

**MASTER OF SCIENCE**

**IN**

**MATHEMATICS**

**CURRICULUM AND SYLLABUS**

**(For students admitted from academic year 2017-2018 onwards)**

**UNDER CHOICE BASED CREDIT SYSTEM**



**DEPARTMENT OF MATHEMATICS**

**FACULTY OF SCIENCE AND HUMANITIES**

**SRM INSTITUTE OF SCIENCE AND TECHNOLOGY**

**SRM NAGAR, KATTANKULATHUR – 603 203.**

**M.Sc. MATHEMATICS (For students admitted from the academic year 2017-2018 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.

**Duration:**

2 Years (4 semesters)

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## CURRICULUM

M. Sc. (Mathematics)

Total credits: 82

As per UGC (Credit Framework for Online Learning Courses through SWAYAM) Regulation 2016, SRM Institute of Science and Technology strongly encourages the use of SWAYAM (Study Web of Active Learning by Young and Aspiring Minds) platform. Based on the availability of relevant courses on SWAYAM, students shall choose an online course on the recommendation of faculty advisor and the credits will be transferred.

### SEMESTER - I

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	17PMA101	Real Analysis	3	1	-	1	4	4
Major Core	17PMA102	Linear Algebra	3	1	-	1	4	4
Major Core	17PMA103	Ordinary Differential Equations	3	1	-	1	4	4
Major Core	17PMA104	Numerical Analysis	3	1	-	1	4	4
Major Core	17PMA105	Introduction to Scientific Programming in C/Matlab/Python	2	-	6	-	8	5
<b>Total</b>			<b>14</b>	<b>4</b>	<b>6</b>	<b>4</b>	<b>24</b>	<b>21</b>

### SEMESTER - II

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	17PMA201	Algebra	3	1	-	1	4	4
Major Core	17PMA202	Complex Analysis	3	1	-	1	4	4
Major Core	17PMA203	Partial Differential Equations	3	1	-	1	4	4
Major Core	17PMA204	Probability and Statistics	3	1	-	1	4	4
Non Major Elective-I		Open Elective-I	2	-	-	-	2	2
Seminar	17PMA205	Seminar*(Based on recent research articles)	-	-	2	-	2	1
<b>Total</b>			<b>14</b>	<b>4</b>	<b>2</b>	<b>4</b>	<b>20</b>	<b>19</b>

**SEMESTER - III**

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	17PMA301	Topology	3	1	-	1	4	4
Major Core	17PMA302	Operations Research	3	1	-	1	4	4
Major Core	17PMA303	Calculus of Variations and Mechanics	3	1	-	1	4	4
Project Work -1	17PMA304	Project Phase I* (Research and seminar)	-	-	8	-	8	4
Major Elective -I	17PMA3EA	Multivariate Calculus	3	1	-	1	4	4
	17PMA3EB	Fuzzy Sets and Applications						
	17PMA3EC	Fluid Dynamics						
	17PMA3ED	Discrete Mathematics						
	17PMA3EE	Numerical Solutions to Partial Differential Equations						
	17PMA3EF	Introduction to Statistical Learning						
	17PMA3EG	Introduction to Mathematical Finance						
Non Major Elective-II		Open Elective-II	2	-	-	-	2	2
<b>Total</b>			<b>14</b>	<b>4</b>	<b>8</b>	<b>4</b>	<b>26</b>	<b>22</b>

**SEMESTER - IV**

Category	Course Code	Course Name	L	T	P	O	Total of L+T+P	Credit
Major Core	17PMA401	Functional Analysis	3	1	-	1	4	4
Major Core	17PMA402	Integral Equations and Transformation Techniques	3	1	-	1	4	4
Project Work-2	17PMA403	Project Phase-II (Research and seminar)	-	-	16	-	16	8
Major Elective-II	17PMA4EA	Dynamical Systems	3	1	-	1	4	4
	17PMA4EB	Applied Functional Analysis						
	17PMA4EC	Non-Linear Partial Differential Equations						
	17PMA4ED	Graph Theory						
	17PMA4EE	Introduction to Functional Data Analysis						
	17PMA4EF	Formal Languages and Automata Theory						
<b>Total</b>			<b>9</b>	<b>3</b>	<b>16</b>	<b>3</b>	<b>28</b>	<b>20</b>
<b>Total number of credits to be earned for the award of degree</b>			<b>82</b>					

Note:

\* Continuous assessment [Full Internal]

L=Lecture hours, T=Tutorial hours, P= Practical hours, O= Outside class and C=Credits

<b>Guidelines for selecting course</b>				
<b>Category</b>	<b>No. of Courses</b>			
	<b>I Semester</b>	<b>II Semester</b>	<b>III Semester</b>	<b>IV Semester</b>
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
<b>Total number of credits</b>				<b>82</b>

**Non Major Electives (Offered to the other departments)**

1. **17PMA2NA:** Numerical Methods using C++
2. **17PMA2NB:** Introduction to Differential Equations
3. **17PMA3NA:** Applied Mathematics
4. **17PMA3NB:** Bio-Mathematics

**SYLLABUS  
SEMESTER - I**

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA101	Real Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Introduction to real number system, sequence and series. 2. Familiarity with function of several variables. 3. Exposure to Riemann integration and Improper integrals.							

**Unit-I: Real number systems**

Elementary set theory, 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: Differentiation and integration**

Limit, continuity, uniform continuity, differentiability, mean value theorem, Riemann sums and Riemann integral, Riemann-Stieltjes integral and its properties, improper integrals.

**Unit-III: Sequences and series**

Sequences and series of functions, convergence, uniform convergence, power series, Fourier series.

**Unit-IV: Multi-variable calculus**

Functions of several variables, directional derivatives, partial derivatives, derivative as a linear transformation, inverse and implicit function theorems, maxima and minima.

**Unit-V: Metric spaces and properties**

Basic concepts, continuous functions, completeness, Baire category theorem, contraction mapping theorem, connectedness, intermediate value theorem, compactness, Weierstrass approximation theorem.

**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 1, 2 [Rudin].
  - Unit-II: Chapter 4-6 [Rudin]
  - Unit-III: Chapter 7, 8 [Rudin]
  - Unit-IV: Chapter 9 [Rudin]
  - Unit-V: Chapter 1, Chapter 4, Sec 4.7, 4.11-5 [Kreyszig]

**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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA102	Linear Algebra	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To be thorough with the fundamental concepts of matrices and determinants. 2. Familiarity with the operators in the finite dimensional inner product spaces. 3. To understand the different canonical forms.							

#### 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 orthonormalization process, self-adjoint operators, quadratic forms.

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

#### Textbooks:

- G. Strang, *Introduction to Linear Algebra*, Wellesley-Cambridge Press, 1993.
- K. Hoffman and R. Kunze, *Linear Algebra*, 2<sup>nd</sup> 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:

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

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA103	Ordinary Differential Equations	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand the concept of well posed differential equation. 2. To study Green's functions, Sturm-Liouville type problems. 3. Exposure to solve system of ODE.							

#### Unit-I: Existence and uniqueness of solutions

Review of exact solutions of first order ODE, method of successive approximations, Lipschitz condition, convergence of successive approximations, existence and uniqueness of solutions of IVP, non-local existence of solutions, existence and uniqueness of solutions to systems, existence and uniqueness of solutions to linear systems, equations of order  $n$ .

#### 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,

#### Unit-IV: Series solutions

Series solution of second order linear equations: ordinary points, regular singular points, Sturm-Liouville problems, Green's functions, 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, *An Introduction to Ordinary Differential Equations*, PHI Learning 1999.
2. G. F. Simmons, *Differential Equations with Applications and Historical Notes*, 2<sup>nd</sup> Ed, McGraw- Hill, 1991.
3. R. P. Agarwal and D. O'Regan, *An Introduction to Ordinary Differential Equations*, Springer- Verlag, 2008.
  - Unit-I: Chapter 2: Sec. 7-11 [Simmons]; Chapter 5 [Coddington], Chapter 6: Sec. 6-8 [Coddington]
  - Unit-II: Chapter 3: Sec. 14-19 [Simmons]
  - Unit-III: Chapter 4 [Simmons]
  - Unit-IV: Chapter 5: Sec. 26-30, Chapter 7: Sec-43 [Simmons]; Lecture33 [Agarwal and O'Regan]  
Chapter 8: Sec. 44-47 [Simmons]
  - Unit-V: Chapters 25, 26 [Agarwal and O'Regan]

#### References:

1. G. Birkhoff and G. -C. Rota, *Ordinary Differential Equations*, John Willey and Sons, 4<sup>th</sup> Ed., 1989.
2. R. P. Agarwal and R. C. Gupta, *Essentials of Ordinary Differential Equations*, McGraw-Hill, 1993.
3. M. Braun, *Differential Equations and Their Applications*, 3<sup>rd</sup> Ed., Springer-Verlag, 1983.
4. S. G. Deo, V. Raghavendra, R. Kar and V. Lakshmikantham, *Textbook of Ordinary Differential Equations*, McGraw Hill Education, 3<sup>rd</sup> Ed., 2015.
5. G. F. Simmons and S. G. Kantz, *Differential Equations: Theory, Technique and Practice*, Tata McGraw-Hill, 2007.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA104	Numerical Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with numerical method for solving algebraic and transcendental equations. 2. To understand various methods for solving systems of linear equations. 3. To be familiarize with different methods to handle differential equation and integrals.							

#### 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, 3<sup>rd</sup> 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, 1<sup>st</sup> Ed., 1989.
6. R. L. Burden and J. D. Faires, *Numerical Analysis*, Brooks/Cole, 9<sup>th</sup> Ed., 2011.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA105	Introduction to Scientific Programming in Matlab	-	2	6	-	8	5
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>To develop the skills in scientific programming tools.</li> <li>At the end of the course the students should be able to apply the knowledge gained in solving problems by numerical methods.</li> </ol>							

#### Unit-I: Introduction to variables and workspace

Define and examine numbers, characters, string, text workspace command, built-in functions, mathematical functions, graphics, loops, logicals, 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:

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

#### Textbooks:

- W. J. Palm III, *Introduction to Matlab for Engineers*, Tata McGraw Hill, New Delhi, 2011.
- E. Kreyszig, *Advanced Engineering Mathematics*, Wiley, 10<sup>th</sup> Ed., 2011.

#### References:

- S. C. Chopra, *Applied Numerical Methods with Matlab For Engineers and Scientists*, Tata McGraw Hill Company Limited, New Delhi, 2<sup>nd</sup> Ed., 2007.
- D. F. Griffith, *Introduction to Matlab*, 2005.  
[www.maths.dundee.ac.uk/uftp/na-reports/matlabnotes.pdf](http://www.maths.dundee.ac.uk/uftp/na-reports/matlabnotes.pdf).

<b>Course Code</b>	<b>Course Title</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>O</b>	<b>L+T+P</b>	<b>C</b>
<b>17PMAOC1</b>	<b>Online Course*(Related to major core can be selected from Course era, NPTEL, MIT OCW, MOOC, Udacity, etc.)</b>	-	-	2	-	2	1
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Exposure to skill based e-learning.</li> <li>2. To develop the skills of self-learning.</li> </ol>							

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
17PMA201	Algebra	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with theory of Groups, homomorphism and Cayley's theorem. 2. Familiarity with Sylow's theorem and their applications. 3. Basic understanding of CRT and field extension theory.							

### Unit-I: Group theory

Groups, subgroups, normal subgroups, Euler's  $\phi$ - 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, 4<sup>th</sup> 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, 2<sup>nd</sup> Ed., 1999.
4. S. Lang, *Algebra*, Addison-Wesley, 3<sup>rd</sup> Ed., 1999.
5. J. B. Fraleigh, *A First Course in Abstract Algebra*, Pearson, 7<sup>th</sup> Ed., 2003.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA202	Complex Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand the basic concept related to limit, continuity, differentiability in complex system. 2. Familiarity with analyticity and power series. 3. To evaluate complex integral using residue theorem.							

#### 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*, Birkhauser, Boston, 2006.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 10<sup>th</sup> 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<sup>nd</sup> Ed., 2005.
2. J. B. Conway, *Functions of One Complex Variables*, Springer-Verlag, 2<sup>nd</sup> Ed., 1978.
3. J. W. Brown and R.V. Churchill, *Complex Variables and Applications*, McGraw Hill, 2008.
4. L. Ahlfors, *Complex Analysis*, McGraw-Hill, 2<sup>nd</sup> Ed., New York, 1966.
5. M. J. Ablowitz and A. S. Fokas, *Complex Variables: Introduction and Applications*, Cambridge University Press, NY, 2003.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA203	Partial Differential Equations	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand solving linear and nonlinear first order PDE's. 2. To be able to classify the second order PDE's and its reduction to canonical form. 3. To develop the strength to analyze the wave, diffusion and Laplace equations using different techniques.							

#### Unit-I: Introduction to PDE

Surfaces and curves, 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, Jacobi's method.

#### Unit-III: Second order PDE

Origin of second order PDE, equations with variable coefficients, classification and canonical forms of second order equations in two variables, classification of second order equations in  $n$  variables, characteristic curves of second order equations in two variables, importance of 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, Poisson 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. 1-6 [Sneddon]
  - Unit-II: Chapter 2 [Sneddon] or Chapter 1 [Stavroulakis]
  - Unit-III: Chapter 3 [Sneddon] or Chapter 2 [Stavroulakis]
  - Unit-IV: Chapter 5 [Sneddon] or Chapter 3 [Stavroulakis]
  - Unit-V: Chapter 4, 6 [Sneddon] or Chapter 6 [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<sup>nd</sup> Ed., 2012.



Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA204	Probability and Statistics	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Learning the techniques to develop discrete and continuous probability distribution and its applications. 2. Study about related statistical characteristics and its properties with applications. 3. Learn the models in sequential analysis for hypotheses testing.							

#### Unit-I: Special random variables

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-II: Statistical inequalities

Weak law of large numbers, strong law of large numbers, central limit theorem.

#### Unit-III: Parameter estimation

Point estimation, properties of estimation: unbiasedness, consistency, sufficiency, efficiency, Method of estimation: method of moments, maximum likelihood estimation.

#### Unit-IV: Testing of hypothesis

Different type of hypothesis, acceptance region, critical region, test function, type-I and type-II errors, level of significance, power of the test, uniformly most powerful test, Neyman-Person's lemma.

#### Unit-V: Distributions

Chi-square distribution, chi-square test for goodness of fit, student's t-distribution, t-test for single mean, t-test for difference of means, paired t-test for difference of means, f-distribution, f-test for equality of population 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, 2<sup>nd</sup> Ed., 2001.
  - Unit-I: Chapter 1-4 [Rohatgi]
  - Unit-II: Chapter 6 [Rohatgi]
  - Unit-III: Chapter 8 [Rohatgi]
  - Unit-IV: Chapter 9: Sec. 9.1-9.3 [Rohatgi]
  - Unit-V: Chapter 10: Sec. 10.3-10.5 [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, 8<sup>th</sup> Ed., 2007.
3. D. C. Montgomery and G. C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley & Sons, 3<sup>rd</sup> Ed., 2003.

<b>Course Code</b>	<b>Course Title</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>O</b>	<b>L+T+P</b>	<b>C</b>
<b>17PMA205</b>	<b>Seminar*(Based on recent research articles)</b>	-	-	2	-	2	1
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Exposure to an advance special topic or programming.</li> <li>2. To develop the skills in understanding the research articles.</li> </ol>							

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
17PMA301	Topology	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Introduction to topological spaces, definitions of sets. 2. Familiarity with connected spaces, components and path components. 3. Exposure to countability.							

#### 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  $\mathbb{R}$ , 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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA302	Operations Research	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with LPP. 2. To understand various method for solving LPP. 3. To familiarize with transportation problems. 4. To learn integer programming problems. 5. To learn queuing systems.							

**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, 9<sup>th</sup> Ed., 2013.
2. A. Ravindran, D. T. Phillips and J. J. Solberg, *Operations Research: Principles and Practice*, John Wiley and Sons, NY, 2<sup>nd</sup> Ed., 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, 7<sup>th</sup> Ed., 2001.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA303	Calculus of Variations and Mechanics	3	1	-	1	4	4
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Be thorough with Calculus of variations.</li> <li>2. Familiarity with generalized coordinates, its properties and applications.</li> <li>3. Exposure to Hamilton's variables.</li> <li>4. Be familiar with Poisson's brackets and its application in mechanics.</li> </ol>							

**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, Foucault'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, Noether's 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*, 3<sup>rd</sup> Ed., Addison-Wesley, 2001.
3. N. H. Louis and D. F. Janet, *Analytical Mechanics*, Cambridge University Press, 1998.
4. S. Ramsay, *Dynamics Part II*, 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.

## Major Elective-I

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EA	Multivariate Calculus	3	1	-	1	4	4
<b>Instructional objectives</b>							
<ol style="list-style-type: none"><li>1. To understand the concept of differential calculus in several variable framework.</li><li>2. Be familiar with the concept of maxima and minima in several variables.</li><li>3. Go through the concept of gradient, divergence and curl.</li><li>4. Be familiar with line, surface and volume integrals.</li><li>5. To understand the connection between the line, surface and volume integrals through Green's, Gauss' and Stokes' Theorem.</li></ol>							

### 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 Wiley & Sons, 2<sup>nd</sup> Ed., 2003.
2. D. V. Widder, *Advanced Calculus*, PHI Learning, 2<sup>nd</sup> 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, 2<sup>nd</sup> 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*, Birkhauser, 1994.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EB	Fuzzy Sets and Applications	3	1	-	1	4	4
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Understand the basic knowledge of fuzzy sets and fuzzy logic.</li> <li>2. Be familiar with the concept of fuzzy numbers and arithmetic operations.</li> <li>3. To gain knowledge in fuzzy relations.</li> <li>4. Be thorough with the concept of Logical connectives and fuzzy graphs.</li> <li>5. Be exposed to basic fuzzy system modelling methods and knowledge of fuzzy information processing.</li> </ol>							

#### 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. Klir 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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EC	Fluid Dynamics	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand the basic concepts in fluid mechanics. 2. To be thorough with the conservation laws. 3. To familiarize with vortex dynamics, velocity potential and streamfunctions. 4. To understand the importance of dimensional analysis. 5. To be acquainted with linear stability analysis of benchmark problems in fluid mechanics.							

#### Unit-I: Introduction to fluid flows

Real and ideal fluids, velocity, acceleration, streamlines, pathlines, 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. Kundu and 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, 2<sup>nd</sup> Ed., 2000.
2. F. M. White, *Fluid Mechanics*, McGraw Hill, New York, 8<sup>th</sup> Ed., 2015.
3. P. G. Drazin and W. H. Reid, *Hydrodynamic Stability*, Cambridge Press, 2<sup>nd</sup> Ed., 2004.



Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3ED	Discrete Mathematics	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand the basic set theoretic concepts. 2. To familiarize with concept of graph theory. 3. To learn the concepts of Boolean algebra and recurrence relations.							

### 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, 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, 2<sup>nd</sup> 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, 2<sup>nd</sup> Ed., 2001.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EE	Numerical Solutions to Partial Differential Equations	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Understand the finite difference schemes (FDS), order of accuracy of scheme. 2. Exposure to concept of stability convergence dissipation and dispersion. 3. Be exposed to FDS for hyperbolic, parabolic and elliptic PDE's.							

#### 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, 2<sup>nd</sup> 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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EF	Introduction to Statistical Learning	3	1	-	1	4	4
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Introduction to statistical method data analysis.</li> <li>2. Well versed with supervised and unsupervised learning.</li> <li>3. Exposure to data problem in practice.</li> </ol>							

### 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, 2<sup>nd</sup> Ed., 2009.
2. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley, 8<sup>th</sup> 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, 4<sup>th</sup> Ed., 2014.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3EG	Introduction to Mathematical Finance	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To familiarize with application of mathematics in finance. 2. Exposure to Black-Scholes equation, portfolio management. 3. To understand the concept of arbitrage and hedging.							

**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, 4<sup>th</sup> 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.

## Semester-IV

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA401	Functional Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with continuous linear transformations and related theorems. 2. Familiarity with Banach and Hilbert spaces and their properties. 3. Exposure to spectral theorem.							

### Unit-I: Algebraic systems

Linear spaces and dimension of spaces, linear transformations and linear 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<sup>nd</sup> Ed., 1996.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA402	Integral Equations and Transform Techniques	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with linear integral equation and solution tools. 2. Familiarity with Laplace transformation, properties and applications. 3. Familiarity with Fourier transformation, properties and applications.							

### Unit-I: Linear integral equations

Linear integral equations of 1<sup>st</sup> and 2<sup>nd</sup> 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-th minor, 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., 3<sup>rd</sup> Ed., 2010.

## Major Electives–II

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA4EA	Dynamical Systems	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. To understand the concepts of well-posedness of differential equations. 2. Familiarity with Bifurcations in 1D and 2D flows, introduction to chaos. 3. Exposure to Stability analysis.							

### 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, 2<sup>nd</sup> 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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA4EB	Applied Functional Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be thorough with the theory of distributions, weak derivatives. 2. Familiarly with Sobolev spaces and their properties. 3. Exposure to Lax-Milgram and Eigen value problems.							

**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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA4EC	Non-linear Partial Differential Equations	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Understand first order non-linear equations and method of characteristics. 2. Be thorough with boundary value problems using Fourier transforms. 3. Be exposed to conservation laws and shock waves and their solutions.							

**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, 2<sup>nd</sup> 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, 2<sup>nd</sup> Ed., 2010.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA4ED	Graph Theory	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be familiar with graphs and subgraphs. 2. Be exposed to connectivity and cycles. 3. Be thorough with matchings and colorings. 4. Understand fully the planar graphs and the color theorems.							

### 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 theorem and 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: Chapter 9, 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, 4<sup>th</sup> Ed., 2004 (Indian Print).
4. S. A. Choudum, *A First Course in Graph Theory*, MacMillan India Ltd., 2000.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA4EE	Introduction to Functional Data Analysis	3	1	-	1	4	4
<b>Instructional objectives</b>							
<ol style="list-style-type: none"> <li>1. Exposure to functional data, some mathematical tools for functional data.</li> <li>2. Well versed with principal and regularized component analysis of functional data.</li> <li>3. Familiarity with differential equations and FDA.</li> </ol>							

#### 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 values and 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, 2<sup>nd</sup> 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 Code	Course Title	L	T	P	O	L+T+P	C
17PMA4EF	Formal Languages and Automata Theory	3	1	-	1	4	4
<b>Instructional objectives</b>							
1. Be familiar with a machine language. 2. To study in regular grammar and context-free grammar. 3. Get exposed to compiler design.							

**Unit I: Finite automata**

Regular expressions and regular grammars: finite state systems, basic definitions, non-deterministic finite automata, finite automata with  $\epsilon$  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:**

- 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)

## Non Major Electives

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA2NA	Numerical Methods using C++	2	-	-	-	2	2
<b>Instructional objectives</b>							
1. To expose the students to various tools in solving numerical problems.							
2. To enable the students to apply these methods in a computer environment.							

### 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, Gauss-Jordan elimination method, Gauss-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, 6<sup>th</sup> Ed., 2007.
3. E. Balagurusamy, *Object Oriented Programming with C++*, Tata McGraw Hill, 1996.
4. C. E. Froberg, *Introduction to Numerical Analysis*, Addison-Wesley, 2<sup>nd</sup> Ed., 1972.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA2NB	Introduction to Differential Equations	2	-	-	-	2	2
<b>Instructional objectives</b>							
1. To understand the concepts of ordinary and partial differential equations. 2. To familiarize with boundary value problems. 3. To learn the qualitative analysis of differential equations.							

**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, 38<sup>th</sup> Ed., 2004.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, Singapore, 8<sup>th</sup> Ed., 2000.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3NA	Applied Mathematics	2	-	-	-	2	2
<b>Instructional objectives</b>							
1. To expose the students to the concepts of functions of several variables. 2. To familiarize with Fourier series. 3. To give the insight of complex integration and residue theory.							

**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, 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, 8<sup>th</sup> Ed., 2000.
2. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publishers, New Delhi, 38<sup>th</sup> Ed., 2004.

Course Code	Course Title	L	T	P	O	L+T+P	C
17PMA3NB	Bio-Mathematics	2	-	-	-	2	2
<b>Instructional objectives</b>							
1. To introduce mathematics as a tool in the study of Biology.							
2. Be familiar with graphs and subgraphs.							

#### 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, ClustalWV1.7, Rasmol, Oligo, Molscript, Tree view, ALSRIPT, 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.