and G.-C. Rota, *Ordinary Differential Equations*, John Willey and Sons, 4th Ed., 1989.
2. R.P. Agarwal and R.C.Gupta, *Essentials of Ordinary Differential Equations*, McGraw-Hill, 1993.
3. E.A. Coddington an, *An Introduction to Ordinary Differential Equations*, PHI Learning 1999.
4. M. Braun, *Differential Equations and Their Applications*, 3rd Ed., Springer-Verlag, 1983.
5. S. G. Deo, V. Raghavendra, R. Kar and V. Lakshmikantham, *Textbook of Ordinary Differential Equations*, McGraw Hill Education, 3rd Ed., 2015.
6. G.F. Simmons and S.G. Kantz, *Differential Equations: Theory, Technique and Practice*, Tata McGraw-Hill, 2007.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA104	**Numerical Analysis**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Be thorough with numerical method for solving algebraic and transcendental equations	**a**				
2.	To understand various methods for solving systems of linear equations	**a**				
3.	To be familiarize with different methods to handle differential equation and integrals	**a**				

Unit-I: Solution of equations
Computer arithmetic, errors, numerical solution of algebraic and transcendental equations, bisection, secant method, Newton-Raphson method, rate of convergence.

Unit-II: Direct methods for solving linear system of equation
Norms of vectors and matrices, solution of systems of linear equations: direct methods (Gauss elimination, LU decomposition), iterative methods (Jacobi and Gauss-Seidel), ill conditioning and convergence analysis.

Unit-III: Interpolation
Error of polynomial interpolation, Lagrange, Hermite and spline interpolations, Newton interpolations, Chebyshev approximation, power method to find the eigenvalues.

Unit-IV: Numerical differentiation and numerical integration
Numerical differentiation based on interpolation, Trapezoidal and Simpson rules.

Unit-V: Numerical solution of differential equations
Numerical solutions of ODE's using Picard, Euler, modified Euler and Runge-Kutta methods, single step and multi-step methods, order, consistency, stability and convergence analysis, stiff equations, two point boundary value problems: shooting and finite difference methods.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. D. Kincaid and W. Cheney, *Numerical Analysis and Mathematics of Scientific Computing*, Brooks/Cole, 1999.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New age International Publishers, 2012.
   - Unit-I: Chapter 1: Sec 1.1-1.3; Chapter 2: Sec 2.1-2.7, 2.9 [Jain]
   - Unit-II: Chapter 3: Sec 3.1-3.9, 3.11-3.12 [Jain]
   - Unit-III: Chapter 4: Sec. 4.1-4.6, 4.9-4.10 [Jain]
   - Unit-IV: Chapter 5: Sec. 5.1-5.4, 5.6-5.9, 5.11 [Jain]
   - Unit-V: Chapter 6: Chapter 7, Sec. 7.1-7.3 [Jain]

References:

1. K. Atkinson, *Elementary Numerical Analysis*, John Wiley, 3rd Ed., 2003.
2. S. D. Conte and C. de Boor, *Elementary Numerical Analysis*, McGraw-Hill, 1980.
3. A. Iserles, *A First Course in the Numerical Analysis of Differential Equations*, Cambridge University Press, 1996.
4. J. C. Butcher, *The Numerical Analysis of Ordinary Differential Equations*, John Wiley, 1987.
5. H. R. Schwarz, *Numerical Analysis: A Comprehensive Introduction*, Wiley, 1st Ed., 1989.
6. R. L. Burden and J. D. Faires, *Numerical Analysis*, Brooks/Cole, 9th Ed., 2011.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA105	**Introduction to Scientific Programming in Matlab**	**-**	**2**	**6**	-	**8**	**5**

Instructional objectives At the end of this course the learner is expected:		**Student Outcomes**				
1.	To develop the skills in scientific programming tools	**a**	**k**			
2.	At the end of the course the students should be able to apply the knowledge gained in solving problems by numerical methods	**a**	**k**			

Unit-I: Introduction to variables and workspace
Define and examine numbers, characters, string, text workspace command, built-in functions, mathematical functions, graphics, loops, logical, timing, reading and writing data files, copying to and from word and other applications, vectors, products, division and powers of vectors, matrices, solving system of linear equations.

Unit-II: Solution of equations
Root finding methods: secant and Newton-Raphson method, numerical linear systems: Gaussian elimination method, LU factorization method, Gauss-Seidel and Jacobi iteration method.

Unit-III: Interpolation
Lagrange interpolation, Newton divided difference and splines.

Unit-IV: Numerical differentiation and numerical integration
Numerical methods for ODE: Euler's method, fourth order Runge-Kutta method, Adams-Bashforth multi-step method, Numerical integration trapezoidal and Simpson 1/3 rule,

Unit-V: Finite difference method for BVPs
Elliptic equations, parabolic equations, hyperbolic equations**.**

List of programs:
1. Root finding by Bisection, Newton's and Secant methods.
2. Finding polynomial third degree polynomial passing through four given points in Cartesian plane.
3. Solving linear system with Gaussian elimination and/or LU Factorization methods
4. Solving linear system with Gauss-Seidel and/or Jacobi iteration methods.
5. Solving first order IVP by: Euler's or improved Euler methods, multistep 4th order Runge - Kutta method or Adams-Bash forth method.
6. Computer implementation of Lagrange and Newton interpolation, cubic spline data interpolation.
7. Numerical integration by Trapezoidal and Simpson 1/3 rules.
8. Numerical solution of Laplace and Poisson equation in rectangular domain using central difference approximation with Dirichlet and Neumann boundary conditions.
9. Numerical approximation of linear transport equation using first order upwind and central difference methods.
10. Numerical approximation of convection diffusion problems using a finite difference scheme.

Textbooks:

1. W. J. Palm III, *Introduction to Matlab for Engineers*, Tata McGraw Hill, New Delhi, 2011.
2. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley, 10th Ed., 2011.

References:

1. S. C. Chopra, *Applied Numerical Methods with Matlab For Engineers and Scientists*, Tata McGraw Hill Company Limited, New Delhi, 2ndEd., 2007.
2. D. F. Griffith, *Introduction to Matlab*, 2005.
   www.maths.dundee.ac.uk/uftp/na-reports/matlabnotes.pdf.

Course Nature : Theory							
Assessment Method (Max.Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMAOC1	**Online Course*(Related to major core can be selected from Course era, NPTEL, MIT OCW, MOOC, Udacity, etc.)**	-	-	**2**	-	**2**	**1**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Exposure to skill based e-learning.	**a**				
2.	To develop the skills of self-learning.	**a**				

Topic will be decided by the individual student's guide/Faculty advisor.

SEMESTER-II

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA201	**Algebra**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Be thorough with theory of Groups, homomorphism and Cayley's theorem.	**a**				
2.	Familiarity with Sylow's theorem and their applications	**a**				
3.	Basic understanding of CRT and field extension theory	**a**				

Unit-I: Group theory
Groups, subgroups, normal subgroups, Euler's Ø- function, quotient groups and homomorphism theorems,automorphisms, cyclic groups and permutation groups, Cayley's theorem.

Unit-II: Sylow's theorems
Class equations, Sylow's theorems and their applications.

Unit-III: Ring theory
Rings, ideals, prime and maximal ideals, quotient rings, fundamental theorem of arithmetic, unique factorization domain, principal ideal domain, Euclidean domain, polynomial rings and irreducibility criteria.

Unit-IV: Field theory
Finite and algebraic extensions, existence and cardinality of algebraic closure, finite fields.

Unit-V: Galois Theory
Chinese remainder theorem, Galois Theory of polynomial in characteristic zero and simple examples.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J.A. Gallian, *Contemporary Abstract Algebra*, Narosa, 4th Ed., 1999.
2. I. N. Herstein, *Topics in Algebra*, John-Wiley, 1995.
    - Unit-I, II: Chapter 2 [Herstein]
    - Unit-III: Chapter 3 [Herstein]
    - Unit-IV, V: Chapter 5 [Herstein]

References:

1. M.Artin, *Algebra*, Prentice Hall Inc., 1994.
2. T. A. Hungerford, *Algebra, Graduate Texts in Mathematics*, Vol. 73, Springer-Verlag, 1980.
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, John-Wiley, 2nd Ed., 1999.
4. S. Lang, *Algebra*, Addison-Wesley, 3rd Ed., 1999.
5. J. B.Fraleigh, *A First Course in Abstract Algebra*, Pearson, 7thEd., 2003.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA202	**Complex Analysis**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To understand the basic concept related to limit, continuity, differentiability in complex system	**a**				
2.	Familiarity with analyticity and power series	**a**				
3.	To evaluate complex integral using residue theorem	**a**				

Unit-I: Algebra of complex numbers
Complex plane, Riemann sphere, limits, continuity and differentiability, polynomials.

Unit-II: Analytic functions
Analytic functions, harmonic functions, multi-valued functions, Cauchy-Riemann equations, convergence of power series, radius of convergence of power series, and power series as an analytic function.

Unit-III: Complex integration
Contour integral, Cauchy's integral theorem and formula, Morera's theorem, Taylor's theorem, Laurent's theorem, Liouville's theorem, maximum modulus principle, Schwarz lemma, open mapping theorem.

Unit-IV: Singularities
Laurent Series, zeros and singularities, calculus of residues, residue theorem and applications for evaluating real integrals, argument principle.

Unit-V: Conformal mapping
Conformal mapping, linear fractional transformations, special linear fractional transformations, Riemann surface.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Birkha user, Boston, 2006.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 10^{th} Ed., 2011.
   - Unit-I: Chapter 1 [Ponnusamy]; Chapter 13 [Kreyszig]
   - Unit-II: Chapter 5, 6 [Ponnusamy]
   - Unit-III: Chapter 7, 8 [Ponnusamy]
   - Unit-IV: Chapter 9 [Ponnusamy]
   - Unit-V: Chapter 11, Sec 11.1 [Ponnusamy]

References:

1. S. Ponnusamy *Foundations of Complex Analysis*, Narosa Publishing House, 2^{nd} Ed., 2005.
2. J.B. Conway, *Functions of One Complex Variables*, Springer-Verlag, 2^{nd} Ed., 1978.
3. J.W. Brown and R.V. Churchil, *Complex Variables and Applications*, McGraw Hill, 2008.
4. L. Ahlfors, *Complex Analysis*, McGraw-Hill, 2^{nd} Ed., New York, 1966.
5. M. J. Ablowitz and A. S. Fokas, *Complex Variables: Introduction and Applications*, Cambridge University Press, NY, 2003.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA203	**Partial Differential Equations**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To understand solving linear and nonlinear first order PDE's	**a**				
2.	To be able to classify the second order PDE's and its reduction to canonical form	**a**	**e**			
3.	To develop the strength to analyze the wave, diffusion and Laplace equations using different techniques	**a**	**e**			

Unit-I: Introduction to PDE
Simultaneous differential equations of first order and first degree, integral curves of vector fields, methods of solution of $dx/P = dy/Q = dz/R$, Orthogonal trajectories of a system of curves on a surface, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables.

Unit-II: First order PDE
Partial differential equations, origins and classification of first order PDE, initial value problem for quasi-linear first order equations: Existence and uniqueness of solutions, non-existence and non-uniqueness of solutions. Surfaces orthogonal to a given system of surfaces, nonlinear PDE of first order, Cauchy method of characteristics, compatible systems of first order equations ,Charpit's method, solutions satisfying given conditions.

Unit-III: Second order PDE
Origin of second order PDE, equations with variable coefficients, classification of second order equations, characteristic curves of second order equations in two variables, Reduction into canonical form using characteristic curves.

Unit-IV: Wave equation
One dimensional wave equation: D'Alembert's solution, reflection method for half-line, inhomogeneous wave equation, Fourier method.

Unit-V: Laplace and diffusion equation
Maximum-minimum principle, uniqueness of solutions, solutions of Laplace equation in Cartesian and polar coordinates: rectangular regions, circular regions, annular regions, Poison integral formula. Diffusion equation: One dimensional diffusion equation, maximum minimum principle for the diffusion equation, diffusion equation on the whole line, diffusion on the half-line, inhomogeneous equation on the whole line, Fourier method.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. I. P. Stavroulakis and S. A. Tersian, *Partial Differential Equations- An Introduction with Mathematica and Maple*, world - Scientific, Singapore, 1999.
2. I. N. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, 1998.
   - Unit-I: Chapter 1, (sec. 2-6) [Sneddon]
   - Unit-II: Chapter 2, (section 1-12) [Sneddon]
   - Unit-III: Chapter 3 (section 1, 5,6) [Sneddon] and Chapter 2, section 2 [Stavroulakis]
   - Unit-IV: Chapter 3, (section 3.1-3.2, 3.4), Chapter 7 (section 7.4) [Stavroulakis]
   - Unit-V: Chapter 4, Chapter 6 (section 6.1), Chapter 7 (section 7.3 and section 7.5) [Stavroulakis]

References:

1. L. C. Evans, *Partial Differential Equations*, American Mathematical Society, 2010.
2. K. S. Rao, *Introduction to Partial Differential Equations*, Prentice Hall India, 2006.
3. W. E. Williams, *Partial differential Equations*, Clarendon Press, Oxford, 1980.
4. T. Amarnath, *An Elementary Course in Partial Differential Equations*, Narosa Publishing House, 2^n Ed., 2012.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA204	**Probability and Statistics**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Learning the techniques to develop discrete and continuous probability distribution and its applications	**a**				
2.	Study about related statistical characteristics and its properties with applications	**a**				
3.	Learn the models in sequential analysis for hypotheses testing	**a**				

Unit-I: Probability and random variables
Sample space, probability axioms, finite sample space, Baye's theorem, total probability theorem, independent events, random variables, probability distribution of random variables, discrete and continuous random variables, functions of random variables.

Unit-II: Moment generating functions and multiple random variables
Moments of distribution functions, generating functions, moment inequalities, multiple random variables, independent random variables, functions of several random variables, covariance, correlation, moments, conditional expectations, ordered statistics and their distributions.

Unit-III: Some special distributions and limit theorem
Some discrete distributions, continuous distribution, bivariate and multivariate normal distributions, exponential family of distributions, mode of convergence, weak and strong law of large numbers, limiting moment generating functions, central limit theorem.

Probability measure, random variable, function of random variable, probability mass function, probability density function, cumulative probability distribution function, independent event, expectation, conditional probability, Baye's formula, Baye's theorem, function of several variables, joint and marginal distribution function, moments, moments generating function, characteristic function.

Unit-IV: Sample moments and their distributions
Types of sampling, Sample characteristics and their distributions, Chi square test, T test, F test and their distributions, Large sample theory.

Unit-V: Parameter estimation
Point estimation, unbiased estimation, lower bound and lower bound for variance of estimator, method of moments, maximum likelihood estimators, Baye's and min-max estimation, and principle of equi - variance.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.
Textbooks:

1. M. Fisz, *Probability Theory and Mathematical Statistics*, John Wiley and Sons, 2012.
2. V.K.Rohatgi and A.K.Md.E. Saleh, *An Introduction to Probability and Statistics*, Wiley series of probability and statistics, 2nd Ed., 2001.
   - Unit-I: Chapter 1-2 [Rohatgi]
   - Unit-II: Chapter 3-4 [Rohatgi]
   - Unit-III: Chapter 5-6 [Rohatgi]
   - Unit-IV: Chapter 7, 10: Sec.7.1-7.5, Sec. 10.3-10.5 [Rohatgi]
   - Unit-V: Chapter 8: [Rohatgi]

References:

1. B. R. Bhat, *Modern Probability Theory*, New Age International, 1999.
2. R. E. Walpole, R. H. Myers, S. L. Myers, K. Ye, Probability *& Statistics for Engineers & Scientists*, Pearson Prentice Hall, 8th Ed., 2007.
3. D. C. Montgomery and G. C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley & Sons, 3rd Ed., 2003.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA205	**Seminar*(Based on recent research articles)**	-	-	**2**	-	**2**	**1**
Instructional objectives							
1. To develop the skills in understanding the research articles.							

Instructional objectives At the end of this course the learner is expected:		Student Outcomes					
1.	Exposure to an advance special topic or programming.	**a**					
2.	To develop the skills in understanding the research articles.	**a**					

Topic will be decided by the individual student's guide/Faculty advisor.

SEMESTER-III

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA301	Topology	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Introduction to topological spaces, definitions of sets	a				
2.	Familiarity with connected spaces, components and path components	a				
3.	Exposure to countability	a				

Unit-I: Basic concepts of topology
Topological spaces, basis for a topology, order topology, subspace topology.

Unit-II: Topological spaces and continuous functions
Closed sets, countability axioms, limit points, continuous functions, product topology, metric topology, quotient topology.

Unit-III: Connectedness
Connected spaces, connected sets in R, components and path components.

Unit-IV: Compactness
Compact spaces, compactness in metric spaces, local compactness, convergence of nets in topological spaces.

Unit-V: Countability and separation axioms
Countability and separation axioms, normal spaces, Urysohn's lemma, Urysohn metrization theorem.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J. R. Munkres, *Topology*, Prentice Hall, NJ, 2000.
2. G. F. Simmons, *Introduction to Topology and Modern Analysis*, International Student Edition, 1963.
   - Unit-I, II: Chapter 2 [Munkers]
   - Unit-III, IV: Chapter 3 [Munkers]
   - Unit-V: Chapter 4, Sec. 4.1-4.5. [Munkers]

References:

1. K.D. Joshi, *Introduction to General Topology*, New Age International, New Delhi, 2000.
2. J.V. Deshpande, *Introduction to Topology*, Tata McGraw-Hill, 1988.
3. J. Dugundji, *Topology*, Allyn and Bacon Inc., 1966.
4. J.L. Kelley, *General Topology*, Van Nostrand, 1955.
5. M.G. Murdeswar, *General Topology*, New Age International, 1990.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA302	**Operations Research**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional objectives At the end of this course the learner is expected:		**Student Outcomes**				
1.	Be thorough with LPP	**a**				
2.	To understand various method for solving LPP	**a**				
3.	To familiarize with transportation problems	**a**				
4.	To learn integer programming problems	**a**				
5.	To learn queuing systems	**a**				

Unit-I: Basics of LPP
Different types of OR models, convex sets, graphical method, infeasible and unbounded LPP's, simplex method, big-M method, two phase method, revised simplex method.

Unit-II: Duality theory
Dual simplex method, sensitivity analysis, parametric linear programming.

Unit-III: Transportation problems
Transportation problems and assignment problems.

Unit-IV: Integer programming
Cutting plane and branch and bound techniques for all integer and mixed integer programming problems.

Unit-V: Game theory
Graphical method and linear programming method for rectangular games, saddle point, notion of dominance, queuing theory, steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1, inventory models.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. H. A. Taha, *Operations Research: An Introduction*, MacMillan Pub Co., NY, 9th Ed., 2013.
2. A. Ravindran, D. T. Phillips and J. J. Solberg, *Operations Research: Principles and Practice*, John Wiley and Sons, NY, 2ndEd., 2012.

- Unit-I Chapter 1: Sec. 1.1, 1.2, Chapter 2: Sec. 2.1, 2.2, Chapter 3 [Taha]
- Unit-II Chapter 4 [Taha]
- Unit-III Chapter 5: Sec. 5.1-5.4 [Taha]
- Unit-IV Chapter 9: Sec. 9.2-9.3 [Taha]
- Unit-V Chapter 13: Sec 13.4, Chapter 15 [Taha]

References:

1. R. Bronson and G. Naadimuthu, *Schaum's Outline of Operations Research*, McGraw-Hill Education, 1981.
2. F. S. Hillier and G. J. Liberman, *Introduction to Operations Research,* McGraw-Hill, 7th Ed., 2001.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA303	**Calculus of Variations and Mechanics**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Be thorough with Calculus of variations	**a**				
2.	Familiarity with generalized coordinates, its properties and applications	**a**	**e**			
3.	Exposure to Hamilton's variables	**a**	**e**			
5.	Be familiar with Poisson's brackets and its application in mechanics	**a**	**e**			

Unit-I: Method of variation in problems with fixed and moving boundaries
Variation of a functional, Euler-Lagrange equation, variational problems with fixed and moving boundaries.

Unit-II: Variational problem involving a conditional extremum
Necessary and sufficient conditions for extrema, variational problems involving a conditional extremum.

Unit-III: Generalized coordinate systems
Generalized coordinates, virtual work, D'Alembert's principle, unilateral and bilateral constraints, holonomic and non-holonomic systems, scleronomic and rheonomic systems, Lagrange's equations of first and second kind, uniqueness of solutions, energy equation for conservative fields, Euler's dynamical equations.

Unit-IV: Rotating coordinate system
Rotating coordinate system, motion related to rotating earth, Faucaull's pendulum and torque free motion of a rigid body about a fixed point, motion of a symmetrical top and theory of small vibrations, Hamilton's variables, Hamilton canonical equation, homogeneity of space and time conservation principles, Noethers theorem, cyclic coordinates, Routh's equation, Hamilton's principle, principle of least action, Poisson's Bracket, Poisson's identity, Jacobi-Poisson theorem.

Unit-V: Canonical transformations
Time dependent Hamilton-Jacobi equation and Jacobi's theorem, Lagrange brackets, condition of canonical character of transformation in terms of Lagrange brackets and Poisson brackets, invariance of Lagrange brackets and Poisson brackets under canonical transformations.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. L. Elsgolts, *Differential Equations and the Calculus of Variations*, Mir Publishers, 1977.
2. N. C. Rana and P. S. Jog, *Classical Mechanics*, Tata McGraw-Hill Education Pvt. Ltd., 2015.

   - Unit-I: Chapter 6, 7 [Elsgolts]
   - Unit-II: Chapter 8, 9 [Elsgolts]
   - Unit-III: Chapter 1, 2[Rana]
   - Unit-IV: Chapter 3, 5, 6 [Rana]
   - Unit V: Chapter 9, 10 [Rana]

References:

1. M. Gelfand and S. V. Fomin, *Calculus of Variations*, Prentice Hall, Inc., NJ, 1963.
2. H. Goldstein, C. P. Poole, J. L. Safko, *Classical Mechanics*, 3rdEd., Addison-Wesley, 2001.
3. N. H. Louis and D. F. Janet, *Analytical Mechanics*, Cambridge University Press, 1998.
4. S. Ramsay, *Dynamics PartII*, Cambridge University Press, 1944.
5. P. K. Nayak, *A Textbook of Mechanics*, Narosa Publishing House, 2016.
6. A. S. Gupta, *Calculus of Variations with Applications*, Prentice-Hall of India Pvt. Limited, 2004.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Major Elective-I

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EA	Multivariate Calculus	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To understand the concept of differential calculus in several variable framework	a				
2.	Be familiar with the concept of maxima and minima in several variables	a				
3.	Go through the concept of gradient, divergence and curl	a				
4.	Be familiar with line, surface and volume integrals	a				
5.	To understand the connection between the line, surface and volume integrals through Green's, Guass' and Stokes' Theorem	a				

Unit-I: Differential calculus
Functions of several variables, open sets, limits and continuity, derivatives of a scalar field with respect to a vector, directional derivatives, partial derivatives, total derivative, gradient of a scalar field, level sets and tangent planes, derivatives of vector fields, chain rules for derivatives, derivatives of functions defined implicitly, higher order derivatives, Taylor's theorem.

Unit-II: Applications of differential calculus
Maxima, minima, saddle points, stationary points, Lagrange's multipliers, inverse function theorem, implicit function theorem.

Unit-III: Line integrals
Paths and line integrals, fundamental theorems of calculus for line integrals, vector fields and gradients.

Unit-IV: Multiple integrals
Double and triple integrals, iterated integrals, change of variables formula, applications to area and volume, Green's theorem, two-dimensional vector fields and gradients.

Unit-V: Surface integrals
Parametric representation of a surface, fundamental vector product and normal to a surface, Stokes' theorem, curl and divergence of a vector field, Gauss' divergence theorem.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. T.M.Apostol, *Calculus*, Vol. II, John Wiely& Sons, 2nd Ed., 2003.
2. D.V.Widder, *Advanced Calculus*, PHI Learning, 2nd Ed., 1987.

- Unit-I: Chapter 8 [Apostal]
- Unit-II: Chapter 9 [Apostal]
- Unit-III: Chapter 10 [Apostal]
- Unit-IV: Chapter 11 [Apostal]
- Unit-V: Chapter 12 [Apostal]

References:

1. T. M. .Apostol, *Mathematical Analysis*, Narosa Pub. House,2nd Ed., 1997.
2. M.R.Spiegel, *Vector Analysis*, Schaum's Outline Series, Mc-Graw Hill, 1959.
3. H.M.Edwards, *Advanced Calculus-A Differential Forms Approach*, Birkha user, 1994.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50%
End Semester Weightage							50%
Total							100%

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EB	**Fuzzy Sets and Applications**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Understand the basic knowledge of fuzzy sets and fuzzy logic	**a**				
2.	Be familiar with the concept of fuzzy numbers and arithmetic operations	**a**				
3.	To gain knowledge in fuzzy relations	**a**				
4.	Be thorough with the concept of Logical connectives and fuzzy graphs	**a**				
5.	Be exposed to basic fuzzy system modelling methods and knowledge of fuzzy information processing	**a**				

Unit-I: Fuzzy sets
Basic definitions, level sets, convex fuzzy sets, basic operations on fuzzy sets, types of fuzzy sets, Cartesian products, algebraic products bounded sum and difference.

Unit-II: Extension principle and application
Zadeh extension principle, image and inverse image of fuzzy sets, fuzzy numbers, elements of fuzzy arithmetic.

Unit-III: Fuzzy relations
Fuzzy relations on fuzzy sets, union and intersection of fuzzy relation, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relation.

Unit-IV: Fuzzy decision
Fuzzy linear programming problems: Symmetric fuzzy linear programming problem, fuzzy linear programming with crisp objective function, fuzzy graph.

Unit-V: Fuzzy logic
An overview of classic logic, its connectives, tautologies, contradiction fuzzy logic, fuzzy quantities, logical connectives for fuzzy logic, applications to control theory.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. D.DuBois and H. M. Prade, *Fuzzy Sets and Systems: Theory and Applications*, Academic Press, 1994.
2. H. J. Zimmermann, *Fuzzy Set Theory and its Applications*, Allied publishers Ltd., New Delhi, 2001.
   - Unit I: Part II, Chapter 1: A, B, C, D, E, F and G[DuBois]
   - Unit II: Part II, Chapter 2: A, B and C [DuBois]
   - Unit III: Part II, Chapter 3: A, B and C[DuBois]
   - Unit IV: Part III, Chapter 4: A and B[DuBois]
   - Unit V: Chapter 9.1, 9.2.2 [Zimmermann]

References:

1. G. J. Klirand and B. Yuan, *Fuzzy Sets and Fuzzy Logic Theory And Applications*, Prentice Hall of India 1995.
2. T. J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill, International Editions, 2010.
3. J. J. Buckley and E. Eslami, *An Introduction to Fuzzy Logic and Fuzzy Sets*, Springer-Verlag Heidelberg, 2002.
4. G. Chen and T. T. Pham, *Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems*, CRC Press LLC, N.W. Florida, 2000.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EC	**Fluid Dynamics**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To understand the basic concepts in fluid mechanics	**a**				
2.	To be thorough with the conservation laws	**a**				
3.	To familiarize with vortex dynamics, velocity potential and stream functions	**a**				
4.	To understand the importance of dimensional analysis	**a**				
5.	To be acquainted with linear stability analysis of benchmark problems in fluid mechanics	**a**				

Unit-I: Introduction to fluid flows
Real and ideal fluids, velocity, acceleration, streamlines, path lines, steady and unsteady flows, velocity potential, vorticity vector, local and particle rates of change, equation of continuity, conditions at a rigid boundary.

Unit-II: Conservation laws
Pressure at a point in a fluid, boundary conditions of two inviscid immiscible fluids, Euler's equations of motion, Bernoulli's equation, some potential theorems, flows involving axial symmetry.

Unit-III: Analysis and classification of fluid motion
Two dimensional flows, use of cylindrical polar co-ordinates, stream function, complex potential for two-dimensional flows, irrotational, incompressible flow, complex potential for standard two-dimensional flows, two dimensional image systems, Milne-thomson circle theorem, theorem of Blasius, mathematical formulation and solution procedures.

Unit-IV: Dynamic similarity
Dimensional analysis, Buckingham's pi theorem, dynamic similarity, vorticity diffusion, steady flow between parallel plates, steady flow in a circular pipe, steady flow between two co-axial cylinders.

Unit-V: Flow instability
Navier-Stokes equations of motion and some exact solutions, Flows at small Reynolds numbers, boundary layer theory, Method of normal modes, Benard problem, double-diffusive instability, Taylor problem, Kelvin-Helmholtz instability, instability of continuously stratified parallel flows, Squire's theorem, Orr-Sommerfeld equation, inviscid stability of parallel flows.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.
Textbooks:

1. F. Chorlton, *Textbook of Fluid Dynamics*, CBS Publishers, 1998.
2. P. K. Kunduand I. M. Cohen, *Fluid Mechanics*, Academic Press London, 2002.
   - Unit I: Chapter 2: Sec 2.1-2.10[Chorlton]
   - Unit II: Chapter 3: Sec 3.1-3.7[Chorlton]
   - Unit III: Chapter 5: Sec 5.1- 5.8[Chorlton]
   - Unit-IV: Chapter 8: Sec.1-5, 7, Chapter 9: Sec. 1-6[Kundu]
   - Unit-V: Chapter 10,Chapter 12: Sec.1-9[Kundu]

References:

1. G. K. Batechelor, *An Introduction to Fluid Dynamics*, Cambridge Press, 2nd Ed., 2000.
2. F. M. White, *Fluid Mechanics*, McGraw Hill, New York, 8th Ed., 2015.
3. P. G. Drazin and W. H. Reid, *Hydrodynamic Stability*, Cambridge Press, 2nd Ed., 2004.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3ED	Discrete Mathematics	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To understand the basic set theoretic concepts	a				
2.	To familiarize with concept of graph theory	a				
3.	To learn the concepts of Boolean algebra and recurrence relations	a				

Unit-I: Set theory
Introduction to the theory of sets, combination of sets, power sets, finite and infinite sets, principle of inclusion and exclusion, logic: proposition, predicate logic, logic operators, logic proposition and proof, method of proofs, mathematical induction: different forms of the principle of mathematical induction, selected problems on mathematical induction.

Unit-II: Discrete probability
Counting principles, random experiment, sample space, events, axioms of probability, conditional probability, theorem of total probability, Bayes' theorem, and application to information theory: information and mutual information. Graph Theory: path, cycles, handshaking theorem, bipartite graphs, sub-graphs, graph isomorphism, operations on graphs, Eulerian graphs and Hamiltonian graphs, planar graphs, Euler formula, traveling salesman problem, shortest path algorithms.

Unit-III: Relations
Definitions and properties, equivalence relations and equivalence classes, representations of relations by binary matrices and digraphs, operations on relations, closure of a relation, reflexive, symmetric and transitive closures, Warshall's algorithm to compute transitive closure of a relation, partially ordered sets and lattices: partial order relations, POSETS, lattices.

Unit-IV: Discrete numeric functions
Introduction of discrete numeric functions, asymptotic behavior, generating functions, Boolean algebra and Boolean functions, introduction to Boolean algebra and Boolean functions, different representations of Boolean functions, application of Boolean functions to synthesis of circuits.

Unit-V: Recurrence relations
Linear recurrence relations with constant coefficients (homogeneous case), discussion of all the three sub-cases,linear recurrence relations with constant coefficients (non-homogeneous case), discussion of several special cases to obtain particular solutions, solution of linear recurrence relations using generating functions.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. C. L. Liu, *Elements of Discrete Mathematics*, Second Edition, McGraw Hill 1985.
2. J. L. Mott, A. Kandel and T. P. Baker, *Discrete Mathematics for Computer Scientists and Mathematicians*, Prentice Hall India, 2nd Ed., 1986.
   - Unit-I: Chapter 1 [Liu]
   - Unit-II: Chapter 3, 5 [Liu]
   - Unit-III: Chapter 4 [Liu]
   - Unit-IV: Chapter 9, 12 [Liu]
   - Unit-V: Chapter 10 [Liu]

References:

1. F. Harary, *Graph Theory*, Narosa, 1969.
2. H. C. Thomas, C. E. Leiserson, R. L. Rivest and C.Stein, *An Introduction to Algorithms*, MIT Press and McGraw-Hill, 2nd Ed., 2001.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50%
End Semester Weightage							50%
Total							100%

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EE	**Numerical Solutions to Partial Differential Equations**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Understand the finite difference schemes (FDS), order of accuracy of scheme	**a**				
2.	Exposure to concept of stability convergence dissipation and dispersion	**a**				
3.	Be exposed to FDS for hyperbolic, parabolic and elliptic PDE's	**a**				

Unit-I: Linear stability and convergence
Introduction to hyperbolic PDE's, finite difference schemes, convergence and consistency, CFL number and Fourier and Von Neumann stability analysis for FDS.

Unit-II: Dissipation and dispersion
Order of accuracy of LxW and Crank-Nicolson finite difference schemes boundary condition, Thomas algorithm, dissipation and dispersion.

Unit-III: Parabolic PDE's
Parabolic systems and boundary conditions, finite difference schemes for parabolic and convection diffusion equations, ADI scheme on square, boundary conditions and stability for ADI schemes.

Unit-IV: Well-posed systems and estimations
The theory of well-posed IVPs scalar and systems, convergence estimates for smooth and non-smooth initial conditions, convergence estimate for parabolic differential equations, Lax-Richmyer equivalence theorem, well-posed and stable initial BVP, matrix method for stability.

Unit-V: Elliptic PDE's
Elliptic equations and regularity estimates, maximum principle and boundary condition, finite difference schemes for Poisson's equation.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J. W. Thomas, *Numerical Partial Differential Equations: Finite Difference Methods*, Springer, 1998.
2. J. C.Strikwerda, *Finite Difference Schemes and Partial Differential Equations*, SIAM, Philadelphia, 2nd Ed., 2004.

- Unit-I: Chapter 1, 2 [Strikwerda]
- Unit-II: Chapter 3: Sec. 3.1-3.5, Chapter 4: Sec. 4.1-4.2, Chapter 5: Sec. 5.1-5.3 [Strikwerda]
- Unit-III: Chapter 6: Sec. 6.2-6.4, Chapter 7: Sec. 7.2-7.3 [Strikwerda]
- Unit-IV: Chapter 9: Sec. 9.1-9.2, Chapter 10: Sec. 10.1-10.5, Chapter 11: Sec. 11.1-11.2, Chapter 11: Sec. 11.5 [Strikwerda]
- Unit-V: Chapter 12: Section 12.1-12.5 [Strikwerda]

References:

1. R.J. Leveque, *Finite Difference Methods for Ordinary and Partial Differential Equations, Steady State and Time Dependent Problems*, SIAM Philadelphia, 2007.
2. G. D. Smith, *Numerical Solution of Partial Differential Equations: Finite Difference Methods*, Oxford University press, 1977.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EF	**Introduction to Statistical Learning**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Introduction to statistical method data analysis	**a**				
2.	Well versed with supervised and unsupervised learning	**a**				
3.	Exposure to data problem in practice	**a**				

Unit-I: Supervised learning
Overview of linear regression (LR), and statistical learning, supervised learning, variable types and simple approaches for predication, statistical models, classes of restricted estimates.

Unit-II: Linear methods for regression and classifications
Linear methods for regression, LR models and least square, subset selection and coefficient shrinkage, linear methods for classifications, indicator matrix, separating hyper planes.

Unit-III: Regularizations and smoothing
Basis expansions and regularizations, piecewise polynomial and splines, filtering and feature extraction, spline smoothening, wavelet smoothing, Kernel smoothers, local regression in R^p, Local likelihood and other models, radial basis functions and kernels.

Unit-IV: Model assessment and selection
Model assessment and bias, model complexity, optimism of training error rate, minimum description length, bootstrap and maximum likelihood methods, the EM algorithm.

Unit-V: Unsupervised learning
Unsupervised learning, association rules, market basket example and analysis, cluster analysis, proximity matrices, algorithms, self-organizing maps, principal components, curves and surfaces, non-negative matrix factorization.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J. H. Friedman, R. Tibshirani and T. Hastie, *The Elements of. Statistical Learning: Data Mining, Inference, and Prediction*, Springer, 2nd Ed., 2009.
2. E.Kreyszig, *Advanced Engineering Mathematics*, Wiely, 8th Ed., 1998.
   - Unit-I: Chapter 2 [Friedman] & Sec. 23.9 [Kreyszig]
   - Unit-II: Chapter 3, 4[Friedman]
   - Unit-III: Chapter 5, 6[Friedman]
   - Unit-IV: Chapter 7: Sec. 7.1-7.8; Chapter 8:Section 8.1-8.5 [Friedman]
   - Unit-V: Chapter 14:Sec. 14.1-14.6 [Friedman]

References:

1. B. Siegmund, *Data Analysis: Statistical and Computational Methods for Scientists and Engineers*,Springer, 4th Ed., 2014.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3EG	**Introduction to Mathematical Finance**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To familiarize with application of mathematics in finance	**a**				
2.	Exposure to Black-Scholes equation, portfolio management	**a**				
3.	To understand the concept of arbitrage and hedging	**a**				

Unit-I: Fundamentals of the financial markets
Fundamentals of the financial markets, meaning of notions like asset portfolio derivatives (example: futures, options forwards etc.).

Unit-II: Asset pricing model
Binomial asset pricing model under no arbitrage condition single-period model, multi-period model. Risk-neutral probabilities, martingales in the discrete framework, risk-neutral valuation of European and American options under no arbitrage condition in the Binomial framework.

Unit-III: Black-Scholes formula
Random walk and Brownian motion, Geometric Brownian motion, Black-Scholes formula, properties of Black-Scholes option cost, estimation of sigma, pricing American put option and European call option.

Unit-IV: Portfolio management
Risk, risk and expected return on a portfolio, capital asset pricing model: capital market line, beta factor and security market line.

Unit-V: Arbitrage:
Arbitrage theorem, multi-period binomial model, hedging: delta hedging, Greek parameters, hedging business risk, value at risk, speculating with derivatives.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. S. M. Ross, *An Introduction to Mathematical Finance*, Cambridge University Press, 1999.
2. M Capinski and T. Zastawniak, *Mathematics for Finance: An Introduction to Financial Engineering*, Springer-Verlag, London, 2003.

- Unit-I: Chapter 5 [Ross]
- Unit-II: Chapter 4 [Capinski]
- Unit-III: Chapter 3, Chapter 7 [Ross]
- Unit-IV: Chapter 5 [Capinski]
- Unit-V: Chapter 6 [Ross]; Chapter 9 [Capinski]

References:

1. D. G. Luenberger, *Investment Science*, Oxford University Press, NY, 1998.
2. J. C. Hull, Options, *Futures and Other Derivatives*, Prentice Hall Inc., Upper Saddle River, 4th Ed., 2000.
3. D Lamberton and B Lapeyre, *Introduction to Stochastic Calculus Applied to Finance*, Chapman and Hall, London, 1996.
4. M. V. Tretyakov, *Introductory Course on Financial Mathematics*, Imperial College Press, 2013.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Semester-IV

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA401	Functional Analysis	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Be thorough with continuous linear transformations and related theorems.	a				
2.	Familiarity with Banach and Hilbert spaces and their properties	a				
3.	Exposure to spectral theorem	a				

Unit-I: Algebraic systems
Linear spaces and dimension of spaces, linear transformations andlinear operators, algebras, normed linear spaces, definition of Banach spaces with examples.

Unit-II: Banach spaces
Continuous linear transformations, The Hahn-Banach theorem, natural imbedding of a space into its second conjugate space, open mapping theorem, closed graph theorem, conjugate of an operator, Banach Steinhaus's uniform boundedness theorem.

Unit-III: Hilbert spaces
Inner product spaces, definition and properties, Schwarz inequality and theorems, orthogonal complements, orthonormal sets, Bessel's inequality, complete orthonormal sets, conjugate space H***.**

Unit-IV: Operators on Hilbert spaces
Adjoint of an operator, self- adjoint operators, normal and unitary operators, projections.

Unit-V: Finite dimensional spectral theory
Matrices representation of operators, determinants and the spectrum of an operator, the spectral theorem.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata McGraw-Hill International Ed.2004, Fourteenth reprint 2010.
2. M. T. Nair, *Functional Analysis: A First Course*, PHI-Learning (Formerly: Prentice-Hall of India), New Delhi, 2002.

- Unit-I: Chapter 8: Sec.42, 43, 44, 45[Simmons]; Chapter 9: Sec. 46 [Simmons]
- Unit-II: Chapter 9: Sec. 47, 48, 49, 50, 51[Simmons]
- Unit-III: Chapter 10: Sec. 52, 53, 54, 55[Simmons]
- Unit-IV: Chapter 10: Sec. 56,57,58,59[Simmons]
- Unit-V: Chapter 11: Sec. 60,61, 62[Simmons]

References:

1. E.Kreyszig, *Introductory Function Analysis with Applications*, John Wiley and Sons, 2010.
2. W. Rudin, *Functional Analysis*, TMH Edition, 2006.
3. B. V. Limaye, *Functional Analysis*, New Age International, 2^{nd} Ed., 1996.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA402	**Integral Equations and Transform Techniques**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Be thorough with linear integral equation and solution tools	**a**				
2.	Familiarity with Laplace transformation, properties and applications	**a**				
3.	Familiarity with Fourier transformation, properties and applications	**a**				

Unit-I: Linear integral equations
Linear integral equations of 1st and 2nd kinds: Fredholm and Volterra types relation between integral equations and initial boundary value problems, existence and uniqueness of continuous solutions of Fredholm and Volterra's integral equations of second kind, solution by the method of successive approximations, iterated kernels, separable kernels, resolvent kernels.

Unit-II: Volterra and Fredholm integral equations
Volterra's solution of Fredholm's integral equation, Fredholm theory for the solution of Fredholm's integral equation, Fredholm's determinant $D(\lambda)$, Fredholm's first minor $D(x,y,\lambda)$,Fredholm's first and second fundamental relations, Fredholm's p-thminor, Fredholm's first, second and third fundamental theorems, Fredholm's alternatives.

Unit-III: Fourier transforms
Fourier integral theorem, definition and properties, Fourier transform of the derivatives, derivative of Fourier transform, Fourier transforms of some useful functions, Fourier cosine and sine transforms, inverse of Fourier transforms, convolution, properties of convolution function, convolution theorem, applications.

Unit-IV: Laplace transforms
Definition and properties, sufficient conditions for the existence of Laplace transform. Laplace transform of some elementary functions. Laplace transform of the derivatives, inverse of Laplace transform, Bromwich integral theorem, initial and final value theorems, convolution theorem, applications.

Unit-V: Z transformation
Definition of the Z transform and examples, basic operational properties of Z transforms, inverse Z transform and examples, applications of Z transforms to finite difference equations.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.
Textbooks:

1. M. Rahman, *Integral Equations and their Applications*, WIT Press, 2007.
2. L. Debnath and D.Bhatta, *Integral Transforms and Their Applications*, Chapman and Hall/CRC, 2014.

- Unit-I: Chapter 1 and 2 [Rahman]
- Unit-II: Chapter 3 [Rahman]
- Unit-III: Chapter 7 [Rahman]
- Unit-III: Chapter 2 [Debnath and Bhatta]
- Unit-IV: Chapter 3 and 4 [Debnath and Bhatta]
- Unit-V: Chapter 12, Sec. 12.1-12.6 [Debnath and Bhatta]

References:

1. I. N. Sneddon, *The Uses of Integral Transforms*, McGraw-Hill, New York, 1972.
2. I. N. Sneddon, *Fourier Transforms*, Dover Publications, 1995.
3. W. V. Lovitt, *Linear Integral Equations*, Dover Publications, 2005.
4. F. G. Tricomi, *Integral Equations*, Interscience Publishers, New York, 1985.
5. L. C. Andrews and B. K. Shivamoggi, *Integral transforms for Engineers*, SPIE Press, 1999.
6. S. L. Ross, *Differential Equation*, John Wiley and Sons Inc., 3rd Ed., 2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Major Electives–II

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4EA	Dynamical Systems	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To understand the concepts of well-posedness of differential equations	a				
2.	Familiarity with Bifurcations in 1Dand 2D flows, introduction to chaos	a				
3.	Exposure to Stability analysis	a				

Unit-I: Mathematical preliminaries
Open and closed sets, compact set, dense set, continuity of functions, Lipschitz condition, smooth functions, vector space, normed linear space, inner product space, well-posedness of ordinary differential equations, Lipschitz continuity and contraction mapping theorem.

Unit-II: One-dimensional flows
Fixed points and stability, linear stability analysis, saddle- node bifurcation, transcritical bifurcation, pitchfork bifurcation, flows on the circle.

Unit-III: Two-dimensional flows
Linear systems, nonlinear autonomous systems, phase portraits, fixed points and linearization, conservative systems, index theory, limit cycles, Poincare Bendixson theorem, Bendixson's criteria, Lienard systems.

Unit-IV: Lyapunov stability
Variable gradient method, LaSalle's invariance property, transcritical and pitchfork bifurcations, Hopf bifurcation, Poincare maps.

Unit-V: Chaos:
Introduction to chaos and attractors.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. S. H. Strogatz, *Nonlinear Dynamics and Chaos*, Perseus books publishing, 1994.
2. H. J. Ricardo, *A Modern Introduction to Differential Equations*, Academic Press, 2nd Ed., 2009.
3. H. K. Khalil, *Nonlinear Systems*, PHI, 1996.
   - Unit-I: Chapter 1 [Ricardo]
   - Unit-II: Chapter 2, Chapter 3, Sec. 3.0-3.4, Chapter 4 [Strogatz]
   - Unit-III: Chapter 5, Chapter 6, Sec. 6.1-6.6, Chapter 7, Sec. 7.0-7.4 [Strogatz]
   - Unit-IV: Chapter 4, Sec. 4.1-4.2 [Khalil]; Chapter 8: Sec. 8.0-8.3, 8.7 [Strogatz]
   - Unit-V: Chapter 9, Sec. 9.0-9.4 [Strogatz]

References:

1. S. Wiggins, *Introduction to Applied Nonlinear Dynamical Systems and Chaos*, Springer, 1996.
2. J. D. Meiss, *Differential Dynamical Systems*, SIAM, 2007.
3. R. Grimshaw, *Nonlinear Ordinary Differential Equations*, Blackwell Scientific Publications, 1990.
4. K. Alligood, T. Sauer and James A. Yorke, *Chaos: An Introduction to Dynamical Systems*, Springer-Verlag, 1996.
5. M. Tabor, *Chaos and Integrability in Non-linear Dynamics*, Wiley-Blackwell, 1989.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4EB	Applied Functional Analysis	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Be thorough with the theory of distributions, weak derivatives	a				
2.	Familiarly with Sobolev spaces and their properties	a				
3.	Exposure to Lax-Milgram and Eigen value problems	a				

Unit-I: Distribution theory
Lebesgue integrals, Lebesgue space, distributions and weak derivatives, mollifiers, convolution of distributions, Schwartz space, tempered distributions.

Unit-II: Sobolev spaces
Introduction to Sobolev spaces, imbedding theorems, Sobolev's inequality, variations of Sobolev's inequality, Rellich's lemma.

Unit-III: Dual spaces and trace theory
Compactness theorems, dual spaces, fractional order spaces, trace theory**.**

Unit-IV: Theory of weak solutions
Weak formulation, Lax-Milgram lemma, existence and regularity of weak solutions**.**

Unit-V: Elliptic boundary value problems
Weak solutions of second order elliptic equations on bounded and unbounded domains, maximum principle, eigenvalue problems.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. S. Kesavan, *Topics in Functional Analysis and Applications*, New Age International Publishers, 2008.
2. L. C. Evans, *Partial Differential Equations*, American Mathematical Society, 2009.
    - Unit-I: Chapter 1 [Kesavan]
    - Unit-II, III: Chapter 2 [Kesavan] and Chapter 5 [Evans]
    - Unit-IV, V: Chapter 3 [Kesavan]

References:

1. R. A. Adams and J. J. F. Fournier, *Sobolev Spaces*, Academic Press, 2005.
2. H. Brezis, *Functional Analysis, Sobolev Spaces and Partial Differential Equations*, Springer, 2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50%
End Semester Weightage							50%
Total							100%

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4EC	**Non-linear Partial Differential Equations**	3	1	-	1	4	4

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Understand first order non-linear equations and method of characteristics	a				
2.	Be thorough with boundary value problems using Fourier transforms	a	e			
3.	Be exposed to conservation laws and shock waves and their solutions	a	e			

Unit-I: First order linear PDE
First order PDE, linear equations of first order, Charpit's method, Jacobi's method, quasi-linear equations.

Unit-II: First-order non-linear PDE
First-order nonlinear equations and their applications, the generalized method of characteristics, complete integrals of certain special nonlinear equations, the Hamilton-Jacobi equation and its applications.

Unit-III: Second-order linear PDE
Second-order linear equations and method of characteristics, the method of separation of variables, Fourier transforms and initial boundary value problems**.**

Unit-IV: Second-order non-linear PDE
Non-linear model equations and variational principles, basic concepts and definitions, some nonlinear model equations,variational principles and the Euler-Lagrange equations, the variational principle for nonlinear Klein-Gordon equations.

Unit-V: Conservation laws:
Conservation laws and shock waves, conservation laws, discontinuous solutions and shock waves, weak or generalized solutions.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. T. Amaranath, *An Elementary Course in Partial Differential Equations*, Narosa Publications, 2008.
2. Lokenath and Debnath, *Nonlinear Partial Differential Equations for Scientists and Engineers*, Springer, 2nd Ed., 2005.

- Unit-I: Chapter 1: Sec. 1.1, 1.10 [Amaranath]; Chapter 1: Sec. 1.7-1.8, 1.10-1.11 [Lokenath]
- Unit-II: Chapter 4: Sec. 4.1- 4.4 [Lokenath]
- Unit-III: Chapter 1: Sec.1.5-1.7 [Lokenath]
- Unit-IV: Chapter 2: Sec.2.1- 2.5[Lokenath]
- Unit-V: Chapter 5: Sec. 5.1-5.4[Lokenath]

References:

1. K. S. Rao, *Introduction to Partial Differential Equations*, Prentice Hall India, 2006.
2. J. D. Logan, *An Introduction to Non-linear Partial Differential Equations*, John Wiley and Sons, 2010.
3. L. C. Evans, *Partial Differential Equations*, Vol.19, American Mathematical Society, 2nd Ed., 2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4ED	**Graph Theory**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	Be familiar with graphs and subgraphs	**a**				
2.	Be exposed to connectivity and cycles	**a**	**e**			
3.	Be thorough with matchings and colorings	**a**	**e**			
4.	Understand fully the planar graphs and the color theorems	**a**	**e**			

Unit-I: Graphs, subgraphs and trees
Graphs and simple graphs, graph isomorphism, the incidence and adjacency matrices, sub-graphs, vertex degrees, paths and connection, cycles, trees, cut edges and bonds, cut vertices.

Unit-II: Connectivity
Euler tours and Hamilton cycles: connectivity, blocks, Euler tours, Hamilton cycles.

Unit-III: Matchings and edge colorings
Matchings, matchings and coverings in bipartite graphs, edge chromatic number, Vizing's theorem.

Unit-IV: Independent sets and cliques
Vertex colorings: independent sets, Ramsey's theorem, chromatic number, Brook's theorem, chromatic polynomials.

Unit-V: Planar graphs
Plane and planar graphs, dual graphs, Euler's formula, the five-color theoremand the four-color conjecture.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J.A.Bondy and U.S.R. Murty, *Graph Theory*, Springer-Verlag London, 2008.
2. J. Clark and D. A. Holton, *A First look at Graph Theory*, Allied Publishers, New Delhi, 1995.
    - Unit-I:Chapter 1, Sec. 1.1, 1.7, Chapter 2, Sec. 2.1, 2.3 [Bondy]
    - Unit-II: Chapter 3, Sec. 3.1, 3.2, Chapter 4, Sec. 4.1, 4.2 [Bondy]
    - Unit-III: Chapter 5, Sec. 5.1, 5.2, Chapter 6 Sec. 6.1, 6.2 [Bondy]
    - Unit-IV: Chapter 7, Sec. 7.1, 7.2, Chapter 8, Sec. 8.1, 8.2, 8.4 [Bondy]
    - Unit-V: Chapter9, Sec. 9.1, 9.3, 9.6 [Bondy]

References:

1. R. Gould, *Graph Theory*, Dover Publications, Reprint Edition, 2012.
2. A.Gibbons, *Algorithmic Graph Theory*, Cambridge University Press, Cambridge, 1999.
3. R.J. Wilson, *Introduction to Graph Theory*, Pearson Education, 4th Ed., 2004(Indian Print).
4. S.A.Choudum, *A First Course in Graph Theory*, MacMillan India Ltd., 2000.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4EE	**Introduction to Functional Data Analysis**	**3**	**1**	-	**1**	**4**	**4**

Instructional objectives At the end of this course the learner is expected:		**Student Outcomes**				
1.	Exposure to functional data, some mathematical tools for functional data	**a**				
2.	Well versed with principal and regularized component analysis of functional data	**a**				
3.	Familiarity with differential equations and FDA	**a**				

Unit-I: Functional data and functions
Overview of functional data analysis, mathematics and statistics for functional data, anatomy of function, phase plane plot, properties of functional data, representing functions by basis functions, useful basis systems.

Unit-II: Smoothing functional data by least squares and penalty
Smoothing functional data by least square and roughness penalty method, fitting data using basis system by least square, performance assessment, computing sampling variances and confidence limits, fitting data by localized least squares, spline smoothing, choosing the smoothing parameter, confidence intervals for function valuesand functional probes.

Unit-III: Constrained functions and registration
Constrained functions, fitting positive and strictly monotone functions, fitting probability function and probability density function, registration and display of functional data, computational details, defining functional.

Unit-IV: Principal component analysis
Principal component analysis(PCA), visualizing the results, computational methods for PCA, regularized principal component analysis, smoothing and alternative approaches, general PCA for mixed data.

Unit-V: Data to differential equations
Derivatives and functional linear models, differential equations and operators, principal differential analysis.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J. O. Ramsay and B. W. Silverman, *Functional data analysis*, Springer, NY, 2nd Ed.,2005.
   - Unit-I: Chapter 1-3
   - Unit-II: Chapter 4-5
   - Unit-III: Chapter 6-7
   - Unit-IV:Chapter 8-10
   - Unit-V:Chapter 17-20

References:

1. J. O. Ramsay and B. W. Silverman, *Applied Functional Data Analysis: Methods and Case Studies*, Springer series in statistics, New York, London: Springer, 2002.
2. C. Gu, *Smoothing Spline ANOVA Models*, New York, Springer, 2016.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA4EF	**Formal Languages and Automata Theory**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	Be familiar with a machine language	**a**				
2.	To study in regular grammar and context-free grammar	**a**				
3.	Get exposed to compiler design	**a**				

Unit I: Finite automata
Regular expressions and regular grammars: finite state systems, basic definitions, non-deterministic finite automata, finite automata with ϵ moves, regular expressions, regular grammars.

Unit II: Properties of regular sets
The pumping lemma for regular sets, closure properties of regular sets, decision algorithms for regular sets, the Myhill-Nerode theorem and minimization of finite automata.

Unit III: Context-free grammars
Motivation and introduction, context-free grammars, derivation trees, simplification of context-free grammars, Chomsky normal form, Greibach normal form.

Unit IV: Push-down automata
Informal description, definitions, push-down automata and context-free languages.

Unit V: Properties of Context-free languages
Pumping lemma for CFL's, closure properties for CFL's.

Tutorials: Tutorial sheets with relevant problems will be provided by the instructor.

Textbooks:

1. J. E. Hopcraft and J. D. Ullman, *Introduction to Automata Theory, Languages and Computation*, Narosa Publishing House, New Delhi, 1989.
   - Unit-I: Chapter 2: Sec.2.1, 2.5; Chapter 9: Sec. 9.1
   - Unit-II: Chapter 3: Sec. 3.1, 3.4
   - Unit-III: Chapter 4: Sec. 4.1, 4.6
   - Unit-IV: Chapter 5: Sec. 5.1, 5.3
   - Unit-V: Chapter 6: Sec. 6.1, 6.2 (Ogden's lemma in section 6.1 is not included)

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Non Major Electives

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA2NA	**Numerical Methods using C++**	**2**	**-**	-	**-**	**2**	**2**

Instructional objectives At the end of this course the learner is expected:		**Student Outcomes**				
1.	To expose the students to various tools in solving numerical problems	**a**				
2.	To enable the students to apply these methods in a computer environment	**a**				

Unit I: Introduction to C++
Variables, input and output, if statement, logical operators, nested if and switch statements, for statements, while statement, arrays, pointers, library functions, user defined functions.

Unit II: Systems of linear equations
Gauss-elimination method, pivoting, Guass-Jordan elimination method, Guass-Seidal iteration method.

Unit III: Non-linear equation and interpolation
Bisection method, Newton's method, interpolation, Newton's divided difference formula, Lagrange's interpolation, Newton's forward and backward difference formula.

Unit IV: Differentiation and integration
Numerical differentiation, numerical integration, Newton Cotes method, Trapezoidal rule, Simpson's rule.

Unit V: Ordinary differential equations
Initial value problems, Euler's method, Runge-Kutta method, Boundary value problems.

References:

1. J. M. Ortega and A. S. Grimshaw, *An Introduction to C++ and Numerical Methods*, Oxford university press, NY, 1999.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods For Scientific and Engineering Computation*, New age international publishers, 6th Ed., 2007.
3. E. Balagurusamy, *Object Oriented Programming with C++*, Tata McGraw Hill, 1996.
4. C. E. Froberg, *Introduction to Numerical Analysis*, Addison-Wesley, 2nd Ed., 1972.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA2NB	Introduction to Differential Equations	2	-	-	-	2	2

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To understand the concepts of ordinary and partial differential equations	a				
2.	To familiarize with boundary value problems	a	e			
3.	To learn the qualitative analysis of differential equations	a	e			

Unit I: Ordinary differential equations
Second and higher order linear ODE, Homogeneous linear equations with constant and variable coefficients, non-homogeneous equations, solutions by variation of parameters.

Unit II: Partial differential equations
Formation of PDE by elimination of arbitrary constants and functions, solutions, general and singular solutions, Lagrange's linear equations, linear PDE of second and higher order with constant coefficients.

Unit III: Boundary value problems
Classification of PDEs, solutions by separation of variables, one dimensional heat and wave equation.

Unit IV: Systems of differential equations
Phase plane, stability, introduction to vector and matrices, introductory examples, basic concepts and theory, homogeneous linear systems with constant coefficients.

Unit V: Non-linear systems
Phase plane, critical points, stability, phase plane methods for non-linear systems, non-homogeneous linear systems.

References:

1. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publishers, New Delhi, 38th Ed., 2004.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, Singapore, 8th Ed., 2000.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3NA	Applied Mathematics	2	-	-	-	2	2

Instructional objectives At the end of this course the learner is expected:		Student Outcomes				
1.	To expose the students to the concepts of functions of several variables	a				
2.	To familiarize with Fourier series	a				
3.	To give the insight of complex integration and residue theory	a				

Unit-I: Functions of several variables
Partial derivatives, total differential, Taylor's expansions, maxima and minima of functions, differentiation under integral sign.

Unit-II: Fourier series
Dirichlet conditions, general Fourier series, half range sine and cosine series, Parseval's identity, harmonic analysis.

Unit-III: Fourier integrals
Fourier integral theorem, Fourier transform pairs, Fourier sine and cosine transforms, properties, transform of simple functions, convolution theorem, Z-transforms.

Unit-IV: Complex integration
Line integrals in the complex plane, two integration methods, Cauchy's integral theorem, existence of indefinite integral, Cauchy's integral formula, and derivatives of analytic functions.

Unit-V: Residue integration method
Residues, residue theorem, evaluation of real integrals, further type of real integrals.

References:

1. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, Singapore, 8th Ed., 2000.
2. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publishers, New Delhi, 38th Ed., 2004.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**

Course Code	Course Title	L	T	P	O	L+T+P	C
18PMA3NB	**Bio-Mathematics**	**2**	**-**	-	**-**	**2**	**2**

Instructional objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1.	To introduce mathematics as a tool in the study of Biology	**a**				
2.	Be familiar with graphs and subgraphs	**a**				

Unit-I: Determinants
Properties of determinants, minors, cofactors, multiplication of determinants, matrices, operations on matrices, inverse of matrices, solution of simultaneous equations.

Unit-II: Permutation and combination
Identities and simple problems, binomial theorem, exponential and logarithmic series (statement only), simple problems, basic ideas of graph theory, connectivity, trees, various matrices connected with graphs, construction of evolutionary trees, phylogeny construction.

Unit-III: Differential calculus
Limits, differentiation, successive differentiation, maxima and minima, simple problems, integration of $f(x) = x^n$,e^x, $\log x$, definite integrals

Unit-IV: Concepts of computers and flowcharts
Fundamentals of computers, algorithms, flowcharts, introduction to systems and application programs, concept of data processing and handling of file for large volume of data, elements of database management in connection with biological databases.

Unit-V: Introduction to programming languages
C-programming and internet programming fundamentals, specific features of image analysis in Java, software characteristics and applications, ClustalWVI.7, Rasmol, Oligo, Molscript, Tree view, ALSCRIPT, Genetic analysis software, Phylip.

References:

1. S. Narayan and T. K. M. Pillai., *Calculus*, Vol I, S. Viswanathan printers, 1996.
2. T. K. M. Pillai, T. Natarajan and K. S. Ganapathy, *Algebra*, Vol I, S. Viswanathan printers and publishers, 1994.
3. D. W. Mount, *Bioinformatics: Sequence and Genome Analysis*, Cold Spring Harbor Laboratory Press, New York.
4. D. C. Liebler, *Introduction to Proteomics: Tools for New Biology*, Humana Press, Totowa, NJ., 2002
5. S. Pennington and M .J. Dunn, *Proteomics: From Protein Sequence to Function*, Springer publications, 2001.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	**Assessment Tool**	**Cycle Test I**	**Cycle Test II**	**Model Examination**	**Assignment**	**Attendance**	**Total**
	Marks	**10**	**10**	**20**	**5**	**5**	**50%**
End Semester Weightage							**50%**
Total							**100%**