Enclosure –IX

Shree Manibhai Virani & Smt. Navalben Virani Science College, Rajkot
(Autonomous)
Affiliated to Saurashtra University, Rajkot.

Department of Mathematics
M.Sc. Mathematics

Syllabi For M.Sc. Mathematics Degree Programme under OBE

FOR STUDENTS ADMITTED FROM A.Y. 2019-2020 & ONWARDS

Semester – I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC101	**Core 1: Group and Ring Theory**	**4 Credits - 4hrs / wk**

Course Description:
This course focuses on some fundamental and advanced concepts of groups and rings in abstract algebra. The course deals with concepts of algebra which are introduced based on the knowledge the students have gained in their undergraduate programme. Algebra is the language of modern mathematics. This course introduces students to that language through a study of groups, homomorphism of groups, direct products of groups, basic concepts of ring and ideals. The concepts of this course will be very useful as a tool to study more advanced topics and also for further research in abstract algebra and other branches of mathematics.

Course Purpose:
This course aims to provide an extensive approach to the topics of abstract algebra from the graduation study, which is one of the basic pillars of modern mathematics. This is a required course for all M.Sc. Mathematics majors in the area of pure Mathematics with focused study of certain structures called groups and rings. Study of Abstract algebra develops mathematical maturity in the students and It also strengthens their abstract mathematical thinking skill.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand basic principles of algebraic structure of group, abelian group, cyclic group.	K1, K2

CO_2	Focus and analyse the homomorphic image of group.	K1, K2
CO_3	Extend the concepts of automorphism and product of sets to the structure of group.	K2, K4
CO_4	Understand the special classes of groups: Finite Abelian Groups and the converse of well-known Lagrange's theorem	K2
CO_5	More conceptual learning of the structure of ring, Recognize and understand the concept of Ideals.	K2, K4

Course Content **Hours**

Module-I : Basic concepts of group theory 10 hrs

- Group
- Abelian group
- Cyclic group
- Normal subgroup

Module-II : Homomorphism of Groups 10 hrs

- Quotient group
- Permutation group
- Group homomorphism and its properties
- Group isomorphism

Module-III : Group Automorphisms and Direct Products 9 hrs

- Cayley's theorem
- Automorphism of groups
- Inner automorphism
- Direct Products of groups

Module-IV : Finite Abelian Groups and Sylow Theorems 9 hrs

- Finitely Generated Abelian Groups
- Invariants of a finite Abelian Groups
- Sylow Theorems

Module-V : Quick look at Ring Theory 10 hrs

- Euclidean ring
- Quotient ring and zero divisors
- Division ring and Integral Domain
- Ideals and ideal rings
- Principal ideal
- Maximal ideal and prime ideal
- Homomorphisms of ideals

- Sum and Direct Sum of Ideals
- Nilpotent and Nil Ideals

Suggested laboratory experiments:
- Not applicable

Pedagogic tools:
- Chalk and Board
- LCD and Videos.

Text books
1. I. N. Herstein, (1975), Topics in Algebra, 2nd edition, Wiley Pub. , New York.
2. N. S. Gopalakrishnan, (1998), University Algebra, 6th reprint, New Age International Private Ltd. Publishers, New Delhi.

Reference Books:
1. J. A. Gallian,(1999), Contemporary Abstract Algebra, 4th edition, Narosa Publishing House, New Delhi.
2. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, (1995), Basic Abstract Algebra**,** 2nd edition, Cambridge University Press..
3. M. Artin, (1995), Algebra, Prentice-Hall of India Private Ltd., New Delhi.

Laboratory Manual/ Book
- Not applicable

Suggested reading / E-resources
- https://www.extension.harvard.edu/open-learning-initiative/abstract-algebra
- http://mathworld.wolfram.com/AbstractAlgebra.html
- https://onlinecourses.nptel.ac.in/noc16_cs15/preview

Suggested MOOCs
- saylor academy | free and open online courses for people everywhere/ABSTRACT ALGEBRA
- https://www.coursebuffet.com/course/847/nptel/advanced-abstract-algebra-iit-delhi

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V (CIE-I+CIE-II=20 Marks)
M2) Attendance in Classes
M3) Assignments:
- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:
- Surprise Quiz

- Group discussion (M2+M3+M4=20 Marks)

Semester - I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC102	**Core 2: Topology**	**4 Credits -** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:
This course focuses on fundamentals of topological spaces as generalization of metric spaces. The course also deals with subspaces of topological spaces and important results of topological spaces including those about continuity and homeomorphism. This course also includes discussion of types of topological spaces and concept of the hierarchy among topological spaces.

Course Purpose:
This is a required course for all **M.Sc. Mathematics majors** with a focus in general topology. After studying metric spaces as a foundation course at undergraduate level more generalized notion of topological spaces is required to be introduced at this level. The concept of topology and its results are very useful as mathematical tools which is very instrumental in other areas of mathematical research. The propose of this course is to explore the foundations of mathematics at a level and depth appropriate for someone aspiring to study higher-level mathematics and/or to become a professional mathematician.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Recognize and interpret the topological structures and their characterizations.	K1, K2
CO_2	Identify and understand the subspace topology and product topology.	K1, K2
CO_3	Identify and classify the types of topologies including quotient topology	K2, K4

	and metric topology.	
CO_4	Understand differentiate and apply the hierarchy of the topological spaces and their characterizations.	K2, K3
CO_5	Understand and apply the continuity of functions	K1, K3

Course Content **Hours**

Module-I : Topological spaces. 10 hrs

- Topological spaces
- Basis for a Topology

Module-II : The Subspace Topology. 10 hrs

- The Subspace Topology
- Order Topology

Module-III : Product Topology. 10 hrs

- Product Topology and related concepts
- Closed sets and limit points

Module-IV : Continuity. 10 hrs

- Continuous functions
- Metric Topology

Module-V : Hierarchy in topological spaces. 10 hrs

- T_1- spaces
- Hausdorff spaces
- Regular spaces and Normal spaces
- Urysohn's Lemma and Tietze extension theorem

Suggested laboratory (inbuilt) experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text book:

1. Munkres J., (1974), Topology: A first course, Prentice-Hall of India Pvt. Ltd, New Delhi.

Reference Books:

1. Simmons G. F., (1963), Introduction to Topology and Modern Analysis, McGraw Hill Company, Tokyo.
2. Willards S., (1970), General Topology, Addition-Wesley, Reading.

Laboratory Manual/ Book

- Not applicable.

Suggested reading / E-resources

- https://ocw.mit.edu/courses/mathematics/18-901-introduction-to-topology-fall-2004/index.htm#
- http://freevideolectures.com/Course/3528/Topology

Suggested MOOCs

- http://nptel.ac.in/courses/111106054/Topology%20complete%20course.pdf

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Report on Case study of a topic
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz

(M2+M3+M4=20 Marks)

Semester - I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC103	**Core 3: Functions of Several Variables**	**4 Credits –** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:
This course covers the fundamentals of the concepts of limit, continuity, partial derivative, gradient and differentiability for functions of several variables and tensor analysis.

Course Purpose:
The purpose of this course of Functions of Several Variables is introduce the students with the concepts of parameterize curves and surfaces, basics of limit, continuity, partial derivative, gradient and differentiability for functions. Compute partial derivatives of elementary functions. More generally, the students will improve their ability to think critically, to analyse a real problem and solve it using a wide array of mathematical tools. These skills will be very useful to them in whatever path they choose to follow, be it as a mathematician or as an academician.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Identify and define functions of the form $T: R^n \rightarrow R^m$	K1
CO_2	Understand the concepts including limit, continuity for the functions of several variables.	K1, K2
CO_3	Understand the concepts of partial derivative of first and higher order for functions of several variables.	K1
CO_4	Recognize and understand the concepts of tensor algebra on finite dimensional vector spaces,	K1, K2
CO_5	Understand and apply alternating and symmetric tensors, wedge products, vector fields and forms as well as their basic properties.	K2, K3

Course Content **Hours**

Module-I : Euclidean Space and It's basic properties 10 hrs

- Euclidean Space R^n and its basic properties
- Functions From: $R^n \rightarrow R^m$
- Limit, Continuity and Oscillation
- Relation between Linear Transformation $T: R^n \rightarrow R^m$ and m * n Matrices

Module-II : Differentiation 10 hrs

- Differentiations and their Basic Prosperities
- Chain Rule and Jacobian Matrix

Module-III : Partial Differentiation 10 hrs

- Partial Derivatives and its Relation with Jacobian Matrix
- Partial Derivatives of Higher Order
- Picard's Method of successive Approximations

Module-IV : Partial Derivative and Continuity 9 hrs

- Young's Theorem, and Schwarz's Theorem
- Directional Derivative its Basic Properties its Relation with Derivative
- Partial Derivative and Continuity

Module-V : Tensor algebra on Finite Dimensional Vector Space 9 hrs

- Tensor algebra on Finite Dimensional Vector Space
- Alternating and Symmetric Tensors
- Wedge Product and Relation Among Them
- Vector Fields and Forms, their Basic Properties

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. M. Spivak, (1965), Calculus on Manifolds, W.E. Benjamin Inc.

Reference Books:

1. W. Rudin, (1983), Principles of Mathematical Analysis, 3rd edition, Tata McGraw-Hill Publ. Co., New Delhi..
2. S. R. Ghorpade and B. V. Limaye, (2010), A Course in Multivariable Calculus and Analysis, Springer.

Laboratory Manual/ Book

- Not required

Suggested reading / E-resources

- https://www0.maths.ox.ac.uk/system/files/coursematerial/2015/3063/3/mvc.pdf
- http://ocw.mit.edu/courses/mathematics/18-022-calculus-of-several-variables-fall-2010/lecture-notes/
- www.ams.sunysb.edu/~jiao/teaching/.../lectures/LarCalc9_ch13.pdf

Suggested MOOCs

- Coursera
- edX

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for application of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion.
- Problem Solving sessions

(M2+M3+M4=20 Marks)

Semester - I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC104	**Core 4:** **Theory of Differential Equations**	**4 Credits –** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:

This course focuses on ordinary differential equations, partial differential equations and their applications in science and engineering. The laws of nature are expressed as differential equations. Mathematicians, scientists and engineers must know how to model the world in terms of differential equations, and how to solve those equations and interpret the solutions. Prerequisite for this courses the knowledge of fundamentals of calculus and differential equations.

Course Purpose:

This is a required fundamental course for all **M.Sc. Mathematics majors** with a focus on Ordinary Differential Equations (ODE) and Partial Differential Equations (PDE). The theory of ODE and PDE is nowadays a huge area of active research, and it goes back to the very birth of mathematical analysis in the 18th and 19th century. Purpose of the course is to Emphasize on the modern analytic techniques relying on the notions of Ordinary Differential Equations, Partial differential equations, Gauss hyper geometric equations and Cauchy problem including Charpit's and Jacobi's method.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand the meaning of Ordinary Differential Equations.	K1, K2
CO_2	Understand and solve Partial differential equation.	K2, K3
CO_3	Identify and solve Gauss hyper geometric equation.	K2, K3
CO_4	Understand, identify and solve Cauchy Problem including Charpit's and Jacobi's method.	K1, K2, K3

Course Content **Hours**

Module-I : Review of Simultaneous Ordinary Differential Equations 10 hrs

- Review of Simultaneous Ordinary Differential Equations
- Second order differential equations: the method of variation of parameters
- Review of Simultaneous Ordinary Differential Equations of First Order
- Ordinary and singular points, series solution
- Frobenious method: solution in series near regular singular point, point at infinity

Module-II : Some special kind of equations 10 hrs

- Legendre equation
- Legendre polynomial and its properties
- Bessel's equation
- Bessel's function of first and second kind and their properties

Module-III : Partial differential equations 10 hrs

- Partial differential equation
- Partial differential equation of first order
- Compatible system of first order partial differential equations
- Picard's Method of successive Approximations

Module-IV : Gauss hyper geometric equations 9 hrs

- Gauss hyper geometric equation
- Gauss hyper geometric function and its properties

Module-V : Solution of partial differential equations 9 hrs

- Charpit's and Jacobi's method
- Cauchy Problem

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. Sneddon, I. N., (1957), Elements of Partial Differential Equations, McGraw-Hill Publ. Co.,
2. Raisinghania, M. D., (1995), Advanced Differential Equations, S. Chand & Co.

Reference Books:

1. G. F. Simmons, (1991), Differential equations with applications and historical notes, 2nd edition, McGraw-Hill International Editions..
2. Amarnath, T., (1997), Elementary Course in Partial Differential Equations, Narosa Publ. House, New Delhi.
3. Rabenstein, A. L., (1972), Introduction to Ordinary Differential Equations, Academic Press.
4. Grewal, B.S. and Grewal, J.S., (2000), Higher Engineering Mathematics, (36th edition), Khanna Publ., New Delhi.
5. Somasundaram, D., (2002), Ordinary Differential Equations: A First Course, Narosa Publ. House, New Delhi.
6. William E. Boyce, Richard C. DiPrima, (2012), Elementary Differential Equations and Boundary Value Problems, Wiley.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://ocw.mit.edu/courses/mathematics/18-152-introduction-to-partial-differential-equations-fall-2017/

Suggested MOOCs

- https://www.coursera.org/learn/ordinary-differential-equations
- https://www.coursera.org/learn/partial-differential-equations

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for application of the content.
- Question answer sessions.
- Making a mathematical model for a given problem.

M4) Class Activity:

- Surprise Quiz
- Group discussion.
- Problem Solving sessions

(M2+M3+M4=20 Marks)

Semester - I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTID101	**DISCIPLINE SPECIFIC ELECTIVE - ID - I :** Fundamentals of Classical Mechanics	**4 Credits – 3 hrs-Theory/wk 2 hrs-Tutorial /wk**

Course Description:

This course focuses on the Classical Mechanics which is a very old interdisciplinary branch of Mathematics and Physics that deals with the motion of bodies based on Isaac Newton's laws of mechanics. Classical mechanics describes the motion of point masses and that of rigid bodies. This course covers topics including elementary principles, D'Almbert's principle, Lagrangian and Hamiltonian formulation, Two Body Central force problem, Equations of Motion and Rigid bodies etc.

Course Purpose:

This is one of the interdisciplinary fundamental courses for all **M.Sc. Mathematics majors** with a focus on traditional mathematics. Purpose of this course is to prepare the learners with sufficient background in the subject because the content of this course serves as prerequisites for the many courses including Dynamics, Astronomy and General Relativity etc. This course is also useful if one wants to study interdisciplinary courses of physics including Quantum Mechanics and Electrodynamics. Our goal is to develop a conceptual understanding of the core concepts, a familiarity with the experimental verification of our theoretical laws, and an ability to apply the theoretical framework to describe and predict the motions of bodies.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand and describe elementary principles of motion.	K1, K2
CO_2	Understand and criticize equations of motion and classify the dynamical systems.	K2, K4
CO_3	Derive and utilize Lagrange's equation of motions.	K1, K3
CO_4	Identify, understatnd and solve two body central force problem.	K2, K3
CO_5	Identify, understatnd and solve problems related to Equations of Motion and Rigid bodies.	K2, K3

Course Content **Hours**

Module-I : Survey of elementary principles 7 hrs

- Conservation theorem for linear momentum and angular momentum for a particle
- Conservation theorem for linear momentum and angular momentum for a

system of particles
- Classification of dynamical system.

Module-II : D'Almbert's principle and Lagrange's equation of motions 7 hrs

- Constraints.
- Virtual displacement and principle of virtual work.
- Generalized force in holonomic system
- Mathematical expression for principle of virtual work
- D'Almbert's principle
- Lagrange's equation for holonomic system
- Lagrange's equation for conservative non-holonomic system
- Problems on above topics

Module-III : Variational principle and Lagrange's equations 7 hrs

- Variational principle
- Calculus of variations
- Hamilton's principle
- Derivation of Hamilton's principle from Lagrange's equation
- Derivation of Lagrange's equations from Hamilton's principle
- Cyclic co-ordinates
- Conservation theorems
- Problems on above topics

Module-IV : Two Body Central force problem 7 hrs

- Reduction to equivalent one body problem
- The equations of motion and first integrals
- The equivalent one dimensional problem and classification of orbits
- The inverse square law of force

Module-V : Equations of Motion and Rigid bodies 6 hrs

- Independent co-ordinates of rigid bodies
- Generalized co-ordinates of a rigid bodies
- Euler angles and Cayley-Klein parameters and related quantities
- Components of angular velocity along the body set of axes
- Euler's theorem on the motion of a rigid body, rate of change of a vector
- The Coriolis force
- Euler's equations of motion for a rigid body
- Finite rotations
- Infinitesimal rotations

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books:

1. C. R. Mondal, (2004), Classical Mechanics, Prentice Hall of India Pvt. Ltd.

Reference Books:

1. H. Goldstein, (2018), Classical Mechanics, 2nd edition, Narosa Publishing House.

Laboratory Manual/ Book

- Not applicable.

Suggested reading / E-resources

- http://theoreticalminimum.com/courses/classical-mechanics/2017/fall
- http://www.astro.caltech.edu/~golwala/ph106ab/ph106ab_notes.pdf

Suggested MOOCs

- https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2017/

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Report on the case study of a topic
- Question answer sessions.

M4) Class Activity:

- Group discussion.
- Problem Solving sessions

(M2+M3+M4=30 Marks)

Semester – I		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC105	**PRACTICAL: NUMERICAL METHODS USING SCILAB**	**2 Credits - 6 hrs/wk**

Course Description:

Scilab is a free and open-source, cross-platform numerical computational package and a high-level, numerically oriented programming language. It can be used for signal processing, statistical analysis, image enhancement, fluid dynamics simulations, numerical optimization, and modeling, simulation of explicit and implicit dynamical systems and (if the corresponding toolbox is installed) symbolic manipulations. Scilab is one of the two major open-source alternatives to MATLAB, the other one being GNU Octave. Scilab is similar enough to MATLAB that some book authors (who use it) argue that it is easy to transfer skills between the two systems. Scilab however puts less emphasis on (bidirectional) syntactic compatibility with MATLAB than Octave does.

Course Purpose:

Numerical analysis is the study of algorithms that use numerical approximation for the problems of mathematical analysis. The overall goal of the field of numerical analysis is the design and analysis of techniques to give approximate but accurate solutions to hard problems. Before the advent of modern computers numerical methods often depended on hand interpolation in large printed tables. Since the mid 20th century, computational software such as Scilab calculates, simulates and design the required functions instead. The purpose of this course is to train the students for programming using the Scilab software and to solve the computational problems of Numerical analysis using the programmes of Scilab.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand the concept of open source mathematical software including SCILAB.	K1
CO_2	Understand and utilize the user interface of SCILAB including console, file browser, variable browser, the command history and general commands including clc & clear	K1, K3
CO_3	Utilize pre-defined mathematical constants, variables and operators of Scilab, Input and utilize inbuilt matrix commands and library functions to write programs.	K3
CO_4	Solve numerical problems using Scilab programs.	K3
CO_5	Interpolate the value using tabulated data and numerical methods combined with customized Scilab program.	K3

Course Content **Hours**

6 hrs / practical

1. Revision and practice of the user interface of SCILAB including console, file browser, variable browser and the command history and Sci-notes with help of small program.
2. Revision and practice of the programming concepts of Scilab including pre-defined constants and variables and operators.
3. Revision and practice of the fundamental concepts of SCILAB as a programming language including looping (for statement, break and continue statements) and branching (if statement) and input statement. Functions, defining a function, function libraries, managing output arguments and the return statement.
4. Write a SCILAB program for the solution of given non-linear equations using False Position Method.
5. Write a SCILAB program for the solution of given non-linear equations using Secant Method.
6. Scilab programs to find solution of given equation using fixed point iteration method.
7. Scilab program to find the Lagrange's interpolation polynomial to fit the given data.
8. Scilab programs to fit a straight line to the given set of data and verifying the solution by plotting a graph of data points and the straight line found.
9. Scilab programs to fit a polynomial of degree 2 to the given set of data and verifying the solution by plotting a graph of data points and the curve found.
10. Scilab program to find value of numerical integration using Trapezoidal rule.
11. Scilab programs to find value of numerical integration using Simpson's 1/3 rule and Simpson's 3/8 rule.
12. Scilab program to solve the given differential equation using Fourth – Order Range-Kutta Method.
13. Scilab program to solve the given differential equation using Euler's method.

Suggested laboratory experiments:

- All experiments in Computer Laboratory

Pedagogic tools:

- Computers
- LCD and Videos.

Text books

1. Scilab Group, Scilab Reference Manual, On-line Documentation, INRIA Meta2 Project / ENPC Cergrene, INRIA.

Reference Books:

1. Vinu V. Das, (20018), Programming in Scilab, New Age International (P) Limited.
2. Domaine de Voluceau - Rocquencourt – B, (2010), Introduction to Scilab, Consortium Scilab.
3. Gilberto E. Urroz, (2001), Numerical and Statistical Methods with SCILAB for Science And Engineering, Volume 1, Greatunpublished.
4. Perrine Mathieu, Philippe Roux, Scilab, (2016), From Theory to Practice, Scilab: I. Fundamentals, 2016, Scilab Enterprises.

Laboratory Manual/ Book

- NA

Suggested reading / E-resources

- http://www.scilab.org/
- http://ekalavya.it.iitb.ac.in/contents.do?topic=Scilab
- http://spoken-tutorial.org/Study_Plans_Scilab/
- http://scilab.in/

Suggested MOOCs

- https://www.learncax.com/courses/by-software/scilab

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II= ---- Marks)

M2) Attendance in Classes

M3) Assignments:

- Program writing for assessing the logical thinking of the learner.
- Question answer sessions.

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M4) Class Activity:

- Activity for improving the typing speed in Mathematical notations and equations.

(M2+M3+M4= ---- Marks)

Semester – II

Course Code	Course Title	Course Credit and hrs
19PMTCC201	Core 5: Advanced Ring Theory and Extension Fields	4 Credits - 4hrs / wk

Course Description:

This course focuses on some advanced concepts of ring and field in abstract algebra. The course deals with concepts of polynomial ring, Euclidean domain, extension field and modules in abstract algebra. These concepts are merely extension of the course which the students have studied in their first semester of post-graduate programme. Algebra is the language of modern mathematics. This course introduces students to that language through a study of advanced topics of ring theory and ideals, extension of a field, types of extensions, splitting field, finite field, Galois theory, and Modules. The concepts of this course will be very useful to give extensive knowledge of the advanced topics of abstract algebra and it will also be useful for further research in abstract algebra and other branches of mathematics.

Course Purpose:

The purpose of this course is to provide extension to the knowledge of the topics of abstract algebra gained by the students up to the first semester of post-graduation. This is must required course for all **M.Sc. Mathematics majors** in the area of pure Mathematics with deeper and focused study of certain advanced topics called polynomial rings, division rings, fields, extension fields and modules. Abstract algebra gives to student a good mathematical maturity and enables to build logical thinking skill in the subject mathematics.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO_1	Understand advanced (extended) algebraic structures like polynomial ring, division ring, field and extension fields.	K_2
CO_2	Recognize and understand different types and principles of the structures.	K_1
CO_3	Identify the standard results regarding concepts of extension fields and	K_1

	Galois field.	
CO_4	Explore the applications of the extension fields to geometry and other fields of mathematics.	K_3
CO_5	Analyze and extend the concept of modules and types of modules.	K_4

Course Content	**Hours**
Module-I : Euclidean domains	10hrs
Euclidean domains	
Principal Ideal Domains	
Unique Factorization Domains	
Polynomial Rings over UFD	
Polynomial rings over rational field	
Irreducible polynomials	
Einstein irreducibility criterion	
Module-II : Extension Fields	10 hrs
Field, Extension fields	
Algebraic and transcendental extensions	
Splitting fields	
Normal extensions	
Multiple roots	
Separable extensions	
Module-III : Automorphism Fixed Fields and Galois Extension	10 hrs
Finite fields	
Automorphism fixed fields	
Galois extension	
Fundamental theorem of Galois Theory	

- Fundamental theorem of Algebra

Module-IV : Modules 9hrs

- Modules (Definitions and examples)
- Submodules and Operation on modules

Module-V : Homomorphism of Modules 9hrs

- Homomorphisms of modules and quotient modules
- Completely reducible module
- Finitely generated modules

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

- I. N. Herstein, Topics in Algebra, Second Edition, Wiley Pub. , New York, 1975.

Reference books

- M. Artin, Algebra, Prentice-Hall of India Private Ltd., New Delhi, 1994.
- J. A. Gallian, Contemporary Abstract Algebra, Fourth Edition, Narosa Publishing House, New Delhi, 1999.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra**,** Second Edition, Cambridge University Press, 1995.
- N. S. Gopalakrishnan, University Algebra, New Age International Private Ltd. Publishers, New Delhi, Sixth Reprint, 1998.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://www.extension.harvard.edu/open-learning-initiative/abstract-algebra
- http://mathworld.wolfram.com/AbstractAlgebra.html
- https://onlinecourses.nptel.ac.in/noc16_cs15/preview

Suggested MOOCs

- saylor academy | free and open online courses for people everywhere/
- https://www.coursebuffet.com/course/847/nptel/advanced-abstract-algebra-iit-delhi
- https://www.coursera.org/learn/galois

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II

CIE-II: Content: Modules-I to V

(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.
- Surprise Quiz
- Group discussion (M2+M3+M4=20 Marks)

Semester – II

Course Code	Course Title	Course Credit and hrs
19PMTCC202	**Core :** **Real Analysis and Measure Theory**	**4 Credits -** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:

This course focuses on some fundamental and advanced concepts of real analysis. The course deals with concepts of real number system and measure theory which are introduced based on the knowledge the students have gained in their undergraduate programme. This course introduces students to that enhance the knowledge of real number system, topology on real line, convergence and uniform convergence of sequnce. The concepts of this course will be very useful as a tool to study more advanced topics and also for further research in real analysis and other branches of mathematics.

Course Purpose:

This course aims to provide an extensive approach to the topics of real analysis from the graduation study, which is one of the basic pillars of modern mathematics. This is a required course for all M.Sc. Mathematics majors in the area of pure Mathematics with focused study of Measure. Study of real analysis develops mathematical maturity in the students and It also strengthens their mathematical thinking skill.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO_1	Understand basic principles set theory, Borel set, -Algebra,	K1, K2,K4

	outer measurable sets and Lebesgue measurable sets.	
CO_2	Analyse the Lebesgue measurable function.	K2,K4
CO_3	Understand the concept of Lebesgue Integral and Riemann Integration	K1,K2, K4
CO_4	Extend the concepts of Lebesgue integration to differentiation of integration	K2, K4
CO_5	More conceptual learning of the structure of L Spaces and completeness of the space.	K1,K2, K4

Course Content **Hours**

Module-I : Measure 12 hrs

- Borel Set
- The -Algebra of Sets
- Lebesgue Outer Measure
- Measurable Sets and Lebesgue Measure
- Non-measurable Sets,

Module-II : Measurable Functions 12 hrs

- Sums, Products, and Compositions
- Simple Functions
- Sequential Pointwise Limits and Simple Approximation
- Convergence of Sequence of Measurable Functions
- Littlewood's Three Principles

Module-III : The Lebesgue Integral 12 hrs

- Riemann integral
- The Lebesgue integral of a bounded function over a set of finite measure
- Bounded Convergence Theorem
- The Integral of a Nonnegative Functions
- Fatou's Lemma
- Monotone Convergence Thorem

Module-IV : Differentiation and Integration 12 hrs

- The General Lebesgue Integral
- Convergence in Measure
- Monotonic Functions
- Functions of Bounded Variation
- Differentiation of an Integral

Module-V : The Spaces 12 hrs

- Introduction to L Spaces
- The Minkowski's inequality
- The Holder's inequality
- Convergence and Completeness
- Riesz-Fischer Theorem

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. H.L.Royden, (2003). Real Analysis, 3rd edition, Prentice-Hall India Private Limited.

Reference Books:

1. G.de Barra., (2000), Measure Theory and Integration**,** New Age International Limited Publishers.
2. N.L.Carothers, (2000), Real Analysis, Cambridge University Press, New York
3. K.P.Gupta, (1976), Measure Theory, Krishna Prakashan Mandir.
2. R.G.Bartle, (1964), The Elements of Real Analysis, John Wiley & Sons, New York.

Laboratory Manual/ Book

· Not applicable

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II

CIE-II: Content: Modules-I to V

(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

· Seminar on topics for the exploration of the content.

· Question answer sessions.
· Surprise Quiz

· Group discussion
(M2+M3+M4=20 Marks)

Semester - II

Course Code	Course Title	Course Credit
19PMTCC203	**Theory of Partial Differential Equations**	**4 Credits -** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:

This course covers the fundamentals of differential equations: canonical forms, homogenous and non homogenous forms, Monge's methods, boundary value problems.

Course Purpose:

The purpose of this subject is that students will be able to graph functions, integration and differentiation, to learn the basics of Modeling and solution of differential equations. They will study standard functions with graph, geometrical meaning of differential equations, modeling and solution of ordinary and partial differential equations. More generally, the students will improve their ability to think critically, to analyze a real problem and solve it using a wide array of mathematical tools. These skills will be invaluable to them in whatever path they choose to follow, be it as a mathematics major or in pursuit of a career in one of the other sciences.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO_1	Identify and understand the higher order partial differential equations.	K1, K2
CO_2	Classify the higher order partial differential equations.	K3,K6
CO_3	Distinguish between linear and non linear the higher order partial differential equations	K2,K5

CO_4	Identify and understand the higher order partial differential equations with variable coefficients	K1
CO_5	Understand and solve the given Boundary value problems and Equipotential surfaces	K3,K4,K6

Course Content **Hours**

Module-I : Review of Simultaneous Ordinary Differential Equations 10 hrs

- Origin of second order partial differential equations
- Linear second order partial differential equations with constant coefficients
- Solutions for f(x; y) to be polynomial
- Exponential, sin/cos functions
- General method for homogeneous equations

Module-II : Some special kind of equations 10 hrs

- Classification of second ordered partial differential equations
- Canonical form

Module-III : Partial differential equations 10 hrs

- Non-linear second order partial differential equations
- solution by Monge's method
- Special case and general case

Module-IV : Gauss hyper geometric equations 9 hrs

- Second order partial differential equations with variable coefficients
- Method of changing variables for special type of equations
- Separation of variable Method
- Solution of three special equations –Laplace
- Wave and diffusion equation

- Solution of these equations in different coordinate systems

Module-V : Solution of partial differential equations 9 hrs

- Boundary value problems
- Dirichlet boundary value problems
- Neumann boundary value problems
- Maximum and minimum principles
- Harnack's theorem
- Green's functions
- Equipotential surfaces

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

- Amarnath, T., Elementary Course in Partial Differential Equations, Narosa Publ. House, New Delhi, 1997.
- Sneddon, I. N., Elements of Partial Differential Equations, McGraw- Hill Publ. Co., 1957
- Grewal, B. S. and Grewal, J. S., Higher Engineering Mathematics, (36th Edition), Khanna Publ. New Delhi, 2000.
- Raisinghania, M. D. Advanced Differential Equations, S. Chand & Co., 1995.
- Phoolan Prasad and Ravindran, R., Partial Differential Equations, Wiley Eastern.

Laboratory Manual/ Book

- Not required

Laboratory Manual/ Book

- Not applicable

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II

CIE-II: Content: Modules-I to V

(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.
- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester - II

Course Code	Course Title	Course Credit
19PMTCC204	**Core 8**: Advanced Classical Mechanics	**4 Credits -** **3 hrs-Theory/wk** **2 hrs-Tutorial /wk**

Course Description:

This course focuses on the Classical Mechanics which is a very old interdisciplinary branch of Mathematics and Physics that deals with the motion of bodies based on Isaac Newton's laws of mechanics. Classical mechanics describes the motion of point masses and that of rigid bodies. This course covers topics including Rigid Body Equations of Motion, theory of relativity, Hamilton's equation of motion, Canonical transformations etc.

Course Purpose:

This is one of the interdisciplinary fundamental courses for all **M.Sc. Mathematics majors** with a focus on traditional mathematics. Purpose of this course is to prepare the learners with sufficient background in the subject because the content of this course serves as prerequisites for the many courses including Dynamics, Astronomy and General Relativity etc. This course is also useful if one wants to study interdisciplinary courses of physics including Quantum Mechanics and Electrodynamics. Our goal is to develop a conceptual understanding of the core concepts, a familiarity with the experimental verification of our theoretical laws, and an ability to apply the theoretical framework to describe and predict the motions of bodies.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO_1	Understand, define and verify Rigid Body Equations of Motion.	K1, K2
CO_2	Understand and compare theory of relativity in classical mechanics.	K2, K4
CO_3	Formulate covariant four dimensional equations	K1, K3
CO_4	Derive the Hamilton's equation of motion.	K1, K3

CO_5	Understand and utilize the Canonical transformations and Generating functions.	K1,K2, K3

Course Content **Hours**

Module 1 The Rigid Body Equations of Motion **(10hrs)**

- Angular momentum and kinetic energy of motion about a point
- The inertia tensor and moment of inertia
- The heavy symmetrical top with one point fixed

Module 2 Special Relativity in Classical Mechanics **(10hrs)**

- The basic program of special relativity
- The Lorentz transformations
- Lorentz transformations in real four dimensional spaces
- Further descriptions of the Lorentz transformation

Module 3 Covariant four – dimensional formulations **(10hrs)**

- Covariant four – dimensional formulations
- The force and energy equations in relativistic mechanics

Module 4 Hamilton's equation of Motion **(9hrs)**

- Derivation of Hamilton's equation of motion
- Routh's procedure
- Derivation of Hamilton's equation from Hamilton's P rinciple
- Principle of least action
- Problem related to above topics

Module 5 Canonical transformations and Generating functions (9hrs)

- Poisson's brackets and their properties
- Hamilton-Jacobi theory
- Problem related to above topics

Reference Books:-

- H. Goldstein, Classical Mechanics, 2nd Edition, Narosa Publishing House
- C. R. Mondal, Classical Mechanics, Prentice Hall of India Pvt. Ltd.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Laboratory Manual/ Book

- Not applicable.

Suggested reading / E-resources

- http://theoreticalminimum.com/courses/classical-mechanics/2017/fall
- http://www.astro.caltech.edu/~golwala/ph106ab/ph106ab_notes.pdf

Suggested MOOCs

- https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2017/

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II

CIE-II: Content: Modules-I to V

(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

Report on the case study of a topic

Question answer sessions.

M4) Group discussion.

- Problem Solving sessions
  (M2+M3+M4=30 Marks)

Semester – II

Course Code	Course Title	Course Credit
19PMTCC205	**Core Practical 2:** Introduction to LaTex	**2 Credits (6 hrs/wk)**

Course Description:

LaTeX is a powerful document description language built on top of TeX. It is available on Unix, Windows and Macintoshes. It can be used for the presentation of plain text (including accented characters and letters outside the English alphabet), the typesetting of

mathematics, the generation of tables, and producing simple diagrams. It is particularly suited for the writing of theses, papers and technical documents.

Course Purpose:

LaTeX is an open source document preparation system. It is preferred by academia for technical and scientific document preparation because of its automated and high-quality typesetting features. Our goal is planned to give hands-on training in LaTeX to enhance the document preparation skills of the students.

Course Outcomes: Upon completion of this course, the learner will be able to

CO No.	CO Statement	Blooms taxonomy Level (K_1 to K_6)
CO_1	Understand the purpose and nature of LaTeX.	**K1, K2**
CO_2	Understand how LaTeX differs from a word processor.	**K1, K2**
CO_3	Install and utilize LaTeX and its related components successfully on personal computer.	**K2, K3**
CO_4	Create document using LaTeX including the features like line break, fonts size, page breaks.	**K2, K4**
CO_5	Utilize LaTeX and its templates to compose Mathematical documents, presentations, and reports.	**K2, K3**
CO_6	Identify, remember and effectively utilize symbols useful for mathematical type setting.	**K1, K2, K3**
CO_7	Create complete document including title page, index, chapters, tables graphics and bibliography	**K2, K4**

Course Content	Hours

Module-I : History and Basics of LaTeX. 12

- History of LaTeX, How to install LaTeX,
- Basic Structure of LaTeX Document, Layout Design,
- Advantages and Disadvantages,
- Input file structures, Document class, Page Style, Packages.

Module-II : Simple documents and type setting 12

- Typesetting of Text, Structure of Document,
- Line Break and Page Break,
- Fonts and Size,
- Different Environments,
- Cross references,
- Footnotes, Fancy header.

Module-III : Mathematical Type Setting 12

- Typesetting Mathematics, single equation,
- Mathematical Formulas, multiline single equation, multiple equations,
- array and matrix, command for mathematical symbols,
- theorem and lemmas.

Module-IV : Use of Graphicx and Tables. 6

- Graphicx package,
- tabular environment,
- bibliography.

Module-V : Presentation using LaTeX. 6

- Preparing presentation using LaTeX.

Suggested laboratory experiments:

- Computer Laboratory

Pedagogic tools:

- Computers
- LCD and Videos.

Text books

- Tobias Oetiker, Hubert Partl, Irene Hyna and Elisabeth Schlegl, The Not So Short Introduction to LaTeX 2ε, www.ctan.org.
- George Grätzer (2007), More Math into LaTeX, 4th edition, Springer.
- Michael Doob, A Gentle Introduction to TeX, www.ctan.org.
- F. Mittelbach and M Goossens with Braams, Carlisle, and Rowley, The LaTeX Companion, second edition, Addison-Wesley Professional, 2004.

Laboratory Manual/ Book

Suggested reading / E-resources

- www.ctan.org
- https://www.sharelatex.com
- https://tex.stackexchange.com

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II

CIE-II: Content: Modules-I to V

(CIE-I+CIE-II= ---- Marks)

M2) Attendance in Classes

M3) Assignments:

- Program writing for assessing the logical thinking of the learner.
- Question answer sessions.

M4) Class Activity:

- Activity for improving the typing speed in Mathematical notations and equations. (M2+M3+M4= ---- Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC301	**Core 9:** Complex Analysis	**4 Credits – Theory-3hrs / wk Tutorial-2 hrs/wk**

Course Description:

Introduction to Complex Analysis gives advanced students an introduction to the theory of functions of a complex variable, a fundamental area of mathematics. Topics include complex numbers and their properties, analytic functions and the Cauchy-Riemann equations, the logarithm and other elementary functions of a complex variable, integration of complex functions, the Cauchy integral theorem and its consequences, power series representation of analytic functions, the residue theorem and applications to definite integrals. Definitions and proofs will be stressed throughout the course.

Course Purpose:

The course aims to introduce the basic ideas of complex analysis, with particular emphasis on Cauchy's Theorem and the calculus of residues.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand the concept of complex plane and generalize the concept of coordinate plane.	K1
CO_2	Determine continuity/differentiability/analyticity of a complex function and find the derivative of a function.	K1, K2,K3
CO_3	Evaluate a contour integral using parameterization, fundamental theorem of calculus and Cauchy's integral formula.	K1, K4
CO_4	Compute the residue of a function and use the residue theory to evaluate a contour integral or an integral over the real line.	K2,K4
CO_5	Analyze and classify the singularities of complex function in given region.	K1, K3,K4

Course Content **Hours**

Module-I : Introduction to complex plane **(10 Hrs)**

- The extended complex plane and its spherical representation

- Analytic functions, bilinear transformations, their properties and classifications
- Branches of many valued functions with special reference to arg z, log z and z^a, elementary Riemann surfaces
- Definition and properties of conformal mapping.

Module-II : Riemann – Steiltjes integral and cauchy's integral formula (10 Hrs)

- Riemann – Steiltjes integral and ie properties
- Line integral and its properties, fundamental theorem of calculus for line integral
- Leibnitz rule, Taylor's theorem
- Cauchy's integral formula and Cauchy's theorem for analytic functions on an open disc
- Winding number of a closed rectifiable curve with respect to a point outside the curve and its properties
- Cauchy's integral formula first version and second version
- Cauchy's theorem first version.

Module-III : Cauchy – Goursat theorem and its related theorems. (10 Hrs)

- Cauchy – Goursat theorem, Morera's theorem
- Cauchy's inequality, entire functions
- Liouville's theorem, identity theorem
- Fundamental theorem of algebra, maximum modulus theorem and minimum modulus theorem.

Module-IV : Schwartz lemma and Inverse function theorem (9 Hrs)

- Schwartz lemma, meromorphic functions
- Argument principle, Rouche's theorem
- Open Mapping Theorem
- Inverse function theorem.

Module-V : Singularities and their classifications (9 Hrs)

- Isolated singularities, classifications of singularities
- Laurent's series
- Residue theorem
- Evaluation of integrals.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. John B. Conway, (1973), Functions of One Complex Variable, Springer International Student Edition, Narosa Publishing House, Third Edition. (The course is covered by relevant portions from this text book)

Reference Books:-

1. L. V. Ahlfors, (1979), Complex Analysis, International Student Edition, Mc Graw – Hill Book Company.
2. Karunakaran, (2006), Complex Analysis Narosa Publishing House, Second Edition.
3. Dennis G. Zill and Patrik D. Shanahan, (2010), A First Course in Complex Analysis with Applications Jones & Bartlett Second Edition, Student Edition.
4. S. Lang, (1977), Complex Analysis, Addison-Wesley.
5. S. Ponnusamy, (1977), Foundations of Complex Analysis, Narosa Publishing House.
6. D. Sarasan, (1994), Notes on Complex Function Theory, Hindustan Book Age.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- http://web.math.ku.dk/noter/filer/koman-12.pdf
- http://www.maths.lth.se/matematiklu/personal/olofsson/CompHT06.pdf
- http://web.math.ku.dk/noter/filer/koman-12.pdf

Suggested MOOCs

- https://www.coursera.org/learn/complex-analysis
- https://www.mooc-list.com/tags/complex-analysis

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC302	**Core 10: Discrete Mathematics**	**4 Credits – Theory-3hrs / wk Tutorial-2 hrs/wk**

Course Description:

The purpose of this course is to understand and use (abstract) discrete structures that are backbones of computer science. In particular, this class is meant to introduce logic, proofs, sets, relations, functions, counting, and probability, with an emphasis on applications in computer science.

Course Purpose:

1. Understand the algebraic structures including semigroups and monoids.
2. State and prove basic results of homomorphism between semigroups.
3. Understand the concept of Boolean algebra and derive related results.
4. Understand and apply the finite state machine and coding theory.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Write an argument using logical notation and determine if the argument is or is not valid.	K1,
CO_2	Demonstrate the ability to write and evaluate a proof or outline the basic structure of and give examples of each proof technique described.	K1, K2,K3
CO_3	Understand the basic principles of sets and operations in sets.	K1, K4
CO_4	Demonstrate an understanding of relations and functions and be able to determine their properties.	K2,K4
CO_5	Demonstrate different traversal methods for trees and graphs	K1, K3,K4

Course Content **Hours**

Module-I : Semigroups and Monoids 10 hrs

- Semigroups and Monoids
- Homomorphism of Semigroups and Monoids
- Products and Quotients of semigroups

- Fundamental theorem of Homomorphism of Semigroups
- Subsemigroups and submonoids
- Relations, Transitive Closure and Warshall's Algorithm.

Module-II : Latices and Boolean algebra 10 hrs

- Lattices as partially ordered sets, Properties of Lattices
- Lattices as algebraic systems, Sublattices
- Direct product and Homomorphisms of Lattices
- Some Special Lattices
- Finite Boolean Algebras, Functions on Boolean Algebras, Karnaugh Map Method.

Module-III : Languages and Grammars 9 hrs

- Languages and Grammars, Finite State Machines, Semigroups
- Machines and Languages, Moore Machines, Simplification of Machines
- Moore Machines and Regular Languages
- Kleene's Theorem
- Pumping Lemma
- Nondeterministic Finite State Automata.

Module-IV : Logical operations 9 hrs

- Propositions and Logical operations
- Truth tables
- Conditional statements and Logical Equivalence
- Quantifiers, Rules of Inference.

Module-V : Coding Theory 10 hrs

- Elements of Coding Theory
- The Hamming Metric
- The Parity-Check and Generator Matrices
- Group Codes: Decoding with Coset Leaders
- Hamming Matrices.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. Grimaldi, R. P, Discrete and Combinatorial Mathematics,3rd Edition, Addison-Wesley

Publishing Company, 1994.
2. Tremblay, J.P., Manohar,R., Discrete Mathematical Structures with Applications to Computer Science, Tata-McGraw Hill Publishing Company Limited, New Delhi,21st Reprint, 2004.

Reference Books:

1. Johnsonbaugh, R., Discrete Mathematics, Pearson Education,First Indian Reprint,2001.
2. Kolman,B, Busby,R.C., Ross,S.C., Discrete Mathematical Structures, 5th Edition, Pearson Education,2006.
3. Lawson,M.V., Finite Automata, Chapman and Hall/CRC Press, 2004.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://www.geeksforgeeks.org/engineering-mathematics-tutorials/
- http://web.stanford.edu/class/cs103/

Suggested MOOCs

- https://www.coursera.org/learn/discrete-mathematics
- https://www.coursera.org/specializations/discrete-mathematics

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC303	Core 11: Advanced Topics in Linear Algebra	4 Credits – Theory-3hrs / wk Tutorial-2 hrs/wk

Course Description:

This course focuses on some fundamental and advanced concepts of linear algebra. The course deals with concepts of linear algebra which are introduced based on the knowledge the students have gained in their undergraduate programme. Linear algebra is the study of linear systems of equations, vector spaces, and linear transformations. This course introduces students to Canonical Form, Matrices in □□ and Real Quadratic Forms. The concepts of this course will be very useful as a tool to study more advanced topics and also for further research in Linear algebra and other branches of mathematics.

Course Purpose:

The main purpose of this course is the study of Canonical forms and real quadratics form also study of Matrices in □□, this course aims to provide an extensive approach to the topics of linear algebra from the graduation study, which is one of the basic pillars of modern mathematics. This is a required course for all M.Sc. Mathematics majors in the area of applied as well as pure Mathematics. Study of linear algebra develops mathematical maturity in the students.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Remember the basic principles of linear transformation describe characteristic roots and understand representation of linear transformation by matrix.	K1, K2
CO_2	Analyze the Canonical forms	K4
CO_3	Identify rational canonical forms and Demonstrate Jordan forms	K2, K4
CO_4	Develop matrices in □□ and explain Eigen value, determinate and trace	K3, K2
CO_5	Recognize and understand the concept of important transformation and real quadratic forms.	K2, K4

Course Content **Hours**

Module-I : Basic concepts of Linear Transformation 10 hrs

- Quick review of linear transformation (Definition, Algebra, Etc.)
- Characteristic roots
- Representation of linear transformation by matrices

Module-II : Triangular Form and Nilpotent Transformation 10 hrs

- Canonical Forms
- Triangular Form
- Nilpotent transformations

Module-III : Rational Canonical Form and Jordan Forms 10 hrs

- The primary decomposition theorem
- Jordan Form
- Rational canonical Form

Module-IV : Matrices in □□ 8 hrs

- Trace and Transpose
- Determinants
- Cayley-Hamilton theorem

Module-V : Some Important transformations and Real quadratic forms 10 hrs

- Hermitian transformation
- Unitary transformation
- Normal transformation
- Real Quadratic Forms

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. I. N. Herstein, (1975) Topics in Algebra, Second Edition, Wiley Pub., New York.
2. K. Hoffman and R. Kunze, **(**1992**)** Linear Algebra, Prentice Hall of India, New Delhi, Tenth printing.

Reference Books:

1. N. S. Gopalakrishnan, (1998) University Algebra, New Age International (P) Limited, Publishers, New Delhi, Sixth Reprint.
2. M. Artin, (1994) Algebra, Prentice Hall of India, New Delhi.
3. N. Jacobson, (1964) Lectures in Abstract Algebra, Volume II- Linear Algebra, Van Nostrand, East West Press.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://nptel.ac.in/noc/individual_course.php?id=noc19-ma06
- http://www.math.iitb.ac.in/~ars/MA106/slides-I.pdf
- https://nptel.ac.in/courses/111106051/

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion
- (M2+M3+M4=20 Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit**
19PMTCC304	**Core 12: Self-Study Course:** Optimization Techniques.	4 credits- 1hr/week

Course Description:

The course is intended to provide basic understanding of Operation Research Techniques of strategic decision planning for optimum utilization of constraint resources in various span of human life viz. industry, business, commerce, administration, management, service supply, maintenance, agriculture, medicines and healthcare, defense etc. The students will learn purpose, importance and applications of optimization techniques of Operation Research and will be able to design and construct suitable optimization models to solve real life strategic problems – issues. It is expected to emphasis on the algorithmic approach rather than on theoretical side. Mathematical derivations are not included for any topic identified.

Course Purpose:

Objectives of this course are to:

- Introduce students to the techniques of operations research in mining operations
- Provide students with basic skills and knowledge of operations research and its application in mineral industry introduce students to practical application of operations research in big mining projects

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand basic principles of Operation Research Techniques of strategic decision planning.	K1, K2
CO_2	Focus and analyze the optimum utilization of constraint resources in various span of human life.	K3
CO_3	Extend the concepts of Minimax & Maximin principles.	K3, K4
CO_4	Understand the project management by critical path method & project evaluation and review techniques.	K2, K4
CO_5	Understand the theory of queue.	K2, K5

Course Content

Module-I : Theory of Games

- Introduction, Two – Person Zero Sum game

- Pure strategies (Minimax & Maximin principles)
- Games with saddle point
- Rules to determine saddle point

Module-II : Production scheduling (job sequencing) 9

- Introduction, Johnson's algorithm for n jobs 2 machines,
- Johnson's algorithm for N jobs m machines,
- 2 jobs m machines using graphical method.

Module-III : Management of Replacement 9

- Definition, replacement of items that deteriorates,
- Replacement of item that fails completely.

Module-IV : Project Management (CPM & PERT) 10

- Network concepts, components,
- Rules for network construction,
- Critical path method (CPM)
- Project evaluation and Review Techniques (PERT)

Module-V : Theory of Queues 10

- Introduction,
- Queuing system and problem, transient and steady states, traffic intensity,
- Probability distributions in queuing systems,
- Single service queuing model.

Suggested laboratory experiments:

- Tools to be Used - 'R' (Open Source Software available under Windows and Linux) and implementation is to be done in 'R'.

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books:

- J. K. Sharma (2016), Operations Research – Theory and Application, 6th Edition, Macmillan Publishers India Ltd.

Reference Books:

- V. K. Kapur (2011), Operations Research – Problems & Solutions, Sultan Chand & Sons, NewDelhi.
- N. D. Vohra (2009), Quantitative Techniques in Management,4th edition, McGraw Hill Education.

Laboratory Manual/ Book:

- NA

Suggested reading / E-resources

- https://onlinecourses.nptel.ac.in/noc17_mg10/preview
- http://www.orcomplete.com/internet/enesbilgin/open-courses-on-operations-research
- https://swayam.gov.in/courses/1342-introduction-to-operations-research
- https://pe.gatech.edu/degrees/online-masters-degrees/operations-research
- https://orc.mit.edu/academics/course-offerings

Suggested MOOCs

- https://www.classcentral.com/course/edx-optimization-methods-for-business-analytics-6735
- https://online.stanford.edu/courses/mse311-optimization

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTDC301	**Financial Mathematics**	**4 Credits - 4hrs / wk**

Course Description:

This course focuses on financial mathematics which is a interdisciplinary branch of mathematics, economics and financial management. This course deals with option theory and risk free investment. The course covers study of option and their types Ito's lemma, Black- Scholes model, elimination of risk and discrete dividend structure.

Course Purpose:

This course is discipline specific elective course for M.Sc. (Mathematics) programme with focus on modern mathematics. Purpose of this course is to give brief idea of options and their types, financial markets and their types, risk -free investment and simple model for asset prices. The learner will get adequate knowledge of portfolio management with mathematical techniques.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	List the financial markets, distinguish between various options.	K_1, K_2
CO_2	Differentiate between options and contracts; define the terms like portfolio, sensitivity to volatility, risk –free investment and solution of problems on option pricining.	K_2, K_3
CO_3	Introduce simple model for asset prices, proof of Ito's lemma and its extension.	K_3, K_4, K_5
CO_4	Black - Scholes Differential equation and its solution.	K_3, K_4
CO_5	Define discrete dividend structure one jump conditions for the same	K_4, K_5

Course Content **Hours**

Module-I : Introduction to Options and Market (10 Hrs)

- An introduction to options and market
- Basic option theory
- Types of options.

Module-II : Interest Rates and Contracts (10 Hrs)

- Interest rates and present value
- Asset price
- Forward and future contracts.

Module-III : Random walks and Black Sholes model (10 Hrs)

- Random walk, Ito's lemma
- The elimination of randomness
- Black-Sholes model
- Arbitrage theorem, option values.

Module-IV : Black – Sholes formulae (9 Hrs)

- The Black – Sholes formulae
- An initial value problem
- Hedging the practice
- Partial differential equations and Black – Sholes formulae.

Module-V : Variations in Black – Sholes model (9 Hrs)

- Variations in Black – Sholes model to include dividends as well as forward and future contracts
- American Options.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. P. Willmontt, S. Howison and J. Dewynne, (1995), The Mathematics of Financial Derivatives, Cambridge Univ. Press.

Reference Books:

1. Sheldon M. Ross, (2003), An elementary introduction to Mathematical Finance, Cambridge Univ. Press.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://www.emis.de/community/financial-mathematics/index.html
- https://global.oup.com/academic/category/science-and-mathematics/mathematics/mathematical-finance/?cc=in&lang=en&

Suggested MOOCs

- https://www.openlearning.com/courses/introduction-to-financial-mathematics
- https://www.mooc-list.com/tags/financial-mathematics
- https://www.mooc-list.com/course/mathematical-methods-quantitative-finance-coursera.

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=30 Marks)

Semester – III		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTDC302	**DSE-Core- I** Quantitative Foundations of Bioinformatics	**4 Credits –4hrs / wk**

Course Description:
Bioinformatics is the science of extracting biologically relevant information from large sets of biomolecular data. The course will introduce students to the mathematical models, statistical techniques, and algorithms on which this process is based.

Course Purpose:
Upon successful completion, students will have the knowledge and skills to:

1. Identify analyses appropriate for different types of data, and explain their theoretical foundations.
2. Describe, present, and critically evaluate analytical methods, models and theories used in published research, and identify, where relevant, more appropriate alternatives.
3. Apply and extend analytical methods, models and theories to biological datasets.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand , analyze and apply the concept of calculus	K1, K2,K3
CO_2	Identify the proper numerical methods and techniques	K1, K2,K3
CO_3	Understand, analyze and apply the concept of Correlation and regression.	K1, K4
CO_4	Understand Probability Theory	K2,K4
CO_5	Understand types of probability distribution.	K1, K3,K4

Module-I: **10 hrs**
Calculus – Differential Calculus- Derivative of a function, Concept of limit, Continuity, Differentiation, Maxima and Minima of a function, Introduction to Partial Differentiation, Integral Calculus: The Idea of the Integral, The Definite Integrals, Indefinite Integrals.

Module-II **10 hrs**
Numerical Methods – Solution of algebraic and transcendental equations: Bisection method, Method of false position / Regula-falsi method, Newton-Raphson method.
Numerical Descriptive Techniques: Measures of central tendency-mean, median, mode, Partition values-quartiles, deciles, percentiles, Measure of dispersion, Moments, Skewness, Kurtosis.

Module-III **10 hrs**

Correlation and Regression: Principle of least squares, scatter diagram, correlation, covariance, correlation coefficient, properties of correlation coefficient, regression, properties of linear regression, rank correlation, multiple correlation.

Module-IV **10 hrs**

Probability Theory: Classical and modern definition of probability, Sample space and events, independent events, mutually exclusive events, axioms of probability, conditional probability, additional and multiplication theorem of probability, Baye's theorem.

Sampling Theory: Objective of sampling, Sampling error, Methods of sampling, Sampling distribution, Sampling distribution of sample mean and sample proportion, Standard error.

Module-V **10 hrs**

Probability Distribution: Bernoulli's trial, Binomial distribution, Poisson distribution, Poisson approximation to Binomial distribution, Normal and Standard normal distribution, Normal approximation to Binomial (Poisson), Student's t distribution, Chi-square distribution, F-distribution.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text Books:

1. Algebra by Serge A. Lang, Pearson Education. 2003
2. Introduction to Calculus & Analysis, Vol I and II by Richard Courant & Fritz John, Springer publisher.1999.

References:

1. Biostatistics (9th Ed.), Wayne W. Daniel, John Wiley, 2004
2. Statistics (3rd Ed.), Murray R. Spiegel and Larry J. Stephens, Tata McGraw-Hill, 2000

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://bmcbioinformatics.biomedcentral.com/articles/10.1186/1471-2105-7-158
- https://www.biorxiv.org/content/10.1101/015065v1.full

Suggested MOOCs

- https://iubmb.onlinelibrary.wiley.com/doi/full/10.1002/bmb.2006.49403403180
- http://www.cbd.cmu.edu/courses-offered/02-604-fundamentals-of-bioinformatics/

- https://programsandcourses.anu.edu.au/course/BIOL8002

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – IV		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC401	**Core13:** Advanced Topics in Number Theory	**4 Credits - 4hrs / wk**

Course Description:

This course focuses on some fundamental and advanced concepts of Number Theory. The course begins with some fundamental topics, study of Numbers System, divisibility, Prime numbers, Congruences and their related concepts. It also covers some advanced topic like Integral solution of Diophantine equation, Pythagorean triangle, Farey Fraction, Finite Continued Fraction, Infinite Continued Fraction and Periodic Continued Fraction.

Course Purpose:

Number Theory is such a charming subject of mathematics. Many great mathematicians devoted to it because of its wealth of easily accessible and fascinating questions, and its intellectual appeal. Gauss once remarked that "mathematics is the queen of the sciences and Number Theory is the queen of mathematics". The main purpose of this course is study of Number Theory develops mathematical maturity and logical thinking in the students. Students will be able to use continued fractions to develop arbitrarily accurate rational approximations to rational and irrational numbers. They will be able to work with Diophantine equations with integer solutions.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level(K_1 to K_6)**
CO_1	Explain the principles of Number systems, divisibility and primes	K2
CO_2	Explain about Congruences and Chinese remainder theorem and compute congruence related problems and their solution	K2, K3
CO_3	Understand Diophantine equation and apply methods to solve Diophantine equation and convert real world problem in find their solution	K2, K3
CO_4	Recall rational and irrational and explain Farey fraction and continued fraction	K1, K2
CO_5	Explain meaning of approximation to irrational and classify continued fraction.	K2, K4

Course Content	Hours

Module-I : Number System 10 hrs

- Divisibility
- Prime Numbers.

Module-II : Congruences and Related Concepts 10 hrs

- Congruences
- Linear Congruences and Their Solutions.
- Chinese Remainder Theorem

Module-III : Diophantine Equations 9 hrs

- The Equation $ax + by = c$
- Pythagorean Triangles
- Some Assorted Examples.

Module-IV : Farey Fraction and Finite Simple Continued Fraction 9 hrs

- Farey Sequences
- Simple continued Fraction
- Rational Approximation
- The Euclidean Algorithm

Module-V : Infinite Continued Fraction 10 hrs

- Infinite Continued Fraction
- Irrational Numbers
- Approximation to Irrational Numbers
- Periodic Continued Fraction

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. Ivan Niven, Herbert S. Zuckerman, Hugh L. Montgomery, (2008) The Theory Of

Numbers, John Wiley & Sons Inc.
2. Burton David M., (2017) Elementary Number Theory, (Seventh Edition) McGraw Hill Education.

Reference Books:

3. Z. I. Borevich And I. R. Shafarevich, (1986) Number Theory, Academic Press, New York
4. J. W. S. Cassels (1971) An Introduction To The Geometry Of Numbers, Springer-Verlag Berlin New York

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://nptel.ac.in/courses/111103020/
- https://wstein.org/ent/ent.pdf
- https://artofproblemsolving.com/articles/files/SatoNT.pdf
- https://www.isinj.com/mt-aime/250%20Problems%20in%20Elementary%20Number%20Theory%20-%20Sierpinski%20(1970).pdf

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:
Seminar on topics for the exploration of the content.
Question answer sessions.

M4) Class Activity:
Surprise Quiz
Group discussion
(M2+M3+M4=20 Marks)

Semester - IV		
Course Code	**Course Title**	**Course Credit**
19PMTCC402	**Core 14: Functional Analysis**	**4 Credits –** **Theory-3 hrs / wk** **Tutorial- 2 hrs / wk**

Course Description:

This course is for students who are majors in pure mathematics or who need functional analysis in their applied mathematics courses. The objective of the module is to study linear mappings defined on Banach spaces and Hilbert spaces, especially linear functionals , C[0, 1] and some sequence spaces. In particular, the four important theorems in functional analysis, namely, Hahn-Banach theorem, uniform boundedness theorem, open mapping theorem and Closed graph theorem will be covered. It mentions representation of functional by applying Riesz' theorems in different forms.

Course Purpose:

Upon completion of the course students will be able to understand the concept of Normed Linear Spaces and Banach Spaces. They will be having the ability to classify the weak and strong convergence of sequences and understand the structures of Inner Product Spaces and Hilbert Spaces.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand the concept of Normed Linear Spaces and Banach Spaces.	K1, K2
CO_2	Classify the weak and strong convergence of sequences.	K2, K3
CO_3	Apply uniform boundedness theorem.	K3
CO_4	Understand the structures of Inner Product Spaces and Hilbert Spaces.	K2
CO_5	Apply the Hahn-Banach Theorem.	K4

Course Content

Module-I : Normed Linear Spaces and Banach Spaces (10 Hrs)

- Normed linear spaces

- Banach spaces
- Quotient space of a normed linear spaces and its completeness
- Bounded linear transformations
- Normed linear spaces of bounded linear transformations
- Dual spaces with examples.

Module-II : Convergence in Normed Linear Spaces (10 Hrs)

- Weak convergence in normed linear spaces, equivalent norms, Riesz lemma
- Basic properties of finite dimensional normed linear spaces and compactness
- weak convergence in normed linear spaces, reflexive spaces.

Module-III : Uniform Boundedness theorem and its consequences. (10 Hrs)

- Uniform Boundedness theorem and its consequences
- Open mapping theorem, closed graph theorem
- Hahn-Banach theorem for normed linear spaces
- Compact operations, solvability of linear equations in Banach spaces
- The closed range theorem.

Module-IV : Inner Product Spaces and Hilbert Spaces (9 Hrs)

- Inner product space
- Hilbert space
- Orthonormal sets
- Bessel's inequality
- Complete orthonormal sets
- Parseval's identity.

Module-V : Structure of Hilbert Spaces (9 Hrs)

- Structure of Hilbert spaces
- Projection theorem
- Riesz representation theorem for bounded linear functional on Hilbert spaces
- Reflexivity of Hilbert spaces.

Suggested laboratory experiments:

- Not Applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books:

1. E. Kreyszig, (1995), Introductory Functional Analysis with Applications**,** John Wiley and Sons, New york.

Reference Books:

1. Bachman G. and Warici L, (1966), Functional Analysis, Academic Press.
2. Convway J. B., (1990), A Course in Functional Analysis, Springer-verlag, Newyork.
3. Krishnan V. K., (2001), Text Book of Functional Analysis; A Problem oriented approach, Printice Hall of India.
4. Tayor A. E., Introduction to Functional analysis, John Wiley and Sons, Newyork, 1958.

Laboratory Manual/ Book:

- Not Applicable

Suggested reading / E-resources:

- https://www.maths.lancs.ac.uk/~belton/www/notes/fa_notes.pdf
- http://personal.lse.ac.uk/sasane/ma412.pdf

Suggested MOOCs:

- https://nptel.ac.in/courses/111105037/
- https://www.mooc-list.com/course/introduction-functional-analysis-coursera

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester - IV		
Course Code	**Course Title**	**Course Credit**
19PMTCC403	**Core 15: Advanced Topics in Graph Theory**	**4 Credits – Theory-3 hrs / wk Tutorial- 2 hrs / wk**

Course Description:

The course treats graph theoretical notions and problems, and the use of algorithms, both in the mathematical theory of graphs and its applications. In the course, the basic theory of graphs of different kinds is developed in detail, especially simple graphs, digraphs, bipartite graphs, complete graphs, Eulerian graphs, Hamiltonian graphs, trees, planar graphs and graph coloring. In the course some of the algorithms that totally or partly solve graph theoretical problems are presented. An example of such a problem is to find a minimal spanning tree by using Kruskal's algorithm and prime's algorithm. The theory for planar graphs and detection of planarity also plays an important role in the graph theory. Further, the theory of vertex and edge coloring, including four color problem are presented.

Course Purpose:

Objectives of this course are to:

This course is aimed to cover a variety of different problems in Graph Theory. In this course students will come across a number of theorems and proofs. Theorems will be stated and proved formally using various techniques. Various graphs algorithms will also be taught along with its analysis.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Understand and apply the fundamental concepts in graph theory	K1, K2
CO_2	Characterize the Euler and Hamiltonian Graphs	K2, K3
CO_3	Analyze the principles and concepts of graph theory in practical situations	K3
CO_4	Validate and critically assess a mathematical proof;	K3, K4
CO_5	Describe and apply some basic algorithms for graphs	K2, K5

Course Content

Module-I : Basic concepts related to graphs

- A quick review of Graph
- Degree of a vertex
- Path
- Circuit

- Connected and disconnected graphs
- Components.

Module-II : Eulerian and Hamiltonian graphs 10

- Euler trail, Euler tour, Euler Graph
- Characterizations of Eulerian graph
- Hamiltonian Paths and Cycles.

Module-III : Trees 10

- Trees and their properties
- Bridges
- Spanning trees
- Kruskal's algorithm
- Prime's algorithm

Module-IV : Planar graphs& Matching 9

- Planar Graphs
- Matching
- Augmenting path
- Kuratowski's two graphs
- Different representation of planarity
- Detection of Planarity.

Module-V : Graph coloring 9

- Coloring of graphs
- Chromatic number
- Chromatic polynomial
- The four color problem.

Suggested laboratory experiments:

- Not Applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books:

- J. Clark and D. A. Hotton (1995), A first Look at Graph Theory, World Scientific Publishing Co. Pte. Ltd.
- F. Harary (1969), Graph theory,Addision – Wesley.

Reference Books:

- R. J. Wilson (2015), Introduction to Graph theory,Fifth edition, Pearson Education Asia.
- R. J. Wilson and J. J. Watkins (1990), Graphs: An introductory approach, Jon Wiley& Sons Inc.

Laboratory Manual/ Book:

- Not Applicable

Suggested reading / E-resources:

- https://www.khanacademy.org/science/organic-chemistry/stereochemistry-topic

Suggested MOOCs:

- Algorithms on Graphs-Coursera
- Introduction to graph theory- Class central

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – IV		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTCC404	**Core 16: Differential Geometry**	**4 Credits - 4hrs / wk**

Course Description:
This course focuses on Differential Geometry. It is a branch of Mathematics in which techniques of differential calculus are used to understand the concepts of geometry. The study deals with local curve and local surface theories.

Course Purpose:
This is one of the fundamental courses for all M.Sc. mathematics majors with focus on various aspects of Differential Geometry .The content of this course is intended to introduce the concepts like regular curve, re- parameterization of curve, unit curve, Frenet - Serret apparatus , Frenet - Serret theorem,Simple surface, first and second fundamental firms as well as Christoffel symbols.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Define functions of class K, regular curve, Unit speed curve, re- parameterization of curves, Curvature of a curve.	K_1, K_2
CO_2	Conpute arc length and re- parameterization of a curve by its are length.	K_1,K_2, K_3
CO_3	Define Frenet - Serret apparatus ,prove Frenet - Serret theorem, conpute the Frenet - Serret apparatus for the given curve.	K_3, K_4
CO_4	Difine simple surface and study of various surfaces.	K_1, K_4
CO_5	Define first and second fundamental forms as well as Christoffel symbols ,compute first - second fundamental forms and Christoffel symbols for the given surface.	K_4, K_5, K_6

Course Content **Hours**

Module-I : Local Curve Theory **(10 Hrs)**

- Local theory of curves, space curves, examples
- Planar curves, Helices, Frenet – Serret apparatus
- Existence of space curves
- Involutes and evolutes of curves.

Module-II : Local Surface Theory **(10 Hrs)**

- Local theory of surfaces – parametric patches on surface
- First Fundamental form and arc length.

Module-III : Curvature and related concepts **(10 Hrs)**

- Normal curvature
- Geodesic curvature and Gauss formulae
- Shape operator Lp of a surface at a point, vector field a curve.

Module-IV : Fundamental forms **(9 Hrs)**

- Second and third fundamental forms of a surface
- Weingarten map
- Principal curvatures, Gaussian curvature, mean and normal curvatures.

Module-V : Riemannian Curvature **(9 Hrs)**

- Riemannian curvatures, Gauss theorem of Egregium
- Isometric groups and fundamental existence theorem for surfaces.

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. R. S. Milman and G. D. Parker, (1977), Elements of Differential Geometry, Prentice – Hall.
2. J. A. Thorpe, Introduction to Differential Geometry, Springer – Verlag.

Reference Books:

1. B. O' Neil, (1966), Elements of Differential Geometry, Academic Press.
2. M. Docermo, (1976), Differential Geometry of curves and surfaces, Prentice – Hall.
3. S. Sternberg, (1964), Lecture notes on Differential Geometry, Prentice – Hall.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- https://people.math.gatech.edu/~ghomi/LectureNotes/index.html
- https://people.math.ethz.ch/~salamon/PREPRINTS/diffgeo.pdf

Suggested MOOCs

- https://ocw.mit.edu/courses/mathematics/18-950-differential-geometry-fall-2008/
- https://www.mooc-list.com/tags/differential-geometry

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)

Semester – IV		
Course Code	**Course Title**	**Course Credit and hrs**
19PMTDC401	DSE Core I1: Mathematical Statistics	4 Credits - 4hrs / wk

Course Description:

Mathematics and statistics permeate modern life. The study of these subjects leads to the acquisition of new knowledge, new skills and a new language for communication. Below we outline the general curricular themes we see as common to all of our programs. Precise learning outcomes that are consistent with these themes and that are feasible to evaluate have been incorporated into our departmental learning outcomes.

Course Purpose:

1. Understand the statistical parameters.
2. Analyse sampling and sampling distributions.
3. Test the given data using student tests.
4. Test the hypotheses using various techniques.

Course Outcomes: Upon completion of this course, the learner will be able to		
CO No.	**CO Statement**	**Blooms taxonomy Level (K_1 to K_6)**
CO_1	Provide a concise and clear description of a statistical problem	K1,K2
CO_2	Provide a description of the method used for analysis, including a discussion of advantages, disadvantages, and necessary assumptions.	K1, K2,K3
CO_3	Provide a discussion of the results and of the statistical analysis.	K2, K3
CO_4	Provide a conclusion to the study including a discussion of limitations of the analysis.	K1,K4
CO_5	Provide a derivation for mathematical statistics problems.	K2, K3

Course Content **Hours**

Module-I : Probability of Events 10 hrs

- Introduction
- Counting Techniques, Probability Measure, Some Properties of the Probability Measure, Conditional Probability
- Distribution Functions of Discrete Variables, Distribution Functions of Continuous Variables
- Percentile for Continuous Random Variables
- Moments, Expected Values, Variances, Moment Generating Functions of Random Variables

- Chebychev Inequality

Module-II : Discrete Distributions and Continuous Distributions 10 hrs

- Bernoulli Distribution
- Binomial Distribution
- Geometric Distribution
- Negative Binomial Distribution
- Poisson Distribution
- Uniform Distribution
- Gamma Distribution
- Chi-Square distribution
- Exponential Distribution
- Normal Distribution

Module-III : Bivariate Random Variables and Their Distributions 10 hrs

- Bivariate Discrete Random Variables
- Bivariate Continuous Random Variables
- Conditional Distributions
- Independence of Random Variables
- Distribution of Sample Mean and Variance
- Laws of Large Numbers
- The Central Limit Theorem
- Chi-square distribution
- Student's t-distribution
- Snedecor's F-distribution
- Order Statistics

Module-IV : Point Estimators of Parameters and Their Properties 10 hrs

- Moment Method
- Maximum Likelihood Method
- The Unbiased Estimator
- The Relatively Efficient Estimator
- Minimum Variance Unbiased Estimator
- Consistent Estimator

Module-V : Statistical Inference 10 hrs

- Test of significance for Large Samples: Difference between Small & Large Samples;
- Two-tailed test for Difference between the Means of Two Samples;
- Standard Error of the Difference between two Standard Deviations.
- Tests of significance for Small Samples: The Assumption of Normality;

- Students' t-Distribution; Properties & Applications of t-Distribution;
- Testing Difference between Means of Two Samples (Independent Samples; Dependent Samples)
- Definition of chi-square; Degrees of freedom; chi-square Distribution; Conditions for Applying chi square
- Test; Uses of chi-square Test; Misuse of chi-square Test

Suggested laboratory experiments:

- Not applicable

Pedagogic tools:

- Chalk and Board
- LCD and Videos.

Text books

1. Probability and Mathematical Statistics, Prasanna Sahoo Louisville, USA
2. S P Gupta, "Statistical Methods", 30th edition S Chand.
3. S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics (11th Edition), Sultan Chand & Sons.

Reference Books:

1. Anderson, Sweeney, Williams, "Statistics for business and economics", 9th edition, Thomson Publication.
2. Johnson Richard A., Miller and Freund's - Probability and Statistics (8th Edition) , PHI.

Laboratory Manual/ Book

- Not applicable

Suggested reading / E-resources

- http://imstat.org/en/index.html

Suggested MOOCs

- https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-042j-mathematics-for-computer-science-fall-2010/index.htm
- Mathematical Statistics I - UCCS MathOnline Couse 481

Methods of assessing the Course Outcomes

The COs of the course will be assessed through

M1) CIE-I: Content: Modules I and II
CIE-II: Content: Modules-I to V
(CIE-I+CIE-II: 5+15=20 Marks)

M2) Attendance in Classes

M3) Assignments:

- Seminar on topics for the exploration of the content.
- Question answer sessions.

M4) Class Activity:

- Surprise Quiz
- Group discussion

(M2+M3+M4=20 Marks)