

**Department of Mathematics**  
**Amrita Vishwa Vidyapeetham, Amritapuri campus**  
**Curriculum and Syllabus Revision –Year 2022-23 onwards**  
**Integrated MSc in Mathematics with Minor in Data Science**

Course Code	Course Title	L	T	P	Cr	ES	Course Code	Course Title	L	T	P	Cr	ES
<b>SEMESTER 1</b>							<b>SEMESTER 2</b>						
22MAT103	Single Variable Calculus	3	1	0	4		22MAT113	Multivariable Calculus	3	1	0	4	
22PHY102	Introduction to Mechanics	3	1	0	4		22MAT114	Ordinary Differential Equations	3	1	0	4	
22MAT104	Vectors and Geometry	3	1	0	4		22MAT115	Discrete Mathematics	3	1	0	4	
21ENG101	Communicative English	2	0	2	3		22CSA112	Introduction to Programming II	3	0	2	4	
22CSA102	Introduction to Programming I	3	0	2	4		21ENG111	Professional Communication	1	0	2	2	
	Language I	1	0	2	2		21CUL111	Cultural Education II	2	0	0	2	
21CUL101	Cultural Education I	2	0	0	2		22MAT182	Mathematics Lab II	0	0	2	1	
22MAT181	Mathematics Lab I	0	0	2	1			Language II	1	0	2	2	
							22AVP103	Mastery Over Mind	1	0	2	2	
	TOTAL				<b>24</b>			TOTAL				<b>25</b>	
<b>SEMESTER 3</b>							<b>SEMESTER 4</b>						
22MAT206	Introduction to Linear Algebra	3	1	0	4		22MAT216	Numerical Methods	3	0	2	4	
22MAT207	Transforms & PDE	3	1	0	4		22MAT217	Introduction to Real Analysis	3	1	0	4	
22MAT208	Introduction to Probability and Statistics	3	1	0	4		22MAT218	Introduction to Abstract Algebra	3	1	0	4	
22CSA202	Data Structures & Algorithms	3	1	0	4		22MAT219	Statistical Inference	3	1	0	4	
22MAT283	Computing using R (Lab 1)	0	0	2	1		22MAT285	Computing Using R (Lab 2)	0	0	2	1	
22MAT284	Mathematics Lab 3	0	0	2	1		21AVP211	Amrita Value Programme II	1	0	0	1	
22MAT209	Problem solving Session I	0	1	0	1		21ENV200	Environmental Science and sustainability	3	0	0	3	
21AVP201	Amrita Value Programme I	1	0	0	1								
	TOTAL				<b>20</b>			TOTAL				<b>21</b>	
<b>SEMESTER 5</b>							<b>SEMESTER 6*</b>						
22MAT306	Real Analysis	3	1	0	4			Elective 1	3	0	0	3	
22MAT307	Introduction to Complex Analysis	3	1	0	4		22MAT316	ODE & Calculus of Variations	3	1	0	4	
22MAT391 <sup>@</sup>	Open Elective / Live in Lab <sup>@</sup>	3	0	0	3		22MAT317	Optimization Techniques	3	0	2	4	
22MAT308	Operations Research	3	0	2	4		22MAT318	Complex Analysis	3	1	0	4	
22CSA301	Introduction to Data Science	3	0	2	4		22CSA311	Introduction to Machine Learning	3	0	2	4	
22MAT309	Problem Solving Session II	0	1	0	1		22MAT319	Problem Solving Session III	0	1	0	1	
21SSK201	Life Skills I	1	0	2	2		21SSK211	Life skills II	1	0	2	2	
	TOTAL				<b>22</b>			TOTAL				<b>22</b>	
								TOTAL (for Exit-option students)				<b>134</b>	
<b>SEMESTER 7</b>							<b>SEMESTER 8</b>						
22MAT506	Abstract Algebra	3	1	0	4		22MAT515	Measure and Integration	3	1	0	4	
22MAT507	Advanced Linear Algebra	3	1	0	4		22MAT516	Multivariate Statistics	3	0	2	4	
22MAT508	PDE & Integral Equations	3	1	0	4			Elective 3	3	0	0	3	
	Elective 2	3	0	0	3		22MAT517	Topology	3	1	0	4	
22CSA503	Advanced Machine Learning	3	0	2	4			Data Science Elective	3	0	0	3	
22MAT509	Problem Solving Session IV	0	1	0	1		22MAT519	Problem Solving Session V	0	1	0	1	
22MAT590	Seminar	0	0	2	1								
21SSK301	Life Skills III	1	0	2	2								
	TOTAL				<b>23</b>			TOTAL				<b>19</b>	
<b>SEMESTER 9</b>							<b>SEMESTER 10</b>						
22MAT604	Functional Analysis	3	1	0	4		22MAT698	Project				15	
	Elective 4	3	0	0	3								
22MAT691	Mini Project				6								
	TOTAL				<b>13</b>			TOTAL				<b>15</b>	
								TOTAL				<b>204</b>	

\* At the end of 6<sup>th</sup> semester, students who wish to exit the programme may do so on specific request to the concerned Head of the institution.

@ Course code for Live in Lab

## LANGUAGES

LANGUAGES										
Paper I					Paper II					
21TAM101	Tamil I	1 0 2	2	B	21TAM111	Tamil II	1 0 2	2	B	
21HIN101	Hindi I	1 0 2	2	B	21HIN111	Hindi II	1 0 2	2	B	
21MAL101	Malayalam I	1 0 2	2	B	21MAL111	Malayalam II	1 0 2	2	B	
21SAN101	Sanskrit I	1 0 2	2	B	21SAN111	Sanskrit II	1 0 2	2	B	

## List of Elective Courses

Mathematics Stream				Statistics Stream			
22MAT541	Commutative Algebra	3 0 0	3	22MAT570	Stochastic Processes	3 0 0	3
22MAT542	Algebraic Geometry	3 0 0	3	22MAT571	Sampling Theory	3 0 0	3
22MAT543	Algebraic Topology	3 0 0	3	22MAT572	Principles Of Experimental Design	3 0 0	3
22MAT544	Introduction To Coding Theory	3 0 0	3	22MAT573	Statistical Quality Control And Six Sigma Quality Analysis	3 0 0	3
22MAT545	Lie Algebras	3 0 0	3	22MAT574	Statistical Pattern Classifications	3 0 0	3
22MAT546	Theory Of Manifolds	3 0 0	3	22MAT575	Time Series Analysis	3 0 0	3
22MAT547	Harmonic Analysis	3 0 0	3	22MAT576	Queuing Theory And Inventory Control	3 0 0	3
22MAT548	Wavelets Analysis	3 0 0	3	22MAT577	Regression Analysis	3 0 0	3
22MAT549	Fixed Point Theory	3 0 0	3	22MAT578	Bayesian Statistics	3 0 0	3
22MAT550	Nonlinear Partial Differential Equations	3 0 0	3	22MAT579	Actuarial Statistics	3 0 0	3
22MAT551	Fractals	3 0 0	3				
22MAT552	Differential geometry	3 0 0	3				
Computer Science Stream				Data Science Elective			
22MAT561	Advanced Data Structures And Algorithms	3 0 0	3	22CSC531	Advanced Topics in Deep Learning	3 0 0	3
22MAT562	Fuzzy Sets And Its Applications	3 0 0	3	22CSC532	Advanced Topics in Machine Learning	3 0 0	3
22MAT563	Graph Theory	3 0 0	3	22CSC533	Data Base Management for Big Data	3 0 0	3
22MAT564	Advanced Graph Theory	3 0 0	3	22CSC534	Data Visualization	3 0 0	3
22MAT565	Introduction To Soft Computing	3 0 0	3				
22MAT566	Computer Aided Design Of VLSI Circuits	3 0 0	3				
22MAT567	Cryptography	3 0 0	3				
22MAT568	Formal Languages And Automata Theory	3 0 0	3				
22MAT569	Algorithms For Advanced Computing	3 0 0	3				

## OPEN ELECTIVES

Open Electives UG				
Course Code	Course Title	L – T – P	Cr.	ES
21OEL231	A Journey towards Free India	3 0 0	3	J
21OEL232	Political Leadership	3 0 0	3	J
21OEL233	Social issues in Contemporary India	3 0 0	3	J
21OEL234	The Story of Indian Business	3 0 0	3	J
21OEL235	Industrial Psychology	3 0 0	3	J
21OEL236	Advertising	3 0 0	3	J
21OEL237	Basic Statistics	3 0 0	3	J
21OEL238	Citizen Journalism	3 0 0	3	J
21OEL239	Creative Writing for Beginners	3 0 0	3	J
21OEL240	Desktop Support and Services	3 0 0	3	J

21OEL241	Development Journalism	3 0 0	3	J
21OEL242	Digital Photography	3 0 0	3	J
21OEL243	Emotional Intelligence	3 0 0	3	J
21OEL244	Essence of Spiritual Literature	3 0 0	3	J
21OEL245	Film Theory	3 0 0	3	J
21OEL246	Fundamentals of Network Administration	3 0 0	3	J
21OEL247	Gender Studies	3 0 0	3	J
21OEL248	Glimpses of Indian Economy and Polity	3 0 0	3	J
21OEL249	Graphics and Web-designing Tools	3 0 0	3	J
21OEL250	Green Marketing	3 0 0	3	J
21OEL251	Healthcare and Technology	3 0 0	3	J
21OEL252	History of English Literature	3 0 0	3	J
21OEL253	Indian Writing in English	3 0 0	3	J
21OEL254	Industrial Relations and Labour Welfare	3 0 0	3	J
21OEL255	Introduction to Ancient Indian Yogic and Vedic Wisdom	3 0 0	3	J
21OEL256	Introduction to Computer Hardware	3 0 0	3	J
21OEL257	Introduction to Event Management	3 0 0	3	J
21OEL258	Introduction to Media	3 0 0	3	J
21OEL259	Introduction to Right to Information Act	3 0 0	3	J
21OEL260	Introduction to Translation	3 0 0	3	J
21OEL261	Linguistic Abilities	3 0 0	3	J
21OEL262	Literary Criticism and Theory	3 0 0	3	J
21OEL263	Macro Economics	3 0 0	3	J
21OEL264	Managing Failure	3 0 0	3	J
21OEL265	Media Management	3 0 0	3	J
21OEL266	Micro Economics	3 0 0	3	J
21OEL267	Micro Finance, Small Group Management and Cooperatives	3 0 0	3	J
21OEL268	Negotiation and Counselling	3 0 0	3	J
21OEL269	New Literatures	3 0 0	3	J
21OEL270	Non-Profit Organization	3 0 0	3	J
21OEL271	Personal Effectiveness	3 0 0	3	J
21OEL272	Perspectives in Astrophysics and Cosmology	3 0 0	3	J
21OEL273	Principles of Marketing	3 0 0	3	J
21OEL274	Principles of Public Relations	3 0 0	3	J
21OEL275	Science, Society and Culture	3 0 0	3	J
21OEL276	Statistical Analysis	3 0 0	3	J
21OEL277	Teamwork and Collaboration	3 0 0	3	J
21OEL278	The Message of Bhagwad Gita	3 0 0	3	J
21OEL279	Understanding Travel and Tourism	3 0 0	3	J
21OEL280	Videography	3 0 0	3	J
21OEL281	Vistas of English Literature	3 0 0	3	J
21OEL282	Web-Designing Techniques	3 0 0	3	J
21OEL283	Organic Farming	3 0 0	3	J
21OEL284	Basic Legal Awareness on Protection of Women and Rights	3 0 0	3	J
21OEL285	Ritual Performances of Kerala	3 0 0	3	J
21OEL286	Documenting Social Issues	3 0 0	3	J
21OEL287	Fabrication of Advanced Solar Cell	3 0 0	3	J

21OEL288	Basic Concepts of X-ray Diffraction	3 0 0	3	J
21OEL289	Introduction to FORTRAN and GNUPLOT	3 0 0	3	J
21OEL290	Introduction to Porous Materials	3 0 0	3	J
21OEL291	Forensic Science	3 0 0	3	J
21OEL292	Introduction to solar Physics	3 0 0	3	J
21OEL293	Recycling Recovery and Treatment Methods for Wastes	3 0 0	3	J
21OEL294	Acting and Dramatic Presentation	2 0 2	3	J
21OEL295	Computerized Accounting	2 0 2	3	J
21OEL296	Kerala Mural Art and Painting	2 0 2	3	J
21OEL297	Painting	2 0 2	3	J
21OEL298	Reporting Rural Issues	3 0 0	3	J

**Integrated MSc in Mathematics with Minor in Data Science  
2022 Revised Syllabus**

**Semester 1**

**22MAT103**

**Single Variable Calculus**

**(3 1 0 4)**

**Course Outcome:**

CO1: Understand the elementary functions and concepts of limit, continuity, derivative and integral

CO2: Study techniques of differentiation and use it in optimization problems and curve sketching

CO3: Defining Integral as a sum and review integration techniques

CO4: Use of integrals for the computation of areas, volumes and arc length

CO5: Discuss some basic concepts in the theory of infinite series with some insight to Power series.

**Unit 1**

Functions-domain, range, graphs of elementary functions, limits - left limit, right limit, and continuity, definition of derivative, derivative as rate of change, implicit differentiation, and review of differentiation techniques.

**Unit 2**

Extreme values of functions, critical points, graphing with  $y''$ , asymptotes, optimization problems, linearization and differentials, L'Hospital's Rule. Riemann sums and definite integrals (just some elementary examples, not the proof), Area, Fundamental theorem of Calculus.

### Unit 3

Review of Integration techniques, Area between curves, Volumes of solids of revolution – washer method and cylindrical shell method, Length of plane curves.

### Unit 4

Areas of surfaces of revolution, Moments and centres of Mass, Sequences, Infinite series as a limit of sequence, Integral test, Comparison tests, Ratio and Root tests.

### Unit 5

Alternating Series, Absolute and Conditional convergence, Power series, Taylor and Maclaurin Series, Error estimates, Applications of Power Series.

Textbook:

Thomas and Finney, *Calculus and Analytic Geometry*, 11<sup>th</sup> edition, Pearson.

References:

N. Piskunov, *Differential and Integral Calculus Vol. I and II*, CBS Publishers.

H. Anton, I. Bivens, S. Davis, *Calculus*, Wiley.

## 22MAT104

## Vectors and Geometry

(3 1 0 4)

### Course Outcome:

**CO1:** Understand the parametric equations of curves and surfaces ,find the vector equations of the lines and planes.

**CO2: Understand to** describe the velocity and acceleration associated with a vector-valued function  
Use vector-valued function to analyze projectile motion

**CO3** Understand to set up and evaluate definite integrals in two dimensions using polar coordinates.  
Change from polar to rectangular coordinates and vice versa

**CO4:** Understand to find unit tangent vector at a point on a space curve ,the tangential and normal components of acceleration, arc length of a space curve the curve at a point on the curvature .

**CO5:** Understand to use cylindrical and spherical coordinates to represent surfaces in space

### Unit 1

Review of Conic Sections, Eccentricity, Quadratic Equations and Rotations, Parametrization of plane curves, Polar coordinates, Graphing in polar coordinates, Areas and Lengths in polar coordinates, Conic Sections in Polar Coordinates.

### Unit 2

Review of vectors (Dot product, Cross product, Unit vector), Lines and Planes in Space, Cylinders and Quadric Surfaces, level curves.

### Unit 3

Vector Functions, Modeling projectile motion, Arc length, Unit Tangent Vector, Curvature and Unit Normal Vector.

#### **Unit 4**

Double integrals, Areas, Moments and Centers of mass, Double integrals in polar form, Triple integrals in Rectangular Coordinates.

#### **Unit 5**

Applications, Triple integrals in cylindrical and spherical coordinates, Change of variables.

Textbook:

Thomas and Finney, *Calculus and Analytic Geometry*, 11<sup>th</sup> edition, Pearson.

References:

N. Piskunov, *Differential and Integral Calculus Vol. I and II*, CBS Publishers.

H. Anton, I. Bivens, S. Davis, *Calculus*, Wiley.

### **22PHY102**

### **Introduction to Mechanics**

**(3 1 0 4)**

#### **Course Outcome:**

CO1: apply to the concepts of measurements, estimating order of magnitudes, vectors, kinematics in one dimension, projectile and circular, and relative motions.

CO2: apply Newton's law of motion to solve, with the help of a free-body diagram, for forces of equilibrium or acceleration, under contact forces, uniform gravity, for rectilinear and circular motions.

CO3: apply the concepts of kinetic energy, work – dot product of force and displacement, work-kinetic energy theorem for constant, spring and general variable forces, power, potential energy and relation to conservative forces, conservation energy, identify types of equilibrium,

CO4: apply Newton's law for center of mass motion, linear momentum and its conservation for collision problems.

CO5: apply concepts of rotation – angle, angular velocity, angular acceleration, torque, inertia, angular oscillations, angular momentum and its conservation, describe gyroscope motion.

CO6: apply Hooke's law, simple harmonic motion, free, damped and forced oscillations, resonance, describe aspects of wave motion, speed, wave equation, traveling waves, interference, standing waves, and resonance.

Unit 1 Measurement: standards of mass, length and time, dimensional analysis, estimation and order of magnitude calculations.

Kinematics: Motion in one dimension; Vectors; Motion in 2D: vectors of displacement, velocity and acceleration, projectile and uniform circular motion; relative motion, relative velocity and relative acceleration.

Unit 2 Laws of motion: concepts of force and mass, Newton's laws, reference frames, gravitational force, free body diagram analysis for simple applications, friction and contact forces; drag force and terminal speed, uniform circular motion.

Unit 3 Work and kinetic energy: scalar product of two vectors, kinetic energy and work-kinetic energy theorem, work done by gravitational and spring forces, power; Work and potential energy, conservative and nonconservative forces, conservative forces from potential energy, energy diagrams and equilibrium; Conservation of energy: examples without and with friction, power.

Unit 4 Linear momentum and Conservation: linear momentum and conservation in an isolated system of two particles, impulse, elastic and inelastic collisions in 1D; basic ideas (simple exercises only) on the concepts of centre of mass and dynamics of system of particles.

Rotational motion about fixed axis: Rotational variables, linear and angular variables, rotational kinetic energy and inertia, torque, Newton's law for rotation, work; rolling – combined translation and rotation; elementary discussions on angular momentum and its conservation.

Unit 5 Oscillations: simple harmonic motion, linear spring and Hooke's law, motion of mass on a spring, angular frequency, period, phase, angular oscillations and pendulums, small angle (linear) approximation, connection with uniform circular motion, average kinetic and potential energies, friction and damping, damped and forced oscillations, resonance, power absorption, Q-value, superposition principle.

Introduction to wave motion (selected topics and simple exercises only): propagation of disturbance, traveling wave on string, speed, reflection and transmission, energy transfer, linear wave equation; Sound: Basic description of sound as travelling wave of pressure variations, elementary discussions on superposition and interference, boundary conditions, standing waves and quantization of frequency, sonometer, resonance in sonometer.

#### Textbook/References

1. Serway and Jewett, Physics for Scientists and Engineers, 9E, Cengage Learning, 2013. Ch. 1 – 8, Ch. 9, 10 (lightly), Ch. 15, topics culled from Ch. 16 – 18.
2. C. Kittel et al, Mechanics – Berkeley Physics Course Vol. 1, 2E, Ch. 1 – 7, McGraw-Hill
3. D. Halliday, R. Resnick and J. Walker, Fundamentals of Physics, 10E, Ch. 2 – 11, 15 – 17.
4. Halliday, Resnick, and Krane, Physics, Vol. 1, 5th Ed., Wiley Indian Reprint, 2007
5. Feynman, Leighton and Sands, The Feynman Lectures on Physics, Vol.1, Narosa.

**22CSA102**

**Introduction to Programming I**

**(3-0-2-4)**

#### **Course Outcome:**

CO1: Understand the foundation concepts of information and information processing in computer systems, data representation, coding systems.

CO2: Understand programming language syntax and its definition by example of Python.

CO3: Adequately use standard programming constructs: repetition, selection, functions, composition, modules, aggregated data (arrays, lists, etc.)

CO4: Identify and repair coding errors in a python program

CO5: Use library software for (e.g.) building a graphical user interface, or mathematical software.

CO6: Understand function concept and how to deal with function arguments and parameters

### **Unit 1**

Introduction to Computers and Programming: Hardware and software; binary representation of numbers, working of a program, high-level languages, compilers and interpreters; Installing python, editors, integrated development environment, writing and running programs.

Introduction to programming: Designing a program: development cycle, pseudo code, flowcharts and algorithm development; variables, numerical data types and literals, strings, assignment and reassignment, input/output, formatted output, reading numbers and strings from keyboard; performing calculations: floating point and integer division, converting math formulas to programming statements, standard mathematical functions, mixed-type expressions and data type conversions.

### **Unit 2**

Program Decision and Control Structures: Boolean expressions, relational expressions, logical operators, Boolean variables; if, if-else, if-elif-else, inline-if statements, nested structures, and flowcharts; use of temporary variables, application: arranging a few numbers in increasing or non-decreasing, decreasing or non-increasing orders, etc.

### **Unit 3**

Repeated calculations and Looping: condition-controlled and count-controlled loops, while-loop (condition-controlled), infinite loops; for-loop (count-controlled), applications: calculating summation of series, Taylor expansion of mathematical functions, etc; nested loops.

### **Unit 4**

Functions: void and value returning functions, defining and calling functions, local and global variables and constants, scope, returning one or more values, Math module, use of standard math libraries and functions, passing functions as arguments, the Main program, Lambda functions, example: numerical integration, testing and test functions; Measuring CPU time and efficiency assessment; examples.

### **Unit 5**

Arrays, Lists and Tuples: lists, index, iterating over a list with for-loop, operations with lists, built-in functions, finding index, sorting, etc., processing lists; Arrays: vectors and tuples, vector arithmetic, arrays, Numerical Python arrays – Numpy, curve plotting: matplotlib, SciTools, making animations and videos; Higher-dimensional arrays: two and three dimensional arrays, matrix objects and matrix operations: inverse, determinant, solving linear systems using standard libraries.

#### **Lab Exercises to be done along with the course:**

- Using computer: Hardware: input/output devices, ports, memory units; Software: Operating systems, File system, application software; Word processor: formatting, including tables, pictures, drawing in a canvas, equations; Spread sheet program: rapidly calculating with formulas and filling columns, etc, plotting; Presentation tools (2 weeks)
- Start programing: keyboard input, assigning and printing variables – numbers, strings, names, etc.; Converting formulas into programming statements: examples of conversion from one unit to



another unit, Calculating distances, areas and volumes; Formatted output, scientific notation; Program to (a) find the roots of a quadratic equation (both real and imaginary root), (b) make tables of mathematical functions like  $\sin x$ ,  $\tan x$ ,  $\exp(x)$ , etc. (3 weeks)

- Control, Looping and Functions: Programs to illustrate logical expressions, arranging a few numbers in a given order; looping statements: summing a numbers from keyboard input, calculating summation of power series of functions, error estimation; Defining custom functions: examples; returning multiple values, passing functions as arguments. (3 weeks)
- Introducing Sage or equivalent Computer Algebra System: using it as calculator, symbolic mathematics, derivatives and integrals, solving linear system of equations, summing series, plotting functions, surfaces, Arrays, vectors and matrix operations. (2 weeks)
- Programs for vector and matrix operations: Define arrays, dot product and cross product of vectors; sum, product, and other operations of two  $n \times n$  matrices; Sorting numbers, searching the index of a sorted set of numbers; Programs to plot mathematical and user defined functions. (2 weeks)

### Textbooks/References

- Tony Gaddis, Starting Out with Python, 3E, Pearson, 2015. Book contains flowcharting and pedagogical program development in an introductory Python book. Ch. 1 to 5, Ch 7.
- Hans Petter Langtangen, A Primer on Scientific Programming with Python, 5E, Springer, 2016. Ch. 1 to 3, Ch. 4 (carefully selected material appropriate for first year students)
- Mark Newman, Computational Physics, Ch. 1 to 3.
- One material and tutorials: [www.python.org](http://www.python.org) ; <https://www.learnpython.org>; [www.vpython.org](http://www.vpython.org).

## Semester 2

22CSA112

Introduction to Programming II

(3-0-2-4)

### Course Outcome

CO1: Understand defensive programming concept. Ability to handle possible errors during program execution

CO2: Write code in Python to perform mathematical calculations and scientific simulations.

CO3: Understand the concepts of object-oriented programming as used in Python: classes, subclasses, properties, inheritance, and overriding.

CO4: Have knowledge of basic searching and sorting algorithms. Have knowledge of the basics of vector computation

CO5: Understand the concept of recursion and solve problems using recursion.

CO6: Implement a given algorithm as a computer program (in Python)

### Unit 1

Review of basics (2 hours); Files: reading from a command-line, option-value pairs, file input and output, filenames and file objects, opening and writing / appending / reading data to a file, writing and reading numerical data, loop operations and file processing; Handling errors and exceptions: try, except, finally statements and catching exceptions; Making modules, example: bisection and root finding.

### Unit 2

More about Strings: basic string operations, slicing, testing, searching, manipulating;  
Dictionaries: creating dictionaries, retrieving values, using for-loop to iterate over a dictionary, etc.;  
Sets: creation and operations on a set.

### Unit 3

Classes: Introduction to procedural and object oriented programming, definition, attributes, methods, examples, instances, accessor and mutator methods, passing objects as arguments; function classes for mathematical computations, complex number class, static methods and attributes.

### Unit 4

Object-Oriented Programming: Inheritance: generalization and specialization, examples; Polymorphism: definition, general examples, mathematical examples, Inheritance and class hierarchies; classes for numerical differentiation and integration; subclasses.

### Unit 5

Recursion: Introduction and problem solving with recursion, examples: factorials, Fibonacci series, Euclid's algorithm of gcd calculation, recursion versus looping; A couple of sorting and searching algorithms; Glimpses of advanced data structures, GUI programming.

### Lab Exercises to be done along with the course:

- More about Computer Algebra System: Problem solving , multiple integrals, vector calculus (3 weeks)
- Programs: (3 weeks)
  - To fit a straight line through the given set of data points using least square fitting algorithm.
  - To sort a given list containing the name of students and their total marks and print the rank list.
  - To searching a sorted list and print the details of the sought item.
- Program to (a) integrate a given function using Simpson's rule and Trapezoidal rules, (b) determine derivative table of a smooth function. (3 weeks)
- Program to solve elementary differential equations: (3 weeks)
  - To compute the trajectory of the projectile thrown at various angles.
  - To compute position and velocity of a spherical body in a viscous fluid, e.g., falling of rain drop, terminal velocity.
  - To study the motion of a body under a central force field: planetary motion - elementary approach.

### Textbooks/References

- Tony Gaddis, Starting Out with Python, 3E, Pearson, 2015. Book contains flowcharting and pedagogical program development in an introductory Python book. Ch. 6, Ch. 8 to 12. (text)
- Hans Petter Langtangen, A Primer on Scientific Programming with Python, 5E, Springer, 2016. Ch. 4, 6, 7, 9 (text)
- Mark Newman, Computational Physics, Ch. 1 to 3.
- One material and tutorials: [www.python.org](http://www.python.org); <https://www.learnpython.org>; [www.vpython.org](http://www.vpython.org).

. CO1: Understand how to write an argument using logical notation and determine if the argument is or is not valid.

CO2: Understand the basic principles of sets and operations in sets.

CO3: Ability to demonstrate an understanding of relations and functions and be able to determine their properties.

CO4: Ability to demonstrate different traversal methods for trees and graphs

CO5: Ability to Model problems in Computer Science using graphs and tree.

### **Unit 1**

Logic Mathematical Reasoning and Counting: Logic, Propositional Equivalence, Predicate and Quantifiers, Theorem Proving, Functions, Mathematical Induction, Recursive Definitions, Recursive Algorithms, Basics of Counting, Pigeonhole Principle, Permutation and Combinations.

### **Unit 2**

Relations and their properties: Representing Relations, Closure of Relations, Partial Ordering, Equivalence relations and Partitions.

### **Unit 3**

Advanced Counting Techniques and Relations: Recurrence Relations, Solving Recurrence Relations, Generating Functions, Solution of Homogeneous Recurrence relations, Divide and Conquer relations, Inclusion-Exclusion.

### **Unit 4**

Graph Theory: Introduction to Graphs, Graph Operations, Graph and Matrices, Graph Isomorphism, Connectivity.

### **Unit 5**

Euler and Hamilton Paths, Shortest Path Problem, Planar Graph, Graph Coloring.

Textbook:

Kenneth H. Rosen, *Discrete Mathematics and its Applications*, McGraw-Hill.

References:

R.P. Grimaldi, *Discrete and Combinatorial Mathematic*, Pearson.

**22MAT113**

**Multivariable Calculus**

**(3-1-0-4)**

### **Course Outcome:**

CO1: Understand the basic concepts of vector valued functions, limits, derivatives and its geometrical interpretations.

CO2: Understand the concept of scalar and vector field

CO3: Understand the concept of Line integrals and its independence of path

CO4: Understand and apply the concepts of double integrals to various problems including Green's theorem for plane

CO5: Understand the concepts of surface integrals, divergence theorem and Stokes theorem.

### **Unit 1**

Limits and continuity of Functions of Severable Variables, Partial derivatives, Differentiability of Functions, Chain rule.

### **Unit 2**

Directional derivatives, Gradient and tangent planes, Extreme values and saddle points, Lagrange multipliers.

### **Unit 3**

Line integrals, Vector fields, Circulation and Flux, Path independence, Potential Functions and Conservative Fields. Green's theorem in a Plane.

### **Unit 4**

Parameterized Surfaces, Surface Areas and Surface Integrals, Orientation of Surfaces

### **Unit 5**

Stoke's Theorem and Divergence Theorem (no proof just applications).

Textbook:

Thomas and Finney, *Calculus and Analytic Geometry*, 11<sup>th</sup> edition, Pearson.

References:

N. Piskunov, *Differential and Integral Calculus Vol. I and II*, CBS Publishers.

H. Anton, I. Bivens, S. Davis, *Calculus*, Wiley.

**22MAT114**

**Ordinary Differential Equations**

**(3-1-0-4)**

#### **Course Outcome:**

**CO1:** Ability to recognize and solve linear, separable and exact first-order differential equations

**CO2:** understand the use of differential equations in modelling engineering problems

**CO3** Ability to recognize and solve first-order and higher order differential equations, analyze trajectories, and comment on the stability of critical points

**CO4** Understand to determine the Laplace transforms for basic functions, derivatives, integrals and periodic functions and find inverse transforms

**CO5** Ability to use Laplace transforms to solve initial value problems, integral equations .

### **Unit 1**

First order ODEs, Modelling, Direction Fields, Separable ODEs, Exact ODEs and Integrating Factors, Linear ODEs and Modelling. (Sections: 1.1 to 1.5)

## **Unit 2**

Second Order Differential Equations: Homogeneous and non-homogeneous linear differential equations of second order, Modelling a Spring-Mass System, Euler-Cauchy Equations, Existence and Uniqueness of solutions (statement), Wronskian, Solution by Undetermined Coefficients and Variation of Parameters, Modelling. (Sections 2.1, 2.2, 2.4 to 2.10)

## **Unit 3**

Homogeneous and non-homogeneous Higher Order Linear ODEs, Systems of ODE. Series Solutions of ODEs: Power Series method, Legendre's equation and Legendre Polynomials. (Sections 3.1, 3.2, 3.3, 4.1, 5.1 to 5.2)

## **Unit 4**

Extended Power Series method – Frobenius method, Bessel's equation and Bessel Functions, General Solution. (Sections 5.3, 5.4, 5.5)

## **Unit 5**

Laplace Transforms: Linearity, first and Second Shifting theorems, Dirac delta functions, Systems of ODEs. (Sections 6.1 to 6.4, 6.7)

Textbook:

Erwin Kreyszig, *Advanced Engineering Mathematics*, 10<sup>th</sup> edition, Wiley.

W.E. Boyce and R.C. DiPrima, *Elementary Differential Equations and Boundary Value Problems*, 7<sup>th</sup> edition, Wiley.

References:

M.D. Raisinghania, *Ordinary and Partial Differential Equations*, S Chand Publications.

Dennis Zill, *A First Course in Differential Equations*, Cengage.

## **Semester 3**

### **22MAT208**

### **Introduction to Probability and Statistics (3-1-0-4)**

CO1: Able to understand the basic statistical concepts and graphical representations of the data

CO2: Able to understand different measures of central tendency and their interpretations

CO3: Able to understand the basic knowledge on fundamental probability concepts, probability of an event, additive rules and conditional probability and Bayes' theorem

CO4: Able to understand the concepts of random variables, probability distributions and moments

CO5: Able to understand standard discrete and continuous distributions in one dimensions.

## **Unit 1**

Introduction to Statistics: Statistical Methods: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement -nominal, ordinal, interval and ratio. Presentation: tabular and graphical, including histogram and ogives, consistency and independence of data with special reference to attributes.

## **Unit 2**

Measures of Central Tendency: mathematical and positional-Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, Moments, absolute moments, factorial moments, skewness and kurtosis, Sheppard's corrections.

### **Unit 3**

Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (Three variables only), rank correlation. Simple linear regression, principle of least squares and Fitting of polynomials and exponential curves.

### **Unit 4**

Elements of Probability: Introduction, random experiments, sample space, events and algebra of events. Axioms of Probability, Sample Spaces Having Equally Likely Outcomes, Conditional Probability, Bayes' Formula, Independent Events.

### **Unit 5**

Univariate Random Variables, Types of Random Variables, Expectation, higher moments and moment generating function of random variables, Chebychev's Inequality.

Special Random Variables and Their Distributions: Bernoulli, Binomial, Poisson and Geometric Random Variables and their distributions, moments and special properties, Uniform, Exponential gamma and Normal Random Variables and their distributions, moments and special properties.

Textbook:

D.C. Montgomery and G.C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley and Sons.

References:

Ross S.M., *Introduction to Probability and Statistics for Engineers and Scientists*, 3<sup>rd</sup> edition, Elsevier Academic Press.

J. Ravichandran, *Probability and Statistics for Engineers*, Wiley.

Hogg, R.V., Tanis, E.A. and Rao J. M., *Probability and Statistical Inference*, Seventh Ed, Pearson Education, New Delhi.

K.L. Chung, *Elementary Probability Theory: With Stochastic Processes and an Introduction to Mathematical Finance*, Springer.

**22MAT206**

**Introduction to Linear Algebra**

**(3-1-0-4)**

**Course Outcome:**

**CO1:** Understand the basic arithmetic operations on vectors and matrices, including inversion and determinants, using technology where appropriate;

**CO2 :**Ability to solve systems of linear equations, using technology to facilitate row reduction

**CO3** Ability to understand the basic terminology of linear algebra in Euclidean spaces, including linear independence, spanning, basis, rank, nullity, subspace, and linear transformation;

**CO4 :** Ability to understand and find Eigen values and eigenvectors of a matrix or a linear transformation, and using them to diagonalize a matrix

**CO5:** Ability to understand orthogonally diagonalize symmetric matrices and quadratic forms

**Unit 1**

Matrices, Operations on Matrices-Addition, Multiplication, Transpose, Special types of matrices. systems of linear equations.

## **Unit 2**

Gaussian elimination and row operations, Echelon form of a matrix, Elementary matrices and rank of a matrix, Existence of solution of  $AX=B$ .

## **Unit 3**

Properties of determinants, Cofactor expansion, Inverse of a matrix. Vector spaces, Subspaces.

## **Unit 4**

Span and linear independence, Basis and dimension, Row and column space of a matrix, Change of Basis. Linear transformations, Range space and rank, null space and nullity, Matrix representation, Isomorphism.

## **Unit 5**

Eigen values and Eigenvectors, Systems of ODEs, Wronskian, Diagonalization and Similar Matrices, Quadratic Forms.

Textbook:

David C. Lay, *Linear Algebra and its Applications*, Pearson.

References:

Gilbert Strang, *Linear Algebra and its Applications*, Cengage.

H. Anton, C. Rorres, *Elementary Linear Algebra*, Wiley.

Derek Robinson, *A Course in Linear Algebra with Applications*, Allied publishers.

**22MAT207**

**Transforms and PDE**

**(3-1-0-4)**

### **Course Outcome:**

CO1: Ability to understand the series solution of certain differential equations give rise to special functions

CO2: Ability to understand the basic concepts of Fourier series for periodic functions.

CO3: Model mathematically one and two Dimensional Wave and Heat Equations and solve using Fourier series

CO4: Ability to understand the general principle in boundary value problems for PDEs to choose coordinates that make the formula for the boundary as simple as possible

CO5: Ability to solve the boundary value problems in Polar, Cylindrical and Spherical coordinates.

## **Unit 1**

Fourier series—Even and Odd functions, Half range expansions, Approximation by Trigonometric Polynomials. (Sections 11.1 to 11.4)

## Unit 2

Sturm-Liouville problems, Generalized Fourier Series, Fourier Integral and Fourier transforms. (Sections 11.5 to 11.10)

## Unit 3

Basic concepts of PDEs, Solution by Separating Variables, D'Alembert's Solution of the Wave Equation. (Sections 12.1 to 12.4)

## Unit 4

Heat Equation, Solution By Fourier Series, 2D Heat Equation and Dirichlet Problem, Heat equation for long bars, Solution by Fourier Integrals and Transforms, Two Dimensional Wave Equation. (Sections 12.5 to 12.8)

## Unit 5

Laplacian in Polar Coordinates, Fourier Bessel Series, Laplace's equation in Cylindrical and Spherical Coordinates, Solution of PDEs by Laplace Transforms. (Sections 12.8 to 12.12)

Textbook:

Erwin Kreyszig, *Advanced Engineering Mathematics*, 10<sup>th</sup> edition, Wiley.

Dennis Zill, *A First Course in Differential Equations*, Cengage.

References:

W.E. Boyce and R.C. DiPrima, *Elementary Differential Equations and Boundary Value Problems*, 7<sup>th</sup> edition, Wiley.

M.D. Raisinghania, *Ordinary and Partial Differential equations*, S Chand Publications.

**22CSA202**

**Data Structures and Algorithms**

**(3 1 0 4)**

### Course Outcome:

CO-1: Understand asymptotic analysis and different methods.

CO-2 : Understand linear data structures and its applications.

CO-3: Understand different non-linear data structures and its applications

CO-4: Understand divide and conquer strategy for various sorting and searching techniques.

CO-5: Understand and apply the greedy approach for various problems.

## Unit 1

Introduction: Overview of Data Structures – A Philosophy of Data Structures - The Need for Data Structures – Cost and Benefits - Abstract Data Types and Data Structures - Principles, and Patterns. Basic complexity analysis – Best, Worst, and Average Cases - Asymptotic Analysis - Analysing Programs – Space Bounds. Recurrence Relations: Analysis using Recurrence Tree based Method.

## Unit 2

Arrays. Linked Lists: Using Arrays - Lists - Array based List Implementation – Linked Lists – LL ADT – Singly Linked List – Doubly Linked List – Circular Linked List. Stacks and Queues: Stack



ADT - Array based Stacks, Linked Stacks – Implementing Recursion using Stacks, Queues - ADT, Array based Queue, Linked Queue, Double-ended queue, Circular queue.

### Unit 3

Trees: Tree Definition and Properties – Tree ADT - Basic tree traversals - Binary tree - Data structure for representing trees – Linked Structure for Binary Tree – Array based implementation. Graphs: ADT- Data structure for graphs - Graph traversal - Transitive Closure - Directed Acyclic graphs - Weighted graphs – Shortest Paths - Minimum spanning tree.

### Unit 4

Sorting and Searching. Bubble sort, Insertion sort, Heap Sort - Merge Sort - Quick Sort. Binary search. Divide and Conquer Strategy.

### Unit 5

Greedy Method. Elements of Greedy Method. Fractional knapsack problem, scheduling problem. Applications of greedy method.

Textbook:

Goodrich M T, Tamassia R and Michael H. Goldwasser, “*Data Structures and Algorithms in Python*”, Wiley publication, 2016.

References:

Clifford A. Shaffer, “*Data Structures and Algorithm Analysis*”, Third Edition, Dover Publications, 2012.

Tremblay J P and Sorenson P G, “*An Introduction to Data Structures with Applications*”, Second Edition, Tata McGraw-Hill, 2002.

**22MAT209**

**Problem Solving Session I**

**(0 1 0 1)**

### Course Outcome:

CO-1: Learn some of the problem solving techniques in Mathematics.

CO-2 : Get a deeper understanding of Calculus through solving problems.

CO-3: Learn the applications of Linear Equations and Mathematical Induction

1. Problem set on Continuity and Differentiability.
2. Problem set on Sequences and Series 1.
3. Problem set on Sequences and Series 2.
4. Problem set on maxima and minima of Functions of several variables 1.
5. Problem set on maxima and minima of Functions of several variables 2.
6. Problem set on solving system of linear Equations 1.
7. Problem set on solving system of linear Equations 2.
8. Problem set on Mathematical Induction.
9. Problem set on Sets and functions.

References: Textbooks and Reference Books in the corresponding topics of the courses

### Semester 4

**22MAT219**

**Statistical Inference**

**(3 1 0 4)**

## Course Outcome:

**CO1:** Understand the joint distribution of random variables, marginal and conditional distributions, independence of random variables, expectation, variance, covariance and correlation of random variables.

**CO2:** Understand the concept of population, sample, parameter and statistic, and distributions of statistic

**CO3:** Able to understand the standard sampling distributions

**CO4:** Able to understand the statistical estimation procedures and standard methods of estimation of parameters

**CO5:** Ability to understand testing of hypothesis and standard statistical tests of hypothesis.

## Unit 1

Jointly Distributed Random Variables, Independent Random Variables, Conditional Distributions, Expectation and Variance and their properties, Expected Value of Sums of Random Variables, Variance, Variance of Sums of Random Variables, Covariance and Correlation Coefficient, Weak law of large numbers and Central limit theorem for i.i.d random variables.

## Unit 2

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, Sampling distribution of sample mean, Standard errors of sample mean, sample variance and Sample proportion. Exact sampling distribution  $\chi^2$ , student's t distribution, Snedecore's F-distribution and nature of p.d.f. curve with different degrees of freedom, mean and variance, Relationship between t, F and  $\chi^2$  distributions.

## Unit 3

Parameter Estimation: Introduction, Definition of estimators, and estimates, Desirable properties of estimates, Maximum Likelihood Estimation and method of moment estimation, Interval Estimates of mean, variance and proportion.

## Unit 4

Hypothesis Testing –Introduction, Significance Levels, Large sample tests for mean, equality of means and proportions, small sample tests for the mean, equality of means and variance of normal populations.

Goodness of Fit Tests and Categorical Data Analysis, Goodness of Fit tests when all parameters are Specified, Goodness of Fit Tests When Some Parameters are unspecified, Tests of Independence in Contingency Tables, Tests of Independence in Contingency Tables having fixed marginal totals.

## Unit 5

Analysis of variance: Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effect models, analysis of variance and covariance in two-way classified data with one observation per cell for fixed effect models.

Text Book:

Douglas C. Montgomery and George C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley and Sons Inc., 2005

References:

Ross S.M., *Introduction to Probability and Statistics for Engineers and Scientists*, 3rd edition, Elsevier Academic Press.

Ravichandran, J. *Probability and Statistics for engineers*, First Reprint Edition, Wiley India, 2012

Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, *Probability and Statistics for Engineers and Scientists*, 8<sup>th</sup> Edition, Pearson Education Asia, 2007

Hogg, R.V., Tanis, E.A. and Rao J.M., *Probability and Statistical Inference*, Seventh Ed, Pearson Education, New Delhi

## Course Outcome:

**CO1:** Understanding the set theoretic statements and the completeness property of  $\mathbb{R}$ .

**CO2:** Understanding the concepts of sequences, series and Limits. Apply the tests for convergence, absolute convergence and analyzing the convergence criteria.

**CO3:** Defining Limits, continuity and monotonicity of a function and understanding the theorems related to them.

**CO4:** Understanding the concepts of extreme values, Mean value theorem and applying Taylor's theorem for approximating functions.

**CO5:** Understanding Riemann Sum and apply it to approximate integrations

## Unit 1

Sets and Functions, surjective and injective functions, inverse functions. Countable and Uncountable sets, Countability of  $\mathbb{Q}$ , Absolute value and the Real line, Completeness property of  $\mathbb{R}$ , Least upper bound property and its applications, Nested intervals, Cantor's proof of uncountability of  $\mathbb{R}$ . (Sections 1.1, 1.3, 2.2, 2.3, 2.4, 2.5)

## Unit 2

Sequences and Their Convergence, Monotone Sequences, Monotone Convergence Theorem, Subsequences and Bolzano-Weierstrass Theorem, Cauchy Sequence and Cauchy Convergence criterion. (Sections 3.1 to 3.5)

## Unit 3

Continuity, Uniform Continuity. Derivative of functions, Mean Value Theorem, L'Hospital Rule, Taylor's Theorem. Infinite Series: Conditional and Absolute Convergence, Tests for Absolute Convergence of Infinite Series, Alternating Series Test, Rearrangement of terms in an infinite Series.

## Unit 4

Riemann Integration: Integral and its properties, Fundamental theorems of Calculus, Sum of an infinite series as an integral, Improper Riemann integrals. (Sections 7.1 to 7.3)

## Unit 5

Open and Closed Sets in  $\mathbb{R}$ , Characterization of Open and Closed Sets, Compact Sets, Heine-Borel Theorem. (Sections 11.1, 11.2)

Textbook:

Robert G. Bartle and Donald R. Sherbert, *Introduction to Real Analysis*, 3<sup>rd</sup> edition, Wiley.

References:

S. Kumaresan and Ajit Kumar, *A Basic Course in Real Analysis*, CRC Press.

V.K. Krishnan, *Fundamentals of Real Analysis*, Pearson.

Terence Tao, *Analysis I*, Hindustan Book Agency.

Terence Tao, *Analysis II*, Hindustan Book Agency.

**22MAT216**

**Numerical Methods**

**(3 0 2 4)**

**Course Outcome:**

CO-1: Understand the basic concepts of root finding methods, system of equations and their solutions.

CO-2: Understand the concepts of interpolation and construction of polynomials.

CO-3: Application of numerical methods to understand the concept of Calculus (Differentiation and Integration).

CO-4: Application of numerical concepts to solve ODEs and PDEs.

CO-5: Usage of software tools to solve various problems numerically.

## **Unit 1**

Solution of Nonlinear Equations: Bisection and False position Methods, Newton Raphson and Secant Methods, Rate of Convergence.

## **Unit 2**

Solution of Linear Systems  $AX=B$  and Eigen value problems (12 hours): Direct methods, Gaussian Elimination, Gauss Jordan method, LU Factorisation, Jacobi & Gauss Seidel iterative Methods.

## **Unit 3**

Interpolation, Curve Fitting (12 hours): Taylor's Series calculation of Functions, Lagrange's Polynomial Approximation and Interpolation, Newton Polynomial Approximation using divided differences and Interpolation, Error, Newton-Gregory forward and backward difference interpolation, Hermite interpolation, Piecewise and Spline interpolation, Polynomial approximation and Weierstrass theorem, Principle of Least Squares.

## **Unit 4**

Numerical Differentiation and Integration (10 hours): Numerical Differentiation using Lagrange, Finite difference interpolation and Undetermined coefficient method, Numerical Integration using Newton-Cotes method, Gauss-Legendre Integration method, Trapezoidal and Simpson method, Quadrature, Composite Trapezoidal and Simpson's Rule, Romberg Integration, Orthogonal polynomials and Gaussian integration.

## **Unit 5**

Solution of Ordinary Differential Equations (10 hours): Euler method, Modified-Euler mid-point method, Taylor series method, Runge-Kutta methods, Error analysis.

### **Lab Exercises to be done Using Python**

1. Bisection and False position Methods.
2. Newton Raphson and Secant Methods.
3. Gaussian Elimination, Gauss Jordan method, LU Factorization
4. Iterative Methods for Solving Linear Equations.
5. Polynomial Approximation and Interpolation Methods 1
6. Polynomial Approximation and Interpolation Methods 2
7. Numerical Differentiation.
8. Numerical Integration 1.
9. Numerical Integration 2.

Textbook:

Jain M.K., Iyengar S.R.K. and Jain R.K., *Numerical Methods for Engineering and Scientific*

*Computation*, 3<sup>rd</sup> edition, New Age International (P), New Delhi, 1995.

References:

John H. Mathews, Kurtis D. Fink, *Numerical Methods Using Matlab*, 4<sup>th</sup> edition, Prentice-Hall.

Rudra Pratap, *Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers*, Oxford University Press, 2005.

**22MAT218**

**Introduction to Abstract Algebra**

**(3 1 0 4)**

**Course Outcome:**

CO1: Ability to demonstrate insight into abstract algebra with focus on axiomatic theories

CO2: Ability to apply algebraic ways of thinking

CO3: Ability to demonstrate knowledge and understanding of fundamental concepts including groups, subgroups, normal subgroups, homomorphisms and isomorphism

CO4: Ability to demonstrate knowledge and understanding of rings, fields and their properties

CO5: Ability to prove fundamental results and solve algebraic problems using appropriate techniques

### **Unit 1**

Number Theory: Mathematical induction, Division Algorithm, Greatest Common Divisor, Euclidean Algorithm for finding GCD, Linear Diophantine Equation, Primes Numbers and Fundamental Theorem of Arithmetic, Euclid's proof of Infinitude of Primes. Basic properties of Congruences, Linear Congruences and Chinese Remainder Theorem, Fermat's Little theorem, Wilson's Theorem, Euler  $\phi$  Function and its Properties, Euler's Theorem.

### **Unit 2**

Definition and examples of Groups, some elementary properties of groups, Order of a Group, Subgroups, Cyclic Groups, Classification of Subgroups of Cyclic Groups, Permutation Groups, Cycle Notation, Properties of Permutations, Isomorphism of Groups.

### **Unit 3**

Left and Right Cosets, Properties of Cosets, Lagrange's Theorem and consequences, Normal Subgroups and Factor / Quotient Groups, Group Homomorphisms, Kernel.

### **Unit 4**

Rings, Properties of Rings, Subrings, Integral Domains, Fields, Characteristic of a Ring.

### **Unit 5**

Ideals and Factor / Quotient Rings, Prime Ideals and Maximal Ideals, Ring Homomorphisms and Field of Quotients.

Textbook:

David M. Burton, *Elementary Number Theory*, 7<sup>th</sup> edition, McGraw-Hill.

Joseph A. Gallian, *Contemporary Abstract Algebra*, 4<sup>th</sup> edition, Narosa.

References:

John B. Fraleigh, *A First Course in Abstract Algebra*, 7<sup>th</sup> edition, Pearson.

I.N. Herstein, *Topics in Algebra*, 2<sup>nd</sup> edition, John Wiley.

## **Semester5**

**22MAT307**

**Introduction to Complex Analysis**

**(3 1 0 4)**

### **Course Outcome:**

**CO1:** Ability to understand basic concepts of the complex numbers

CO2: Understand about complex integrations

CO3: Understand about the singularities and Residues

CO4: Understand the evaluation of different type integrals

CO5: Understand the concept of complex mappings and linear transformations.

### **Unit 1**

Complex Numbers: Definition, Algebra of complex numbers, Geometric representation, Conjugates, Absolute values, properties, Polar form. Complex Functions: Introduction, Limits, Continuity, Differentiability, Analytic functions, Cauchy-Riemann Equations in Cartesian and polar coordinates.

### **Unit 2**

Elementary functions, exponential and Logarithmic functions, Branches of logarithm, Trigonometric and Hyperbolic functions.

### **Unit 3**

Complex Integration: Definitions, Line integrals, Cauchy Goursat theorem, Cauchy's integral formula, Derivatives of analytic functions, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra, Gauss' mean value theorem, Maximum modulus principle.

### **Unit 4**

Power Series: Definitions, Taylor's series, Laurent's series, circle and radius of convergence. Contour Integration: Zeros and Singularities of Analytic functions, types of singularities, Poles, Meromorphic functions, principle of argument, Rouché's theorem, Fundamental theorem of Algebra, Residues, Evaluation of residues at a pole, Cauchy's residue theorem.

### **Unit 5**

Evaluation of Real definite integrals by Contour integration, Evaluation of improper integrals, Jordan's lemma, Mappings by elementary functions, linear fractional Transformation: Image of a line and circle.

Textbook:

R. V. Churchill and J. W. Brown, *Complex Variables and Applications*, Tata McGraw-Hill.

References:

Dennis Zill, *Complex Analysis*, Jones and Bartlett.

Ahlfors, *Complex Analysis*, McGraw-Hill.

Anant R Shastri, *Basic Complex Analysis of one Variable*, Lakshmi Publications.

**22MAT306**

**Real Analysis**

**(3 1 0 4)**

Course outcomes

**CO1** To understand the basics of Real analysis and apply the acquired knowledge in signals and Systems, Digital Signal Processing. Etc

**CO2** Knowledge and Understanding: Learn the theory of Riemann-Stieltjes integrals, to be acquainted with the ideas of the total variation and to be able to deal with functions of bounded variation.

**CO3** Intellectual Skills: Develop a reasoned argument in handling problems about functions, especially those that are of bounded variation.

**CO4** General and Transferable Skills: Develop the ability to reflect on problems that are quite significant in the field of real analysis.

**CO5** Develop the ability to consider problems that could be solved by implementing concepts from different areas in mathematics and identify, formulate, and solve problems.

### **Unit 1**

Metric Spaces – Definition and examples, Open and Closed Sets, Limit points, interior points, Open Balls and Open Sets, Convergent Sequences, Limit Points, Bounded sets, Dense Sets, Boundary of a set. (Sections 2.15 to 2.30)

### **Unit 2**

Compact spaces: Definition and Examples, Compact subspaces of  $\mathbb{R}$  and Heine Borel Theorem, Characterization of Compact Metric Spaces, Connected Sets. (Sections 2.31 to 2.47)

### **Unit 3**

Convergent Sequences, Cauchy Sequence, Complete Metric Spaces, Continuous Functions on a Metric Space, Continuity and Compactness, Continuity and Connectedness. (Sections 3.1 to 3.12, 4.1 to 4.9, 4.13 to 4.19, 4.22, 4.23)

### **Unit 4**

Riemann-Stieltjes Integral, Definition and Existence of the Integral, Properties of the Integral, Integration by parts, Sufficient and Necessary Conditions for Existence of Riemann Integrals, Fundamental Theorem of Calculus. (Sections 6.1 to 6.13, 6.20, 6.21)

### **Unit 5**

Sequences and Series of Functions: Sequence of functions and its point-wise limit, Discussion of main problems, Uniform convergence, Uniform convergence and continuity, Uniform convergence and Integration, Uniform convergence and Differentiation, Equicontinuity and Stone-Weierstrass Theorem, Power Series. (Chapter 7, 8.1)

Textbooks:

W. Rudin, *Principles of Mathematical Analysis*, Tata McGraw-Hill.

References:

Apostol, *Mathematical Analysis*, Narosa.

S.R. Ghorpade and B.V. Limaye, *A Course in Multivariable Calculus and Analysis*, Springer.

**22CSA301**

**Introduction to Data Science**

**(3 0 2 4)**

Course outcomes

CO1: Able to design visualizations that represent the relationships contained in complex data sets and adapt them to highlight the ideas you want to communicate

CO2: Able to support the visualizations with written and verbal explanations on their interpretation.

CO3: Able to use leading open source software packages to create and publish visualizations

CO4: Ability to understand Regression and Classification problems.

CO5: Enable clear interpretations of big, complex and real world data

### **Unit 1**

Data Science – Introduction, Overview of Python, Expressions, Data types, Arrays. (Chapters 1 to 6)

### **Unit 2**

Data Visualization—Bar charts, Histograms, Line Charts, Scatterplots, Overlaid plots. (Chapter 7)

### **Unit 3**

Functions and Tables, Joins, Iteration, Simulation, Sampling. (Chapters 8 to 10)

### **Unit 4**

Empirical Distributions, Assessing Models, Decisions and Uncertainty, A/B Testing, Causality, Bootstrap, Designing Experiments. (Chapters 11 to 14)

### **Unit 5**

Linear Regression, Least Squares, Classification, Case Studies. (Chapters 15 to 18)

Textbook:

Ani Adhikari, John DeNero and David Wagner, *Computational and Inferential Thinking: The Foundations of Data Science*, 2<sup>nd</sup> Edition.

Web Resource: <http://data8.org/fa21/>



**Course Outcome:**

CO1: Ability to understand Methodology of Operations Research.

CO2: Understand the basic concepts of linear programming, theory of duality and methods for solving linear programming problems.

CO3: Understand the Mathematical formation of transportation and assignment problems and solution methods.

CO4: Ability to solve Dynamic programming problems

CO5: Understand the network representation of project works and computation of PERT-CPM

**Unit 1**

Basics of Operational Research: Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Modeling of Real Life Problems.

**Unit 2**

Linear Programming: Linear Programming Problem Formulation, solution by Graphical Method, Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charnes-M Method, Degeneracy, Theory of Duality, Dual-simplex method.

**Unit 3**

Transportation problem (TP) and its formulation. Finding basic feasible solution of TP using North-West Corner Rule, Least Cost and Vogel's Approximation Method, MODI method for finding optimal solution for TP, Assignment problem and its formulation, Hungarian method for solving Assignment problem, Transshipment and Travelling salesmen problem.

**Unit 4**

Introduction to Dynamic Programming. The recursive Equation Approach, Characteristics of Dynamic Programming, Recursive nature of computations in Dynamic programming problem – Forward and Backward Recursion, Cargo-loading Model–Work-Force size model – Equipment Replacement model.

**Unit 5**

Network Representation, Critical Path (CPM) computations, Construction of the Time Schedule, Linear programming formulation of CPM - PERT calculations. Concepts of Game problem, Two-person zero-sum game, Pure and Mixed strategies, Saddle point and its existence Dominance. Fundamental Theorem of Rectangular games, Concept of Dominance and Graphical method of solving Rectangular games. Relationship between rectangular game and Linear Programming Problem. Solving rectangular game by Simplex method.

**Practical/Lab to be performed on a computer using Excel/Statistical packages**

1. To solve Linear Programming Problem using Graphical Method with
  - (i) Unbounded solution
  - (ii) Infeasible solution
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method
  - (i) Unrestricted variables
  - (ii) Unbounded solution

- (iii) Infeasible solution
- (iv) Alternative or multiple solutions.
- 7. Problems based on Dual simplex method.
- 8. Solution of Transportation Problem.
- 9. Solution of Assignment Problem.
- 10. Solution of Travelling Salesman Problem.
- 11. Solution of Dynamic programming problems
- 12. Solution of game problems

Text Books:

- Hamdy A. Taha, *Operations Research - An Introduction*, 8<sup>th</sup> Edition, Prentice Hall.
- KantiSwarup, P.K. Gupta and Man Mohan, *Operations Research*, 9<sup>th</sup> Edition, S Chand and Sons.

References:

- A. Ravindran, D. T. Phillips and James J. Solberg: *Operations Research- Principles and Practice*, John Wiley & Sons, 2005.
- F.S. Hillier. G.J. Lieberman, *Introduction to Operations Research- Concepts and Cases*, 9th Edition, Tata Mc-Graw Hill, 2010
- Ronald L. Rardin, *Optimization in Operations Research*, Prentice Hall, 1999

**22MAT309**

**Problem Solving Session II**

**(0 1 0 1)**

CO1: Ability to solve problems in Linear Algebra.

CO2: Learn the various problem-solving techniques in Abstract Algebra.

CO3: Ability to solve problems in elementary Real Analysis.

1. Problem set on Systems of Linear Equations, rank and Null space of a matrix.
2. Problem set on Vector Spaces, basis, dimension.
3. Problem set on Linear Transformations.
4. Problem set on Groups 1.
5. Problem set on Groups 2.
6. Problem set on Rings.
7. Problem set on Sequences and series.
8. Problem set on Continuity and Differentiability.

References: Textbooks and Reference Books in the corresponding topics of the courses

**Semester 6**

**22MAT318**

**Complex Analysis**

**(3 1 0 4)**

CO1: To understand the basic idea of analytic functions, power series etc.

CO2: Ability to understand power series representation of Analytic function and zero's of analytic functions

CO3: Understand Cauchy's Theorem and integral formula, Homotopic version of Cauchy's Theorem

CO4: To understand Singularities and Residue theorem

CO5: The extended plane and its spherical representation, Analytic function as mapping, Mobius transformations

### **Unit 1**

Elementary properties and examples of analytic functions, Power series, Analytic function, Riemann Stieltjes integrals.(Chapter 3 Sections 1, 2 and Chapter 4 Section 1 of Text)

### **Unit 2**

Power series representation of an analytic function, Zeros of an analytic function, Liouville's Theorem, Maximum Modulus Theorem, Index of a closed curve.(Chapter 4 – Sections 2, 3 and 4 of Text)

### **Unit 3**

Cauchy's Theorem and integral formula, Homotopic version of Cauchy's Theorem, Simple connectivity, Counting zeros: The open Mapping Theorem, Goursat's Theorem. (Chapter 4 Sections 5, 6, 7 and 8 of Text)

### **Unit 4**

Singularities: Classification, Removable, Pole and Essential Singularity, Laurent Series, Casorati Weierstrass Theorem, Residue theorem, The argument principle, Rouché's Theorem. (Chapter 5 Sections 1, 2, and 3 of Text)

### **Unit 5**

The extended plane and its spherical representation, Analytic function as mapping, Mobius transformations, The maximum principle, Schwarz's Lemma.(Chapter 1 Section 6, Chapter 3 Section 3, Chapter 6 Section 1 and 2 of Text)

Textbooks:

John B Conway, Functions of One Complex Variable, Springer.

References:

Elias Stein and Rami Shakarchi, Complex Analysis, New Age Publishers.

Lars V Ahlfors, Complex Analysis,Tata McGraw-Hill.

**22MAT316**

**ODE and Calculus of Variations**

**(3 1 0 4)**

### **Course Outcomes**

CO1: To understand variational problems and the necessary condition for extremal namely Euler equation. To apply these conditions in evaluations of extremal of functionals for several variables.

CO2: To apply the variational problems in solving physical problems which involves the Principle of Least Action, Conservation Laws, The Hamilton-Jacobi Equation.

CO3: To understand the concept of weak and strong extremum. To apply in the Field of a Functional, Hilbert's Invariant Integral, The Weierstrass E-Function.

CO4: To apply these techniques in solving differential equations by the Ritz Method and the Method of Finite Differences. To solve the Sturm-Liouville Problem using variational method.

CO5: To understand the idea of solving various integral equations and to apply these tools to solve Fredholm and Volterra Integro - Differential equation by the methods of the Green's function. Decomposition, direct computation, Successive approximation, series solution, successive approximation.

### **Unit 1**

Existence and Uniqueness: Picard's method of successive approximation, Problems of existence and uniqueness, Lipschitz condition, Existence and Uniqueness Theorem, Cauchy-Peano's Theorem. Linear equations: Basic theory, Homogeneous equation, Wronskian, method of Variation of parameters, equations with constant coefficients and method of undetermined coefficients, Cauchy Euler equation.

### **Unit 2**

Power series solution: Ordinary and Singular points, Gauss's Hypergeometric Equation, Chebyshev Polynomials, Frobenius's method, Bessel equation and Bessel functions, Legendre Polynomials, Gamma Functions.

### **Unit 3**

Systems of Linear Differential equations: Differential operators, Operator method for linear systems with constant coefficients, Matrix method for homogeneous linear systems with constant coefficients.

### **Unit 4**

Sturm-Liouville Boundary value problems: Definition and examples, Characteristic values and characteristic functions, Orthogonality of characteristic functions, series of orthonormal functions. Calculus of Variations: Introduction, Variation and its properties, Variational problems with the fixed boundaries, Euler's equation, the fundamental lemma of the calculus of variations, Functionals involving more than one dependent variables.

### **Unit 5**

Variational problems in parametric form, Isoperimetric problems, Variational problems with moving boundaries, Moving boundary problems with more than one dependent variables, One-sided variations, Field of extremals, central field of extremals, Jacobi's condition, The Weierstrass function, The Legendre condition, weak extremum, strong extremum.

Textbooks:

Shepley L. Ross, *Differential Equations*, Wiley.

M.D. Raisinghania, *Advanced Differential equations*, S Chand Publications.

References:

G.F. Simmons, *Differential Equations with Applications and Historical Notes*, McGraw-Hill.

I.M.Gelfand, S.V.Fomin, *Calculus of Variations*, Dover.

**22MAT317**

**Optimization Techniques**

**(3 0 2 4)**

Course Outcomes:

**CO1:** Understand different types of Optimization Techniques in engineering problems. Learn Optimization methods such as Bracketing methods, Region elimination methods, Point estimation methods.

**CO2:** Learn gradient based Optimizations Techniques in single variables as well as multi-variables (non-linear).

**CO3:** Understand the Optimality criteria for functions in several variables and learn to apply OT methods like unidirectional search and direct search methods.

**CO4:** Learn constrained optimization techniques. Learn to verify Kuhn-Tucker conditions and Lagrangian Method.

**CO5:** Familiarize the concept of optimization in practical applications to find the best feasible solutions in practical applications

### **Unit 1**

Introduction to Optimization, Historical Development, Applications of Optimization, Statement of an Optimization Problem, Classification of Optimization Problems, Optimization Techniques.

### **Unit 2**

Single Variable Optimization- Optimality criteria, bracketing methods-exhaustive search method, bounding phase method- region elimination methods- interval halving, Fibonacci search, golden section search, point estimation-successive quadratic search, gradient based methods.

### **Unit 3**

Multivariable Optimization, optimality criteria, unconstrained optimization-solution by direct substitution, unidirectional search-direct search methods, evolutionary search method, simplex search method, Hook-Jeeves pattern search method.

### **Unit 4**

Gradient based methods-steepest descent, Cauchy's steepest descent method, Newton's method, conjugate gradient method-constrained optimization Multivariable Optimization with no constraints, Multivariable Optimization with Equality Constraints, Solution by Direct Substitution

### **Unit 5**

Solution by the Method of Lagrange Multipliers- Multivariable Optimization with Inequality Constraints, Kuhn-Tucker Conditions, Constraint Qualification, Convex Programming Problem.

### **Practical/Lab to be Performed Using MATLAB/Python**

1. To determine local/Relative optima of a given unconstrained problem.
2. Test whether the given function is concave/convex.
3. Test whether the given matrix is positive definite/negative definite/semi positive Definite/ semi negative definite
4. Solution of optimization problems using Karush-Kuhn-Tucker conditions
  1. Find optimal solution of single variable functions using
    - (i)Exhaustive search methods,
    - (ii)Bounding phase method
    - (iii) Region elimination method interval halving,

- (iv) Fibonacci search
  - (v) Golden section search
  - (vi) Point estimation-successive quadratic search
  - (vii) Gradient based methods
2. Find optimal solution of two variable problems based on the methods
- (i) Hook-Jeeves pattern search method
  - (ii) Gradient based methods-steepest descent
  - (iii) Cauchy's steepest descent method
  - (iv) Newton's method
  - (v) Conjugate gradient method-constrained optimization

Textbook:

Edwin K.P. Chong, Stanislaw H. Zak, "An introduction to Optimization", 2<sup>nd</sup> edition, Wiley, 2013.

S.S. Rao, "Optimization Theory and Applications", Second Edition, New Age International (P) Limited Publishers, 1995.

References:

Kalyanmoy Deb, "Optimization for Engineering Design Algorithms and Examples", Prentice Hall of India, New Delhi, 2004.

M. Asghar Bhatti (2000), *Practical optimization methods*, Springer.

**22CSA311**

**Introduction to Machine Learning**

**3 0 2 4**

CO1: Understand the domain of machine learning with respect to the regression and classification and its huge potential for providing solutions to real-life problems.

CO2: Have a good understanding of the fundamental issues and challenges in basic machine learning algorithms in terms of data, model selection, and complexity.

CO3: Understand the problem of Curse of Dimensionality and different methods to tackle it.

CO4: Understand the mathematical framework for machine learning (both supervised and unsupervised learning) and methods to tackle under fitting & overfitting.

CO5: Learn the motivation and theory behind learning an artificial neural networks for machine learning applications.

CO6: Be able to design and implement right machine learning algorithm for a given real-world problem.

CO1: Have a good understanding of the fundamental issues and challenges of machine learning data, model selection, model complexity, etc.

CO2: Have an understanding of the strengths and weakness of many popular machine-learning approaches.

CO3: To understand the mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised and un-supervised learning

CO4: Be able to design and implement various machine-learning algorithms in a range of real-world applications

**Unit 1**

Introduction, Simple Linear regression, Multiple linear regression, Extensions of the linear model, Classification: overview, Logistic regression, Linear discriminant analysis, comparison of classification methods.

## **Unit 2**

Resampling methods: Cross validation and the bootstrap, Linear model selection and Regularization: Subset selection, Shrinkage methods, Dimension reduction methods, Considerations in high dimensions.

## **Unit 3**

Polynomial regression, step functions, basis functions, regression splines, smoothing splines, local regression, generalized additive models for regression and classification problems, Regression trees, Classification trees, comparison of trees and linear models, Bagging, Random Forests, Boosting.

## **Unit 4**

Support Vector Machines: Hyperplane, Maximum Margin Classifier, Support Vector Classifiers, Support Vector Machines, One vs One Classification and One vs All Classification, Relationship to Logistic Regression. Unsupervised Learning: Principal Component Analysis and its applications, K-Means Clustering and Hierarchical Clustering.

## **Unit 5**

Neural Networks: Introduction, Projection Pursuit Regression, Neural Networks, Fitting Neural Networks, Some issues in Training Neural Networks-Starting Values, Overfitting, Scaling of the Inputs, Number of Hidden Units and Layers, Multiple Minima.

### **Machine Learning Lab I to be performed**

1. Introduction to R: Basic Commands, Graphics, Indexing Data, Loading Data.
2. Linear Regression: Libraries, Simple Linear Regression, Multiple Linear Regression.
3. Logistic Regression, Linear Discriminant Analysis, Quadratic Discriminant Analysis.
4. Cross Validation and Bootstrap, Validation set approach, Leave-One-Out Cross Validation
5. K-Fold Cross Validation, Bootstrap.
6. Subset Selection Methods, Best Subset Selection, Forward and Backward Stepwise Selection.
7. Ridge Regression and the Lasso.
8. Principal Components Regression, Partial Least Squares.
9. Non-Linear Modelling, Polynomial Regression and Step Functions, Splines, GAMS.
10. Decision Trees, Fitting Classification Trees and Regression Trees, Bagging and Random Forests

Textbooks:

G. James, R. Tibshirani, *An Introduction to Statistical Learning: with applications in R*, Springer.

T. Hastie, R. Tibshirani, *Elements of Statistical Learning: Data mining, Inference and Prediction*, Springer.

References:

Kevin Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press.

**22MAT319**

**Problem Solving Session III**

**(0 1 0 1)**

Course Outcome:

CO1: Learn the various problem-solving techniques used in Metric Spaces.

CO2: Understand the topology of Metric Spaces.

CO3: Get a good understanding about Compact Metric Spaces.

1. Problem set on Open sets, Closed sets, Closure of a set.
2. Problem set on Cauchy Sequences and Completeness, Dense sets.
3. Problem set on Continuous functions, equivalent definition of continuity, Uniform Continuity.
4. Problem set on Compact Spaces 1.
5. Problem set on Compact Spaces 2.
6. Problem set on Compact Spaces 3.
7. Problem set on Connected spaces.
8. Problem set on Complete Metric Spaces.

Textbook:

S. Kumaresan, *Topology of Metric Spaces*, Wiley.

## **Semester 7**

**22MAT507**

**Advanced Linear Algebra**

**(3 1 0 4)**

CO1: Ability to understand the basic concepts of vector and matrix algebra, including linear dependence / independence, basis and dimension of a subspace, for analysis of matrices and systems of linear equations

CO2: Ability to find the dimension of spaces such as those associated with matrices and linear transformations

CO3: Ability to understand Dual Space, subspaces, sub space of a linear transformation Minimal and Characteristic Polynomial

CO4: To understand the construction of matrices for a linear transformation in the triangular/Jordan form

CO5: Apply the decomposition theorem in context of mathematical applications to subspaces

### **Unit 1**

Fields, System of Linear Equations, Matrices and Elementary Row Operations, Row Reduced Echelon Matrices, Elementary Matrices, Invertible Matrices. Vector Space over a Field, Definition and Examples, Subspaces, Spanning set, Linear Independence, Basis and Dimension of a Vector Space.

### **Unit 2**

Ordered Basis and Coordinates, Row Space and Row Equivalent Matrices. Linear Transformations: Properties, Rank and Nullity of a Linear transformation, Algebra of Linear Transformations, Isomorphism of Vector Spaces, Representation of Linear Transformations by Matrices, Similar Matrices.



### Unit 3

Linear Functionals, Dual Space, Annihilators of subspaces, Transpose of a Linear Transformation, Characteristics value and Characteristic polynomial of a Linear Operator, Minimal and Characteristic Polynomial.

### Unit 4

Cayley Hamilton Theorem, Invariant Subspaces of an Operator, Diagonalizability of an Operator, Simultaneous Diagonalization.

### Unit 5

Direct Sum Decompositions, Invariant Direct Sums, Primary Decomposition Theorem, Cyclic Subspaces and Annihilators, Cyclic Decomposition Theorem and Rational Form, Jordan Form.

Textbook:

K. Hoffman and R. Kunze, *Linear Algebra*, Prentice Hall.

References:

Sheldon Axler, *Linear Algebra Done Right*, 2<sup>nd</sup> Edition, Springer.

Dummit and Foote, *Abstract Algebra*, Wiley.

M. Artin, *Algebra*, Prentice Hall.

**22MAT506**

**Abstract Algebra**

**(3 1 0 4)**

Course outcomes

**CO 1** Understand the familiarity with the concepts of ring and field, and their main algebraic properties;

**CO 2** Understand correctly use the terminology and underlying concepts of Galois Theory in a problem-solving context

**CO 3** Ability to Reproduce the proofs of its main theorems and apply the key ideas in similar arguments;

**CO 4** Ability to Calculate Galois groups in simple cases and to apply the group-theoretic information to deduce results about fields and polynomials

**CO 5** Ability to Demonstrate the capacity for mathematical reasoning through analyzing, proving and explaining concepts from field extensions and Galois Theory and apply problem –solving in diverse situation in physics, engineering and other mathematical contexts.

### Unit 1

Review of Groups, Normal subgroups, Factor or Quotient Groups and Homomorphisms. Isomorphism of Groups, Cayley's Theorem. External Direct Products, Fundamental theorem of Finite Abelian Groups. Groups acting on themselves by Conjugation- Class Equation, Sylow's Theorem and its applications, Simple Groups, Non Simplicity Tests.

### Unit 2

Review of Rings: Integral domains, Quotient Ring and Ideals, Properties of ideals, Prime and Maximal ideals, Chinese remainder theorem, Ring homomorphisms, Polynomial rings, Polynomial rings over Fields, Division algorithm.

### Unit 3

Principal ideal domain, Factorisation of Polynomials, Gauss's lemma, Eisenstein's irreducibility criteria, Unique Factorisation in  $\mathbb{Z}[x]$ , Euclidean domain, Unique factorization domain.

### Unit 4

Field extensions, Fundamental theorem of Field theory, Splitting fields, Zeros of an irreducible polynomial, Algebraic and Transcendental extensions, Finite extensions, Properties of Algebraic extensions.

### Unit 5

Finite fields, Classification of Finite fields, Structure of Finite fields, Subfields of a Finite field. Galois Theory: Automorphisms of fields, Galois group, examples, Fundamental theorem of Galois Theory and its applications, Cyclotomic extensions, Solving of Polynomials by Radicals, Insolvability of Quintic.

Textbook:

Joseph A. Gallian, *Contemporary Abstract Algebra*, 4<sup>th</sup> edition, Narosa.

References:

Dummit and Foote, *Abstract Algebra*, Wiley.

M. Artin, *Algebra*, Prentice Hall.

I.N. Herstein, *Topics in Algebra*, Wiley.

N. Jacobson, *Basic Algebra 1 & 2*, Dover.

**22MAT508**

**PDE and Integral Equations**

**(3 1 0 4)**

Course outcomes

**CO1:** Develops an understanding for the construction of proofs and an appreciation for deductive logic.

**CO2:** Explore the already familiar properties of the derivative and the Riemann Integral, set on a more rigorous and formal footing which is central to avoiding inconsistencies in engineering applications.

**CO3:** Explore new theoretical dimensions of uniform convergence, completeness and important consequences as interchange of limit operations.

**CO4:** Develop an intuition for analyzing sets of higher dimension (mostly of the  $\mathbb{R}^n$  type) space.

**CO5:** Solve the most common PDEs, recurrent in engineering using standard techniques and understanding of an appreciation for the need of numerical techniques.

### Unit 1

Formation of PDEs, Classification of First order PDEs, Complete, general and Singular integrals, Lagrange's or quasi linear equations, Integral surfaces through a given curve, Orthogonal surfaces to a given system of surfaces, Characteristic curves.

## Unit 2

Pfaffian differential equations, Compatible systems, Charpit's method, Jacobi's method, Linear equations with constant coefficients, Reduction to canonical forms.

## Unit 3

Classification of second order PDEs, Method of separation of variables: Laplace, Diffusion and Wave equations in Cartesian, Cylindrical and Spherical polar coordinates.

## Unit 4

Boundary value problems for transverse vibrations in a string of finite length and heat diffusion in a finite rod, Maximum and Minimum Principles, Integral equations: Fredholm and Volterra integral equations of first, second and third kind, conversion of ODEs into integral equations.

## Unit 5

Fredholm equations of second kind with separable kernels, Fredholm alternative theorem, eigen values and eigen functions, Method of successive approximation for Fredholm and Volterra equations, Resolvent kernel.

Textbooks:

T. Amaranath, *An Elementary Course in Differential equations*, Narosa.

M.D. Raisinghania, *Integral equations and Boundary value problems*, S Chand Publications.

References:

I.N. Sneddon, *Elements of Partial Differential equations*, Dover.

M.D. Raisinghania, *Advanced Differential equations*, S Chand Publications.

**22CSA503**

**Advanced Machine Learning**

**(3 0 2 4)**

**CO1:** To understand the computing capacity of single layer neural networks, and the need for multi-layer neural networks.

CO2: Learn to tackle the under-fitting, overfitting, and getting into local optimal solutions when learning an artificial neural network.

CO3: Learn about the deep neural networks, CNN to understand how it differ from a deep traditional FFN both in terms of the number of parameters to be learned and in terms of the learning by back-propagation.

CO4: Learn to design and use CNN both as a stand-alone classifier and in transfer learning settings.

CO5: Learn the necessary theory behind different recurrent neural networks and its applications to sequential data analysis.

## Unit 1

Machine learning Basics and introduction, Capacity, Overfitting and under fitting, Hyper parameters, Estimator, Bias and Variance, Maximum likelihood estimation, Stochastic Gradient descent

## Unit 2

Deep feedforward networks, Learning XOR, Hidden units, Architecture design, Backpropagation

## Unit 3

Regularization, L1 and L2 regularization, Noise robustness, Semi supervised learning, Parameter typing and sharing, Sparse representation, Dropout

## Unit 4

Optimization, Challenges in neural network optimization, Parameter initialization strategy, Adaptive learning rates, Optimization algorithms

## Unit 5

Convolution operator, Pooling, Structured outputs, Efficient convolution algorithms, Unsupervised features, Convolution Neural networks, Recurrent Neural Networks, Encoder-decoder, LSTM and memory architectures, Optimization for long term dependency

### **Machine Learning Lab II to be performed**

1. Support Vector Classifier, Support Vector Machine, ROC Curves, SVM with Multiple Classes.
2. Principal Component Analysis and Clustering.
3. Overfitting and Underfitting Bias and Variance.
4. Gradient Descent Algorithm.
5. Backpropagation.
6. Neural Network Optimization 1.
7. Neural Network Optimization 2.
8. Convolution Neural networks.
9. Recurrent Neural Networks.
10. LSTM and memory architectures.

Textbooks:

Ian Goodfellow, Yoshua Bengio and Aaron Courville, *Deep Learning*, MIT Press. (Chapters 5-10).

**22MAT509**

**Problem Solving Session IV**

**(0 1 0 1)**

Course Outcomes:

CO1: Learn the problem solving techniques in Complex Analysis.

CO2: Understand the various theorems in Algebra.

CO3: Ability to solve a variety of problems in Linear Algebra and ODE.

1. Problem set on Complex Analysis 1.
2. Problem Set on Complex Analysis 2.
3. Problem set on ODE 1.
4. Problem set on ODE 2.
5. Problem set on Linear Algebra 1.
6. Problem set on Linear Algebra 2.
7. Problem set on Algebra 1.
8. Problem set on Algebra 2.

References: Textbooks and Reference Books in the corresponding topics of the courses

## Semester8:

**22MAT515**

**Measure and Integration**

**(3 1 0 4)**

Course outcomes

- CO1:** Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts.
- CO2:** Introduces the notion of a sigma algebra, introduces measurable functions, measures, and examine their properties..
- CO3:** Study in detail the properties of the Lebesgue integral, and fundamental convergence theorems in Measure and integration namely Lebesgue's Monotone Convergence Theorem and Lebesgue's dominated Convergence Theorems.
- CO4:** In  $L^p$  spaces, study in detail about the fundamental inequalities namely Holders and Minkowski's and hence derive the important fact that  $L^p$  spaces are complete metric spaces.
- CO5:** Introduce the total variation of a complex measure, positive and negative variations of a real measure, and then construct Lebesgue Radon Nikodym theorem which has important applications in Probability theory
- CO6:** Given two measurable spaces and measures on them , obtain a product measurable space and a product measure on this space.

### Unit 1

Lebesgue Outer Measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue Measurability. (2.1-2.5 of Text)

### Unit 2

Integration of Non-negative functions, The General Integral, Integration of Series, Riemann and Lebesgue Integrals, The Four Derivatives, Lebesgue's Differentiation Theorem, Differentiations and Integration. (3.1 to 3.4, 4.1, 4.4 (statements only),4.5 of Text)

### Unit 3

Abstract Measure Spaces: Measures and Outer Measures, Extension of a measure, Uniqueness of the Extension, Completion of the Measure, Measure spaces, Integration with respect to a Measure (5.1-5.6 of Text)

### Unit 4

The  $L^p$  Spaces, Convex Functions, Jensen's Inequality, The Inequalities of Holder and Minkowski, Completeness of  $L^p(\mu)$ . (6.1-6.5 of Text)

### Unit 5

Convergence in Measure, Signed Measures and the Hahn Decomposition, The Jordan Decomposition, The Radon-Nikodym Theorem, Some Applications of the Radon-Nikodym Theorem. (7.1, 8.1-8.4 of Text)

Textbook:

De Barra G, *Measure Theory and Integration*, New Age Publishers.

References:

Elias M Stein, *Real Analysis: Measure Theory, Integration and Hilbert Spaces*, New Age Publishers.

H.L. Royden and P.M. Fitzpatrick, *Real Analysis*, PHI.

**22MAT517**

**Topology**

**(3 1 0 4)**

Course outcomes

CO1: To introduce the concept of Metric spaces as a generalization of the analysis on the real line at a level and depth appropriate for introducing Topological spaces

CO2 providing a prerequisite for the forth coming courses like Differential Geometry, Functional Analysis, Complex Analysis etc..

CO3: To introduce the student to what it means to do mathematics, as opposed to learning about mathematics or to learning to do computational exercises.

CO4: To help the student learn how to write mathematical text according to the standards of the profession.

CO5 Inspiring them to study higher-level mathematics and to become a professional mathematician

### **Unit 1**

Topological spaces, Definition and examples, Interior, Closure and Boundary, Basis and Sub-basis, Continuity, Topological Equivalence, Subspaces.

### **Unit 2**

Connected Spaces, Theorems on Connectedness, Connected subsets of Real line, Applications of Connectedness, Path Connected Spaces.

### **Unit 3**

Compact spaces, Compactness and Continuity, Properties of Compact Spaces, One-Point Compactification.

### **Unit 4**

Finite and arbitrary Products, Tychonoff's theorem, Comparison of topologies, Quotient Spaces,  $T_0$ ,  $T_1$  and  $T_2$  Spaces, Regular Spaces, Normal Spaces, Separation by Continuous functions.

### **Unit 5**

Urysohn's Lemma and Tietze Extension Theorem, Nets, Filters and Convergence, Tychonoff's Theorem.

Textbook:

Fred H. Croom, *Principles of Topology*, Cengage Learning.

J.R. Munkres, *Topology*, PHI.

Sidney A. Morris, *Topology without Tears*, EBook.

References:

K.D. Joshi, *Introduction to General Topology*, New Age Publishers.

Sheldon W Davis, *Topology*, Tata McGraw-Hill.

G.F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill.

**22MAT516**

**Multivariate Statistics**

**(3 0 2 4)**

Course outcomes

CO1: Explore and summarize data using graphical and numerical methods to uncover hidden information and patterns

CO2: Describe the properties of multivariate distributions such as bivariate and multivariate normal.

CO3: Able to make statistical inference on mean vector and analysis of variance on a multivariate data

CO4: Use Principal Component analysis effectively for data exploration and data dimension reduction and

use factor analysis effectively for data exploration and confirmatory data analysis.

CO5: Able to use the canonical correlation analysis effectively in data analysis

### **Unit I**

Aspects of Multivariate Analysis: Introduction, Applications of multivariate techniques, organization of data, Data displays and Pictorial representation, Distance, Random vectors and matrices, mean vectors and covariance matrices, Random samples and expected values of sample mean and covariance matrix, Generalized variance, Sample mean, covariance and correlation as matrix operations, Sample values of Linear combinations of variables.

### **Unit 2**

Multivariate Normal distribution and its properties: Bivariate Normal Distribution (BVN), probability density function of bivariate normal distribution properties marginal and conditional probability density function bivariate normal distribution,

Multivariate Normal density and its properties, Sampling from a multivariate normal distribution and maximum likelihood estimation, the sampling distribution of  $\bar{X}$  and  $S$ , Large sample behavior of  $\bar{X}$  and  $S$ , Assessing the assumption of normality, Detecting outliers and cleaning data, Transformation to near normality.

### **Unit 3**

Inference about the Mean Vector: Introduction, Hotelling's  $T^2$  and likelihood ratio tests, Confidence region and simultaneous comparisons of component means, large sample inferences about the population mean vector, Comparisons of several multivariate means, one way and two way multivariate analysis of variance.

### **Unit 4**

Principal Components: Introduction, Population Principal Components, Summarizing sample variation by principal components, graphing the Principal components, large sample inferences

### **Unit 5**

Factor analysis, orthogonal factor model, methods of estimation, factor rotation and factor scores.

Canonical Correlation Analysis, Canonical variates and canonical correlations, interpreting the population canonical variables, the sample canonical variates and sample canonical correlations.

## **PRACTICALS/ LAB WORK USING R**

Reading multivariate data in R, obtain mean, variances, etc. of multivariate data sets, Multiple Correlation, Partial Correlation, Bivariate Normal Distribution, Multivariate Normal Distribution,

Clustering problems, Multivariate Analysis of Variance, Principal Components Analysis, Factor Analysis and canonical correlation analysis.

**Text Book:**

Johnson, R and Wichern (1992): *Applied Multivariate Statistical Analysis*, Prentice Hall, India, 6<sup>th</sup> edition.

**References:**

- Anderson, T.W. (2003), *An Introduction to Multivariate Statistical Analysis*, John Wiley.
- Alvin C. Rencher (2002), *Methods of multivariate analysis*, 2nd edition, John Wiley and Sons, INC
- Brian Everitt and Torsten Hothorn (2011), *An introduction to applied multivariate analysis with R*, Springer.
  - Douglas C. Montgomery and George C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley, 2005.

**22MAT519**

**Problem Solving Session V**

**(0 1 0 1)**

Course Outcomes:

CO1: Solve various NET Question Papers.

CO2: Ability to apply the techniques learned to a variety of problems.

CO3: Develop a deeper understanding of the Theory through solving problems.

1. Problem set on Real analysis based on CSIR-UGC NET Question papers.
2. Problem set on Linear Algebra based on CSIR-UGC NET Question papers.
3. Problem set on Algebra based on CSIR-UGC NET Question papers.
4. Problem set on Complex Analysis based on CSIR-UGC NET papers.
5. Problem set on Metric Spaces based on CSIR-UGC NET Question papers.
6. Problem set on ODE / Calculus of Variations based on CSIR-UGC NET Question papers.
7. Problem set on PDE / Integral equations based on CSIR-UGC NET Question papers.

**Semester9**

**22MAT604**

**Functional Analysis**

**(3 1 0 4)**

Course outcomes

- CO1:** Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts.
- CO2:** Students will have a firm knowledge of real and complex normed vector spaces with their geometric and topological properties. They will be familiar with the notions of completeness, separability, will know the properties of a Banach space and will be able to prove results relating to the Hahn Banach theorems. They will have developed an understanding of the theory of bounded linear operators on a Banach space



- CO3:** The Hahn Banach theorem is a central tool in functional analysis. It allows the norm preserving extension of bounded linear functional defined on a subspace of some vector space to the whole space and it also shows that there are enough continuous linear functionals defined on every normed vector space to make the study of the dual space interesting.
- CO4:** The Uniform boundedness principle is one of the fundamental results in functional analysis. Together with the Hahn-Banach theorem and the open mapping theorem it is considered one of the cornerstones of the field. In its basic form, it asserts that for a family of continuous linear operators and thus bounded operators whose domain is a Banach space, pointwise boundedness is equivalent to uniform boundedness in operator norm. The completeness of a norm is exploited to obtain four major theorems, namely the Uniform boundedness principle, the closed graph theorem, the open mapping theorem and the bounded inverse theorem.
- CO5:** Inner products allow us to think about geometric concepts in vector spaces. Gram Schmidt processes explain how the basis of a normed linear space can be converted into an orthonormal basis. Complete inner product spaces (that is Hilbert spaces) are studied in detail.
- CO6:** Apply problem solving using functional analysis techniques applied to diverse situations in Physics, Engineering and other mathematical contexts.

### **Unit 1**

Review of metric spaces, completion of metric spaces, Normed space, Banach space, properties of Normed spaces, Finite dimensional normed spaces and subspaces, Equivalent norms, compactness and finite dimension.

### **Unit 2**

Norm of a linear operator, Bounded and continuous linear operators, Linear functionals, Normed spaces of operators, Dual spaces, Computing Dual of some Banach Spaces.

### **Unit 3**

Inner product space, Hilbert space, Orthogonal complements and direct sums, Orthonormal sets, Bessel inequality, Gram-Schmidt Orthonormalisation, Orthonormal basis, Functionals on Hilbert spaces, Riesz's theorem, Projection and Riesz representation theorem, Adjoint operator, Self adjoint, Unitary and Normal Operators.

### **Unit 4**

Hahn-Banach theorem, Baire's Category theorem and Uniform boundedness principle, Open Mapping Theorem, Closed Graph Theorem, Bounded Inverse Theorem, Adjoint Operator, Strong and Weak Convergence, Convergence of sequence of Operators and Functionals.

### **Unit 5**

Spectrum of Bounded Operators, Compact Linear Operators, Spectrum of a Compact Operator, Spectrum and Numerical Range, Spectrum of Bounded Self-Adjoint Operators.

Textbook:

Kreyszig, *Introductory Functional Analysis with Applications*, Wiley.

B.V. Limaye, *Functional Analysis*, Wiley.

References:

M. Thamban Nair, *Functional Analysis- A First Course*, PHI.

A.L.Brown, A.Page, *Elements of Functional Analysis*, Van Nostrand.

**22MAT181**

**Mathematics Lab 1**

**(0 0 2 1)**

Course outcomes:

**CO1: Ability to plot functions in software.**

**CO2 Understand to use maxima minima , mean value theorem maxima minima , mean value theorem, Graphing with derivatives ,definite integrals and Riemann Sums in software.**

**Co3: Understand to use Integration techniques ,Sequences and Series in software.**

**CO4: : Understand to use Conic Sections and Parametric Equations, Hyperbolic Functions in software.**

- Introduction to Sage / Mathematica, plotting functions.
- Limits, Squeeze Theorem, Intermediate Value Theorem.
- Derivatives, Graphing with Derivatives, Asymptotes.
- Mean Value Theorem, Maxima and Minima
- Riemann Sums, Definite and Indefinite Integrals, Fundamental Theorem of Calculus.
- Basic Integration Techniques, Substitution.
- Integration Techniques: Logarithmic Functions, Inverse Trigonometric Functions and Trigonometric Substitution, Partial Fractions.
- Arc length, Surfaces of Revolution.
- Volumes, Work, Differential Equations.
- Improper Integrals, Comparison test for Integrals.
- Conic Sections and Parametric Equations, Hyperbolic Functions.
- Sequences and Series.

Textbook:

C.Arangala, K.A.Yokley, *Exploring Calculus: Labs and Projects with Mathematica*, CRC Press.

**22MAT182**

**Mathematics Lab 2**

**(0 0 2 1)**

Course outcomes:

**Co1: Understand to use Vectors , planes in 3 D**, Multivariate Functions, Limits, Continuity in software.

**CO2: Understand to use** Partial Derivatives, Differentiability, Directional Derivatives and Gradient inSoftware

**CO3 Understand to use** : Double Integrals in Cartesian and Polar Coordinates, Surface Area. Cylindrical and Spherical Coordinates, Triple Integrals, Change of Variables in Software

**CO4: Understand to use Green's theorem, stokes theorem, Divergence theorem in software.**

- Vectors, Lines and Planes in 3D, Cylinders and Quadric Surfaces.
- Vector Valued Functions, Space curves, Arc Length and Curvature.
- Multivariate Functions, Limits, Continuity.
- Partial Derivatives, Differentiability, Directional Derivatives and Gradient.
- Tangent Plane, Extrema of Multivariate Functions, Lagrange Multiplier.
- Double Integrals in Cartesian and Polar Coordinates, Surface Area.
- Cylindrical and Spherical Coordinates, Triple Integrals, Change of Variables.
- Vector Differentiation, Line Integrals, Independence of Path.
- Green's theorem in Plane, Curl and Divergence.
- Surface Integrals.
- Stoke's Theorem.
- Divergence Theorem.

Resource:<http://matrix.skku.ac.kr/Cal-Book/>

**22MAT284**

**Mathematics Lab 3**

**(0 0 2 1)**

Course outcomes

Co1: Ability to find Matrix operations in software

CO2: Ability to find solution of Equations in software

CO3: Ability to apply linear transformations and vector spaces in software

CO4:Ability to apply Diagonalization in software.

- Matrices 1

- Matrices 2
- Gaussian Elimination 1
- Gaussian Elimination 2
- Vector Spaces 1
- Vector Spaces 2
- Linear Transformations 1
- Linear Transformations 2
- Eigen Values and Eigen Vectors
- Characteristic Polynomial and Minimal Polynomial
- Diagonalization

Resource: <http://joshua.smcvt.edu/linearalgebra/lab.pdf>

## **22MAT283**

## **Computing using R (Lab 1)**

**(0 0 2 1)**

Course outcomes:

CO1: Install and use R for simple programming tasks.

CO 2. Extend the functionality of R by using add-on packages

CO 3. Extract data from files and other sources and perform various data manipulation tasks on them.

CO 4. Code statistical functions in R.

CO 5. Use R Graphics and Tables to visualize results of various statistical operations on data .

CO6. Apply the knowledge of R gained to data Analytics for real life applications.

### **List of Practical**

- Graphical representation of data.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation
- Problems based on moments, skewness and kurtosis
- Fitting of binomial distributions for  $n$  and  $p = q = \frac{1}{2}$ .
- Fitting of binomial distributions for given  $n$  and  $p$ .
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of the parameter.
- Fitting of Poisson distributions after computing mean.
- Fitting of negative binomial.
- Fitting of suitable distribution.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Application problems based on negative binomial distribution.
- Problems based on area property of normal distribution
- To find the ordinate for a given area for normal distribution.
- Application based problems using normal distribution.
- Fitting of normal distribution when parameters are given
- Fitting of normal distribution when parameters are not given
- Fitting of polynomials, exponential curves.

- Karl Pearson correlation coefficient.
- Correlation coefficient for a bivariate frequency distribution.
- Lines of regression, angle between lines and estimated values of variables

## **22MAT285**

## **Computing Using R (Lab 2)**

**(0 0 2 1)**

### **Course Outcome**

CO1: Ability to find significance level and testing of hypothesis in software R

CO2: Ability to find regression equations and analyze the data in R

CO3: Ability to understand and analyze Multiple Regression and test using R- software.

CO4: Apply the knowledge of R gained to data Analytics in Estimation theory and Analysis of variance

### **List of Practical**

- Testing of significance and confidence intervals for single proportion and difference of two proportion
- Testing of significance and confidence intervals for single mean and difference of two means and paired tests.
- Testing of significance and confidence intervals for difference of two standard deviations.
- Exact Sample Tests based on Chi-Square Distribution.
- Testing if the population variance has a specific value and its confidence intervals.
- Testing of goodness of fit.
- Testing of independence of attributes.
- Testing based on 2 X 2 contingency table without and with Yates' corrections.
- Testing of significance and confidence intervals of an observed sample correlation coefficient.
- Testing and confidence intervals of equality of two population variances
- Simple Linear Regression
- Multiple Regression
- Tests for Linear Hypothesis
- Bias in regression estimates
- Lack of fit
- Orthogonal Polynomials
- Analysis of Variance of a one way classified data
- Analysis of Variance of a two way classified data with one observation per cell
- Analysis of Covariance of a one way classified data
- Analysis of Covariance of a two way classified data.

**ELECTIVES**  
**Mathematics Stream**

**22MAT541**

**COMMUTATIVE ALGEBRA**

**3- 0 -0- 3**

**Course Outcomes:**

- CO-1: To understand the basic definitions of rings, ideals and modules through examples; To construct new modules by tensor product, Hom, direct sum/product.
- CO-2: To understand the fractions of modules and apply the fractions to construct the field from integral domain. To familiarize the decomposition of rings/modules.
- CO-3: To familiarize the concept of integral dependence of extension ring and chain conditions of modules. To understand the definitions of valuations / Noetherian / Artin rings through examples.
- CO-4: To study the basic properties of Noetherian/Artin rings; use the basic properties to characterize/decompose the Noetherian/Artin rings.
- CO-5: To understand the basic definitions of discrete valuation rings and Dedekind domains. To familiarize the concept of dimension theory of rings/modules.

**Unit I**

Rings and Ideals, Modules and operations on them (tensor product, Direct sum and product)

**Unit II**

Rings and modules of Fractions, primary decomposition.

**Unit III**

Integral dependence and Valuations, Chain Conditions.

**Unit IV**

Noetherian Rings and Artin Rings.

**Unit V**

Discrete valuation Rings and Dedekind Domains, Dimension theory.

**TEXT BOOKS / REFERENCES**

1. Atiyah-Macdonald, *Commutative Algebra*, Westview Press, 1994.
2. Zariski and Samuel, *Commutative Algebra I, II*, Springer, 1991.
3. Eisenbud, *Commutative Algebra with a View Towards Algebraic Geometry*, Springer, 1995.
4. Bourbaki, *Commutative Algebra*, Springer, 1989.

**22MAT542**

**ALGEBRAIC GEOMETRY**

**3- 0- 0- 3**

CO 1: To understand the various structures introduced in Algebraic geometry and to prove the standard theorems due to Hilbert/Krull/Noether, which give correspondence between algebraic

varieties and ideals, rings and fields.

CO 2: To understand properties of morphisms and its applications

CO 3: To familiarize the concept of rational maps

CO 4: To identify non-singularity through various criteria and understand the process of desingularisation

CO 5: To familiarize the idea of multiplicity and intersection with examples

**Unit-I AFFINE AND PROJECTIVE VARIETIES:** Noetherian rings and modules; Emmy Noether's theorem and Hilbert's Basissatz; Hilbert's Nullstellensatz; Affine and Projective algebraic sets; Krull's Hauptidealsatz; topological irreducibility, Noetherian decomposition; local ring, function field, transcendence degree and dimension theory; Quasi-Compactness and Hausdorffness; Prime and maximal spectra; Example: linear varieties, hypersurfaces, curves.

**Unit-II MORPHISMS:** Morphisms in the category of commutative algebras over a commutative ring; behaviour under localization; morphisms of local rings; tensor products; Product varieties; standard embeddings like the segre- and the d-uple embedding.

**Unit-III RATIONAL MAPS:** Relevance to function fields and birational classification; Example: Classification of curves; blowing-up.

**Unit-IV NONSINGULAR VARIETIES:** Nonsingularity; Jacobian Criterion; singular locus; Regular local rings; Normal rings; normal varieties; Normalization; concept of desingularisation and its relevance to Classification Problems; Jacobian Conjecture; relationships between a ring and its completion; nonsingular curves.

**Unit-V INTERSECTIONS IN PROJECTIVE SPACE:** Notions of multiplicity and intersection with examples.

### **TEXT BOOKS / REFERENCES BOOKS**

1. Robin Hartshorne, Algebraic Geometry, *Graduate Texts in Mathematics (GTM)* 8th Printing, Springer, 1997.
2. C. Musili, *Algebraic Geometry for Beginners, Texts and Readings in Mathematics 20*, Hindustan Book Agency, 2001.

**22MAT543**

**ALGEBRAIC TOPOLOGY**

**3-0-0-3**

Course Out Comes:

CO 1: To understand the concept complexes define homology groups

CO 2: To obtain homology groups for various pseudo manifolds

CO 3: To prove Brouwer fixed point theorem and understand its uses

CO 4: To familiarise the concept of homotopy theory and its role in topological spaces

Co 5: To find out the fundamental groups of various spaces and analyse the topological structures.

**Unit-I** Geometric Complexes and Polyhedra: Introduction. Examples. Geometric Complexes and Polyhedra; Orientation of geometric complexes.

Simplicial Homology Groups: Chains, cycles, Boundaries and homology groups, Examples of homology groups; The structure of homology groups.

**Unit-II** The Euler Poincare's Theorem; Pseudomanifolds and the homology groups of  $S_n$ . [Chapter 1 Sections 1.1 to 1.4 & Chapter 2 Sections 2.1 to 2.5 from the text].

**Unit-III** Simplicial Approximation: Introduction; Simplicial approximation; Induced homomorphisms on the Homology groups; The Brouwer fixed point theorem and related results;

**Unit-IV** The Fundamental Group: Introduction; Homotopic Paths and the Fundamental Group; The Covering Homotopy Property for  $S^1$ ;  
[Chapter 3 Sections 3.1 to 3.4; Chapter 4 Sections 4.1 to 4.3]



**Unit-V** Examples of Fundamental Groups; The Relation Between  $H_1(K)$  and  $\pi_1(K)$ ; Covering Spaces: The definition and some examples. Basic properties of covering spaces. Classification of covering spaces. Universal covering spaces. Applications.

[Chapter 4: Sections 4.4, 4.5; Chapter 5 Sections 5.1 to 5.5 from the text]

### **TEXT BOOK**

1. Fred H. Croom: *Basic Concepts of Algebraic Topology*, UTM, Springer, NY, 1978.

### **REFERENCES**

1. Eilenberg S and Steenrod N: *Foundations of Algebraic Topology*, Princeton Univ. Press, 1952.
2. S.T. Hu: *Homology Theory*, Holden-Day, 1965.
3. S.T. Hu: *Homology Theory*, Academic Press, 1959.

**22MAT544**

**INTRODUCTION TO CODING THEORY**

**3-0-0-3**

Course Out Comes:

CO-1: To understand the basic concepts of linear/error correcting codes and apply the concepts to encode and decode the information.

CO-2: To understand the concepts of dual /Hamming codes and apply the concept to find the parameters of given codes and their dual codes using standard matrix and polynomial operations.

CO-3: To familiarize the concepts of cyclic/BCH codes with required properties.

CO-4: To understand the concepts of weight enumerators and apply to find the weight information of the code.

To familiarize the concept of MDS code.

CO-5: Apply the basic concepts of linear codes to solve problems.

### **Unit I**

Introduction to linear codes and error correcting codes, Encoding and decoding of a linear code

### **Unit-II**

Dual codes. Hamming codes and perfect codes.

### **Unit-III**

Cyclic codes. Codes with Latin Squares, Introduction to BCH codes, Reed Solomon Codes

### **Unit-IV**

Weight Enumerators and MDS codes.

### **Unit-V**

Linear coding theory problems and conclusions.

## TEXT BOOKS

1. Raymond Hill, *A first course in Coding Theory*, Clarendon Press, Oxford (1986).
2. J.H. Van Lint, *Introduction to Coding Theory*, Springer (1998).

## REFERENCES

1. W. Cary Huffman and Versa Pless, *Fundamentals of Error Correcting Codes*, Cambridge University Press(2003).
2. W.W. Peterson, *Error Correcting Codes*, Cambridge, MA MIT Press (1961).
3. V. Pless, W.C. Huffman and R.A. Brualdi, *An Introduction to Algebraic Codes*, in Hand book of coding theory, Eds. Amsterdam Elsevier (1998).

**22MAT545**

**LIE ALGEBRAS**

**3-0-0-3**

### Course Outcome:

CO 1: To understand the concept of Lie algebra and to know the substructures and operations on them.

CO 2: To familiarize nilpotent and solvable Lie algebras and prove the Engel's theorem

CO 3: To understand theorems on Semi simple Lie algebras and their applications .

CO 4: To derive various decomposition theorems on Lie algebras

Co 5: To understand the classification of Lie algebras through Dynkin diagrams.

### Unit I

Basic Concepts—Definition and Examples, Lie Algebra of Derivations, Adjoint Representation, Structure Constants, Direct Sums, Homomorphism and Isomorphisms, Ideals, Centre and Derived Algebra of a Lie Algebra, Simple Lie Algebras, The Normalizer of a Subalgebra and Centralizer of a Subset in Lie Algebras, Automorphism and Inner Automorphism of a Lie Algebra.( Book 1, Chapters 1 and 2)

### Unit II

Descending Central Series of a Lie Algebra, Nilpotent Lie Algebras. Derived Series of a Lie Algebra, Radical of a Lie Algebra, Solvable Lie Algebras, Engel's Theorem.  
(Book 1, Chapter 3)

### Unit III

Semisimple Lie Algebras Theorems of Lie and Cartan, Jordan- Chevalley Decomposition, Cartan's Criterion. ( Book 1, Chapter 4)

### Unit IV

Killing Form, Inner Derivations, Abstract Jordan Decomposition, Complete Reducibility of Lie algebras.. ( Book 1, Chapter 5)

### Unit V

The Weyl Group, Root Systems. ( Book 1, Chapter 10)

## TEXT BOOKS / REFERENCES BOOKS

1. J.E. Humphreys, *Introduction to Lie Algebras and Representation Theory*,

Springer-Verlag, 1980.

2. Jacobson, *Lie Algebras*, Dover, 1979.

3. J.P. Serre, *Lie Algebras and Lie Groups*, Benjamin, 1965 (Translated from French).

**22MAT546**

**THEORY OF MANIFOLDS**

**3-0-0-3**

Course Out Comes:

CO 1: To familiarize the concept of manifolds and learn their properties

CO 2: To understand the concept of tangent spaces and its properties

CO 3: To generalize the ideas of curves/derivatives to manifolds

CO 4: To prove the inverse /implicit function theorems in manifolds

Co 5: To understand Riemannian manifolds and their relevance

### **Unit I**

Definition of Manifolds, Differentiable and Analytic Manifolds, Examples of Manifolds, Product of Manifolds, Mappings between Manifolds, Submanifolds, Tangent Vectors.

### **Unit II**

Differentials, The Differential of a Function, Infinitesimal Transformation, Tangent Space, Tangent Vector.

### **Unit III**

Cotangent Space, Vector Fields, Smooth Curve in a Manifold. Differential Forms– k-forms, Exterior Differential, its Existence and Uniqueness.

### **Unit IV**

Exact Differential Forms. De Rham Cohomology Group, Betti Number, Poincare's Lemma, Inverse Function Theorem, Implicit Function Theorem and its Applications, Integral Curve of a Smooth Vector Field.

### **Unit V**

Orientable Manifolds–Definition and Examples. Smooth Partition of Unity– Definition and Existence. Riemannian Manifolds– Definition and Examples.

### **TEXT BOOKS / REFERENCES:**

1. M.Singer., J.A. Thorpe, "*Lecture Notes on Elementary Topology and Geometry*", Undergraduate Texts in Mathematics, 2008.
2. P.M.Cohn, "*Lie Groups*", Cambridge University Press, 1965.
3. Claude Chevalley, "*Theory of Lie Groups*", Fifteenth Reprint, Princeton University Press, 1999.

CO1- Understand the general concept of weak solution and the criterion of having weak solution for hyperbolic equation.

CO2- Able to model the basic diffusion processes and understand the mathematical methods that are useful in studying the structure of their solutions.

CO3-Understand the existence and uniqueness of traveling wave solutions solutions.

CO4-Understand the concept of nonlinear eigenvalue problem the stability of equilibrium solutions for reaction-diffusion equation.

CO5-Understand the formulation of system of PDEs and their applications.

**Unit I:** Fourier series and integrals – Definitions and easy results – The Fourier transform – Convolution – Approximate identities – Fejer’s theorem – Unicity theorem – Parseval relation – Fourier Stieltjes Coefficients – The classical kernels.

**Unit II:** Summability – Metric theorems – Pointwise summability – Positive definite sequences – Herglotz’s theorem – The inequality of Hausdorff and Young.

**Unit III:** The Fourier integral – Kernels on  $\mathbb{R}$ . The Plancherel theorem – Another convergence theorem – Poisson summation formula – Bochner’s theorem – Continuity theorem.

**Unit IV:** Characters of discrete groups and compact groups – Bochner’s theorem – Minkowski’s theorem.

**Unit V:** Hardy spaces- Invariant subspaces – Factoring  $F$  and  $M$ . Riesz theorem – Theorems of Szegő and Beurling.

**Text Book:** Henry Helson, Harmonic Analysis, Hindustan Book Agency, Chapters 1.1 to 1.9, 2.1 to 3.5 and 4.1 to 4.3.

CO1 Understand and apply the concepts of DFT and its significance in Engineering problems

CO2 Understand and apply the concept of first stage wavelet basis and iterative stages of wavelet bases in finite dimensional space.

CO3 Understand and apply the concept of first stage wavelet basis and iterative stages of wavelet bases in infinite dimensional space.

CO4 Understand the concepts of Fourier transform and MRA and the construction of wavelets and its applications.

**Unit-I** Basic Properties of the Discrete Fourier Transform, Translation-Invariant Linear Transformations. The Fast Fourier Transform.

**Unit-II** Construction of Wavelets on  $Z_N$ , The First Stage Construction of Wavelets on  $Z_N$ , The Iteration Step's. Examples and Applications.

**Unit-III** Complete Orthonormal Sets in Hilbert Spaces,  $L_2([-\pi, \pi])$  and Fourier Series, The Fourier Transform and Convolution on  $l_2(Z)$ , First-Stage Wavelets on  $Z$ . The Iteration Step for Wavelets on  $Z$ , Implementation and Examples.

**Unit-IV**  $L_2(R)$  and Approximate Identities, The Fourier Transform on  $R$ , Multiresolution Analysis and Wavelets.

**Unit-V** Construction of Multiresolution Analyses, Wavelets with Compact Support and Their Computation.

**Text Books:**

1. Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer, 1999.

**References:**

1. Daubechis, Ten Lectures on Wavelets, SIAM, 1992.
2. S. Mallat, A Wavelet Tour of Signal Processing, Elsevier, 2008.

Course Outcomes:

CO-1: Understand and apply the concepts of fixed point theorems to prove the existence and uniqueness of solution to certain ordinary differential equations.

CO-2: To understand the existence and uniqueness of fixed point for non expansive and set valued mappings.

CO-3: To understand the existence of best approximation point for non expansive mapping and its applications.

CO-4: To understand the existence and uniqueness of fixed point for partially ordered metric space.

As an application, to prove the existence and uniqueness of solution for a periodic boundary value problem.

CO-5: Applying the fixed point theorems of multivalued mappings to demonstrate the conditions for existence of Nash equilibria in strategic games.

**Unit-I** Contraction Principle, and its variants and applications.

**Unit-II** Fixed points of non-expansive maps and set valued maps, Brouwer -Schauder fixed point theorems.

**Unit-III** Ky Fan Best Approximation Theorem, Principle and Applications of KKM -maps, their variants and applications.

**Unit-IV** Fixed Point Theorems in partially ordered spaces and other abstract spaces.

**Unit-V** Application of fixed point theory to Game theory and Mathematical Economics.

### **TEXT BOOKS / REFERENCES BOOKS**

1. M.A.Khamsi and W.A.Kirk, *An Introduction to Metric Spaces and Fixed Point Theory*, Wiley - Inter Sci. (2001).
2. Sankatha Singh, Bruce Watson and Pramila Srivastava, *Fixed Point Theory and Best Approximation: The KKM - map Principle*, Kluwer Academic Publishers, 1997.
3. Kim C. Border, *Fixed Point Theorems with Applications to Economics and Game Theory*, Cambridge University Press, 1985.

**22MAT550**

**NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS**

**3-0-0-3**

CO1- Understand the general concept of weak solution and the criterion of having weak solution for hyperbolic equation.

CO2- Able to model the basic diffusion processes and understand the mathematical methods that are useful in studying the structure of their solutions.

CO3-Understand the existence and uniqueness of traveling wave solutions solutions.

CO4-Understand the concept of nonlinear eigenvalue problem the stability of equilibrium solutions for reaction-diffusion equation.

CO5-Understand the formulation of system of PDEs and their applications.

Review of first order equations and characteristics.

**Unit-I** Weak solutions to hyperbolic equations- discontinuous solutions, shock formation, a formal approach to weak solutions, asymptotic behaviour of shocks.

**Unit-II** Diffusion Processes-Similarity methods, Fisher's equation, Burgers' equation, asymptotic solutions to Burgers' equations.

**Unit-III** Reaction diffusion equations-traveling wave solutions, existence of solutions, maximum principles and comparison theorem, asymptotic behaviour.

**Unit-IV** Elliptic equations-Basic results for elliptic operators, eigenvalue problems, stability and bifurcation.

**Unit-V** Hyperbolic system.

**TEXT BOOK** : J David Logan, *An Introduction to Nonlinear Partial Differential Equations*, John Wiley and Sons, Inc., 1994

**22MAT551**

**FRACTALS**

**3-0-0-3**

**Course Outcomes:**

CO1: Understand the basic concepts and structure of fractals .

CO2: Understand the space of fractals and transformation on metric spaces.

CO3: Understand the iterated function system with contraction mapping theorem.

CO4: Apply fractal concepts to compute fractal dimension of sets and construct fractal interpolation functions.

CO5: Understand the hidden variable fractal interpolation function, fractal splines and fractal surfaces.

**Unit-I** Classical Fractals, Self-similarity, Metric Spaces, Equivalent Spaces.

**Unit-II** The Space of Fractals, Transformation on Metric Spaces.

**Unit-III** Contraction Mapping and Construction of fractals from IFS.

**Unit-IV** Fractal Dimension, Hausdorff measure and dimension, fractal Interpolation Functions.

**Unit-V** Hidden Variable FIF, Fractal Splines, Fractal Surfaces, Measures on Fractals.

**TEXT / REFERENCES BOOKS**

1. M.F. Barnsley, *Fractals Everywhere*, Academic Press, 1993.

2. P.R. Massopust, *Interpolation and Approximation with Splines and Fractals*, Oxford University Press, 2009.
3. K. Falconer, *Fractal Geometry (Mathematical Foundations and Applications)*, John Wiley & Sons, 2003.
4. P.R. Massopust, *Fractal Functions, Fractal Surfaces and Wavelets*, Academic Press, 1994.
5. Richard M. Crowover, *Introduction to Chaos and Fractals*, Jones and Bartlett Publishers, 1995.
- 6.

**22MAT552**

**Differential Geometry**

**3- 0 - 0 – 3**

**Course Outcomes**

CO1: Students should acquire knowledge about the application of methods of differential calculus to the study of geometry with emphasis on the differential geometry of surfaces

CO2: Students should acquire knowledge about the application of methods of integral calculus to the study of geometry with emphasis on the differential geometry of surfaces.

CO3: Students should be able to apply this knowledge independently to analyze and solve mathematical problems in contexts where methods of differential geometry are relevant.

**Unit-I**

Curves in the plane and in space, arc-length, re-parametrization, level curves Vs parametrized curves.

**Unit-II**

Curvature, plane curves, space curve-global properties of curves, the isoperimetric inequality, the four-vertex theorem.

**Unit-III**

Surfaces in the three dimension, smooth surfaces, tangents, normals and orientability, quadratic surfaces, triply orthogonal systems, applications of inverse function theorem, the first fundamental form, lengths of curves on surfaces, isometric surfaces.

**Unit-IV**

Conformal mapping of surfaces, surfaces area, equiareal maps and a theorem of Archimedes, curvature of surfaces, the second fundamental form, the curvature of curves on a surface, the normal and principal curvatures, geometric interpretation of principal curvatures.

**Unit-V**

The Gaussian curvature and the mean curvatures, the pseudosphere, flat surfaces, surfaces of a constant mean curvature, Gaussian curvature of a compact surfaces, the Gauss map.

Text Book:

1. Andreq Pressley, *Elementary Differential Geometry*, Springer, 2006.

Reference Books:

1. Thierry Aubin, *A Course in Differential Geometry*, American Mathematical Society, 2007.
2. K. L. Wardle, *Differential Geometry*, Dover, 2008.

**Statistics Stream**

**22MAT570**

**Stochastic Processes**

**(3-0-0-3)**

Course outcomes

CO1: Understand to Illustrate and formulate fundamental probability distribution and density functions, as well as functions of random variables

CO2: Able to understand the concept of Stochastic processes, various classifications,



Statistical proprieties and understand about weak stationary and strict stationary processes and ergodic processes.

CO3: Ability to understand discrete time Markov chains and their applications

CO4: Understanding the Poisson processes and their applications in stochastic modelling

CO5: Understand the applications of stochastic processes and use of that in in day to day life

**Unit1:** Random variables and Stochastic Processes: Probability generating function-mean and variance, Laplace transform of probability distributions, geometric and exponential distributions, sums of random number of continuous random variables, Geometric and Exponential distributions and properties.

**Unit2:** Stochastic processes, Introduction, Classification of stochastic processes, statistical properties such as mean, variance, auto covariance and auto correlation, properties, Weak stationary, Strict stationary and non-stationary processes and examples, Mean ergodic processes.

**Unit 3:** Markov Chains: Definition of Markov Chain and examples, higher transition probabilities, Classification of states and chains, Determination of higher transition probabilities-limiting behavior, stability of a Markov System-Computation of equilibrium probabilities, Markov chains with denumerable number of states, Reducible Markov chains.

**Unit 4:** Counting processes, Poisson Process: Definition, Poisson process, properties and related distributions, Generalization of Poisson process, Continuous time Markov chains, Birth and death process, Markov process with discrete state space, Chapman-Kolmogorov equations, limiting distributions.

**Unit 5:** Applications in stochastic models, Queuing systems and models, Birth and death process in queueing theory, M/M/1 and M/M/s models with finite and infinite system capacity.

**Text Book:**

J. Medhi, *Stochastic Processes*, New Age International Publishers.

**References:**

S. Karlin & H.M. Taylor, *A First course in Stochastic processes*, Academic press, 1975.

Sheldon M. Ross, *Stochastic Processes*, second Edition, John Wiley and Sons, Inc.2004

William Feller, *An Introduction to Probability Theory and its Applications*, Vo1.I, Wiley.

Sheldon M Ross, *Simulation*, 4th edition, Elsevier.

Taha, H. (1995), *Operations Research: An Introduction*, Prentice- Hall India.

**22MAT571**

**SAMPLING THEORY**

**3 0 0 3**

CO1: Understand principal steps in a sample survey and notion of sampling error

CO2: To understand estimation of population mean and proportion and their variance

CO3: To explain and to compare various allocations using stratified random sampling and systematic sampling

CO4: To draw a conclusion about the best sampling procedure.

CO5: To apply various sampling methods for agricultural data

Unit I: Concept of sampling - Need for sampling - population and sample - sampling unit and sample frame - Types of Population - Basic properties of population - sample survey and census - Principal steps in a Sample survey - Notion of sampling error.

Unit II: Simple Random Sampling with and without replacement - Estimation of Population mean and proportion and their variances- Determination of sample size.

Unit III: Stratified sampling - Principles of stratification - Estimation of population mean and its variance - Allocation techniques - Estimation of gain due to stratification

Unit IV: Systematic sampling - Estimation of population mean and its sampling variance - Circular systematic sampling - comparison of systematic, simple random and stratified random sampling - cluster sampling with equal sized clusters - estimation of population mean and variance.

Unit V: Large scale sample surveys - Sources of Non sampling errors and methods of controlling them - NSS and CSO and their functions.

**Text Books:** Singh D and Choudhary F.S. (1986): Theory and Analysis of Sample Survey and Designs, New Age International.

### **Books for Reference**

1. Cochran, W.G. (1977): Sampling Techniques, 3/e, Wiley.
2. Desraj (2000): Sample survey theory, Narosa Publishing House.
3. Murthy M.N. (1967): Sampling theory and methods, Statistical Publishing society, Calcutta.
4. Sukhatme et al (1984): Sampling theory of surveys with applications, Iowa State University Press and IARS.
5. Sampath (2000): Sampling Theory and Methods, Narosa Publishing house

**22MAT572**

**PRINCIPLES OF EXPERIMENTAL DESIGN**

**3 0 0 3**

CO1: Compare the pairs of treatment means using different methods when null hypothesis is rejected in ANOVA.

CO2: Analyze the data using split plot, strip plot and general factorial experiments.

CO3: Construct fractional factorial experiments and apply confounding in real life problems.

CO4: Understand the analysis of BIBD, PBIBD, Quasi-Latin square, and cross over design and their applications in agriculture, business and industries

Unit1: Basic Principles for designing statistical experiments: Randomisation, Replication and local control techniques; determination of experimental units and notion of experimental error. Analysis of variance with one-way and two-way classifications; Models and Methods of analysis.

Unit 2: Completely randomized and randomized block designs - Models and estimates of parameters and their standard error - Analysis of data arising from such designs, Analysis when one or two observations are missing.

Unit 3: Latin Square Design – Model – Estimation of parameters – Method of analysis – Missing Plot technique in LSD - Analysis of covariance - One-way classification only

Unit4: Multiple Comparison tests: LSD , Student-Newman-Keuls test , Duncan's Multiple range test, Tukey's test - Transformations to stabilize the variance .

Unit V: Factorial Experiments: 2 2 , 2 3 and 3 2 designs; estimation of main effects and interactions and their standard errors - Principles of confounding

## **Text Books**

1. Das.M.N. and Giri.N.C. (1986): Design and Analysis of Experiments, Wiley eastern. 2.  
Gupta .S.C. and Kapoor.V.K.(2000): Fundamentals of Applied Statistics, Sultan Chand.

## **Reference Books**

1. Montgomery, D.C. (2001)) Design and Analysis of Experiments, John Wiley.
2. Kempthorne. O. (1965): The Design and Analysis of Experiments , Wiley eastern.
3. Goon.A.M, Gupta and Dasgupta.B. (2001): An Outline of statistical theory, vol. II, 6/e  
World Press Calcutta.
4. Parimal Mukhopadhyay(2005):Applied Statistics, 2/e, Books and Allied (P) Ltd, Kolkata

## **22MAT573 STATISTICAL QUALITY CONTROL AND SIX SIGMA QUALITY ANALYSIS**

**3-0-0-3**

Course Out Comes:

CO1: To develop basic knowledge about TQM

CO2: To understand old and new quality improvement tools

CO3: To understand the aspects of project planning and capability analysis

CO4: To understand the concept of Six Sigma and Lean methods

CO5: To apply Taguchi methods

### **Unit I**

Introduction to Quality Management – Japanese System of Total Quality Management

### **Unit II**

Quality Circles - 7 Quality Control tools - 7 New Quality Control tools

### **Unit III**

ISO 9000 Quality system Standards - Project Planning, Process and measurement system  
capability analysis- Area properties of Normal distribution -

### **Unit IV**

Metrics of Six sigma, The DMAIC cycle - Design for Six Sigma - Lean Sigma – Statistical tools  
for Six Sigma

### **Unit V**

Taguchi methods, Loss functions and orthogonal arrays and experiments

## **TEXT AND REFERENCE BOOKS**

1. Montgomery Douglas C., *Introduction to Statistical Quality Control*, Sixth Edition. John Wiley & Sons, 2009.
2. Ishikawa K., *Guide to Quality Control*, 2<sup>nd</sup> Edition. Asian Productivity Organization, Tokyo, 1983.
3. Taguchi G, *Introduction to Quality Engineering: Designing Quality into Products and Processes* Second Edition. 1991.
4. Harry, M and Schroeder R., *Six Sigma: The Breakthrough Management Strategy*. Currency Publishers, USA. 2000.

Course Out Comes:

CO1: To gain knowledge about pattern classification and dimensionality reduction method

CO2: To understand the use of Maximum-likelihood and Bayesian Parameter Estimation

CO3: To understand and apply Nonparametric Techniques and Linear Discriminant Functions

CO4: To apply Nonmetric methods and Algorithm-independent Machine Learning

CO5: To implement clustering methods under unsupervised learning

### **Unit I: Introduction and Bayesian Decision Theory**

Introduction – Pattern recognition systems – the design cycle – learning and adaptation – Bayesian decision theory – continuous features – Minimum error rate classification – discriminant functions and decision surfaces – the normal density based discriminant functions.

### **Unit II: Maximum-likelihood and Bayesian Parameter Estimation**

Maximum likelihood estimation – Bayesian estimation - Bayesian parameter estimation – Gaussian case and general theory – problems of dimensionality – components analysis and discriminants – hidden Markov models.

### **Unit III: Nonparametric Techniques and Linear Discriminant Functions**

Nonparametric techniques – density estimation – Parzen windows – nearest neighborhood estimation – rules and metrics – linear discriminant functions and decision surfaces – generalized linear discriminant functions – two-category linearly separable case – minimizing the perception criterion function.

### **Unit IV: Nonmetric methods and Algorithm-independent Machine Learning**

Nonmetric methods – decision trees – CART methods – algorithm-independent machine learning – lack of inherent superiority of any classifier – bias and variance for regression and classification – resampling or estimating statistics – estimating and comparing classifiers.

### **Unit V: Unsupervised Learning and Clustering**

Unsupervised learning and clustering – mixture densities and identifiability – maximum likelihood estimates – application to normal mixtures – unsupervised Bayesian learning – data description and clustering – criterion functions for clustering – hierarchical clustering – component analysis – low-dimensional representations and multi-dimensional scaling.

### **TEXT AND REFERENCE BOOKS:**

1. Richard O. Duda, Peter E. Hart and David G. Stork, *Pattern Classification*, Second Edition, 2003, John Wiley & Sons.
2. Earl Gose, Richard Johnsonbaugh and Steve Jost, *Pattern Recognition and Image Analysis*, 2002, Prentice Hall of India.

CO1: Understand the concept of time series with its components and able to compute ACVF and ACF.

CO2: Remove trend and seasonality using different methods to convert the time series into stationary.

CO3: Apply auto regressive, moving average, ARMA, ARIMA models, BoxJenkins approach to forecast time-series data empirically.

CO4: Check and validate models with its residual analysis and diagnostic checking

### Unit I

Time series, components of time series, additive and multiplicative models, determination of trend, analysis of seasonal fluctuations

### Unit II

Test for trend and seasonality, exponential and moving average smoothing, holt-winter smoothing, forecasting based on smoothing.

### Unit III

Time series as a discrete parameter stochastic process, auto covariance and auto correlation functions and their properties, stationary processes, test for stationarity, unit root test, stationary processes in the frequency domain, spectral analysis of time series.

### Unit IV

Detailed study of the stationary processes: moving average (MA), autoregressive (AR), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models.

### Unit V

Estimation of ARMA models, maximum likelihood method (the likelihood function for a Gaussian AR(1) and a Gaussian MA(1)) and Least squares, Yule-Walker estimation for AR Processes, choice of AR and MA periods, forecasting, residual analysis and diagnostic checking.

### TEXT BOOKS

1. Peter J Brockwell and Richard A Davis, Introduction to Time Series and Forecasting, Springer 2002
2. Anderson, T.W. *The Statistical Analysis of Time Series*, John Wiley, New York, 1971
3. Box, G.E.P. and Jenkins, G.M. *Time Series Analysis- Forecasting and Control*, Holden-day, San Francisco, 1976.
4. Kendall, Sir Maurice and Ord, J.K., *Time Series*, Edward Arnold, London, 1990.

CO1: Understand the principle concept of Continuous time Markov Chains.

CO2: Work with various distributions such as the negative exponential distribution and Erlang distribution.

CO3: Understand Markovian queues and their solutions

CO4: Apply Markov Chains to general queues, such as M/G/1 and GI/M/1.

CO5: Understand, model and analyze simple deterministic and stochastic inventory control systems.

CO6: Undertake simple cost analyses relating to the above models.

**Unit I:** Basic structure of queueing models, Examples of real queueing systems, Role of Exponential distribution, Birth-Death processes, Queueing models based on birth –death processes- M/M/1, M/M/s, M/M/1/K, M/M/s/K

**Unit II:** Queueing models involving non exponential distribution,- M/G/1, G/M/1, M/D/1, M/E<sub>k</sub>/1, M/E<sub>k</sub>/s, Priority discipline queueing models and Queueing networks.

**Unit III:** Application of Queueing Theory, Examples, Decision making, formulation of waiting cost functions, Decision models

**Unit IV:** Inventory concept – Components of Inventory model, Deterministic continuous review models, EOQ formula, EOQ models with shortages, EOQ models with quantity discount, Deterministic periodic review models,

**Unit V:** Stochastic continuous review models, stochastic single period model for perishable products, stochastic multi-period models, Stochastic periodic review model, inventory systems in practice, Supply chain management.

#### TEXT BOOKS/REFERENCES:

1. Frederick S Hiller and Gerald J Liberman, Introduction to operations research, 7<sup>th</sup> edition, McGraw-Hill series, 2001.

2. Gross D. and Harris C. M, John, “Fundamentals of Queuing Theory”, Third Edition, Wiley & Sons Inc, 2004.

#### Reference Books:

1. J. Medhi, “Stochastic Models in Queuing Theory”, Second Edition, Academic Press, Elsevier, 2003.
2. D. Bartman and M. J. Beckmann, Inventory Control-Models and Methods, Springer Verlag, 1992
3. Ravindran , Phillips and Solberg, Operations research Principles and Practice, 2<sup>nd</sup> Edition, John Wiley & Sons

CO1: Apply simple linear regression model to real life examples.

CO2: Understand multiple linear regression models with applications and concept of Multicollinearity and autocorrelation.

CO3: Compute multiple and partial correlation and checking residual diagnostic to validate model.

CO4: Apply Logistic and Non-linear regression models and its implementation in real life situation.

**Unit I:** Simple linear regression: Examples of simple linear regression; Interpretation of parameters; Estimation of the slope and the intercept in simple linear regression; Sampling properties of estimates. Theory of point estimation: least squares, maximum likelihood, method of moments; Confidence Intervals for parameters in simple linear regression.

**Unit II:** Multiple linear regression: Design matrix; Interpretation and estimation of parameters; Multicollinearity; Hypothesis tests: t-test, F-test, Likelihood-ratio test; Weighted least-squares.

**Unit III:** Residuals and their analysis: Assessing goodness-of-fit, normality, homogeneity of variances, detection of outliers and influential observations; Diagnostic plots for linear regression models.

**Unit IV:** Model selection: Mallow's  $C_p$ , AIC, BIC, R-squared, subset selection of independent variables, transformation of dependent and independent variables, multicollinearity, principal component regression, ridge-regression, Lasso.

**Unit V:** Logistic Regression: Statistical models for binary data; Interpretation of odds and odds ratios; Maximum likelihood estimation in logistic regression; Deviance, Residual analysis for logistic regression.

#### TEXT BOOKS / REFERENCES:

1. G. Seber and A. Lee "Linear Regression Analysis", Second Edition, Wiley, 2003.
2. A. Dobson and A. Barnett, "An Introduction to Generalized Linear Models", Third Edition, Chapman and Hall/CRC, 2008.
3. N. Draper and H. Smith, "Applied Regression Analysis", Third Edition, Wiley, 1998.
4. J. Fox, "Applied Regression Analysis, Linear Models and Related Methods", Sage, 1997.
5. C. Rao and H. Toutenburg, "Linear Models: Least Squares and Alternatives", Second Edition, Springer, 1999.

CO1: To extend understanding of the practice of statistical inference.

CO2: To familiarize the student with the Bayesian approach to inference.

CO3: To describe computational implementation of Bayesian analyses.

CO4: Use Bayesian computational software, e.g. R, for realistically complex problems and interpret the results in context.

**Unit I:** Basics on minimaxity: subjective and frequent probability, Bayesian inference, Bayesian estimation, prior distributions, posterior distribution, loss function, principle of minimum expected posterior loss, quadratic and other common loss functions, Advantages of being a Bayesian HPD confidence intervals, testing, credible intervals, prediction of a future observation.

**Unit II:** Bayesian analysis with subjective prior, robustness and sensitivity, classes of priors, conjugate class, neighborhood class, density ratio class different methods of objective priors: Jeffrey's prior, probability matching prior, conjugate priors and mixtures, posterior robustness: measures and techniques.

**Unit III:** Model selection and hypothesis testing based on objective probabilities and Bayes' factors, large sample methods: limit of posterior distribution, consistency of posterior distribution, asymptotic normality of posterior distribution.

**Unit IV:** Bayesian Computations: analytic approximation, E- M Algorithm, Monte Carlo sampling, Markov Chain Monte Carlo Methods, Metropolis – Hastings Algorithm, Gibbs sampling, examples, convergence issues

Text Book:

1. Albert Jim (2009) Bayesian Computation with R, second edition, Springer, New York
2. Bolstad W. M. (2007) Introduction to Bayesian Statistics 2nd Ed. Wiley, New York

Reference Books

2. Christensen R. Johnson, W. Branscum A. and Hanson T.E. (2011) Bayesian Ideas and data analysis: A introduction for scientist and Statisticians, Chapman and Hall, London
3. Congdon P. (2006) Bayesian Statistical Modeling, Wiley, New York
4. Ghosh, J.K. Delampady M. and T. Samantha (2006). An Introduction to Bayesian Analysis: Theory and Methods, Springer, New York.
5. Lee P.M. (2004) Bayesian Statistics: An Introduction, Hodder Arnold, New York.



CO1: Explain the concept of survival models.

CO2: Assess the properties of a data set and to model real-life data for insurance and finance applications.

CO3: Use actuarial statistics techniques and its application in assessing probability models and data.

CO4: Understand and discuss the ethical dimensions and implications of the modelling introduced in the course.

**Unit I:** 1. Insurance Business – Introduction, Insurance Companies as Business Organizations, Concept of Risk; Future Lifetime Distribution and Life Tables – Future Lifetime Random Variable, Curtate Future Lifetime, Life Table.

**Unit II:** Actuarial Present Values or Benefit in Life Insurance Products – Compound Interest and Discount Factor, Benefit Payable at the Moment of Death, Benefit Payable at the End of Year of Death, Relation between  $A$  and  $A$  .

**Unit III:** Annuities – Annuities Certain, Continuous Life Annuities, Discrete Life Annuities, Life Annuities with mthly Payments; Premiums – Loss at Issue Random Variable, Fully Continuous Premiums, Fully Discrete Premiums.

**Unit IV:** Reserves – Fully Continuous Reserves, Fully Discrete Reserves; Multiple Life Contracts – Joint Life Status, Last Survivor Status.

### **Text Book**

1. Deshmukh, S.R. (2009) Actuarial Statistics – An Introduction using R, University Press (India) Pvt Ltd., Hyderabad.

### **2. Reference Books**

1. Promislow, S.D (2006) Fundamentals of Actuarial Mathematics, John Wiley, Chapters 2- 11 & 14.
2. Neill, A. (1977) Life Contingencies, Heinemann, London.
3. Newton L.Bowers, Jr, Hans U.Gerber, James C.Hickman, Donald A. Jones and Cecil J. Nesbitt (1997) Actuarial Mathematics, The Society of Actuaries.

4. King, G. Institute of Actuaries Text Book. Part 11, Second edition, Charles and Edwin Layton, London. 5. Donald D.W.A. (1970) Compound Interest and Annuities, Heinemann, London.

### Computer Science Stream

**22MAT563**

**Graph Theory**

**3 0 0 3**

Course Out Comes:

CO-1: Understand the basic concepts of graphs and trees.

CO-2: Understand and apply the concepts of graph connectivity and shortest path Problems.

CO-3: Understand and apply the concepts of matching problems in job assignments.

CO-4: Understand the concepts of vertex and edge colorings.

CO-5: Understand the concepts of planar graphs and dual graphs.

**Review of Graphs:** Graphs and Sub graphs, isomorphism, matrices associated with graphs, Degrees, walks, connected graphs, shortest path algorithm.

**Trees:** Trees, cut-edges and cut-vertices, spanning trees, minimum spanning trees, DFS, BFS Algorithms.

**Connectivity:** Graph connectivity, k-connected graphs and blocks.

**Euler and Hamilton Graphs:** Euler graphs, Euler's theorem. Fleury's algorithm for Eulerian Trails. Necessary / sufficient conditions for the existence of Hamilton cycles, Chinese postman-Problem, approximate solutions of traveling salesman problem

**Matching** Matchings, maximal matchings. Coverings and minimal coverings. Berge's Theorem, Hall's theorem, Tutte's perfect matching theorem, Job assignment problem. Coverings, Independent Sets and Cliques; Basic Relations.

**Colorings:** Vertex colorings, greedy algorithm and its consequences, Brooks' theorem. Edgecolorings,

Vizing theorem on edge-colorings.

**Planar graphs:** Euler formula. Dual graphs. Kuratowski's Characterization, Planarity Testing algorithm.

#### **TEXT BOOKS**

1. J.A. Bondy and U.S.R. Murty, *Graph Theory and Applications*, Springer, 2008.

#### **REFERENCES BOOKS**

1. D.B. West, *Introduction to Graph Theory*, P.H.I. 2010.

2. Frank Harary, *Graph Theory*, New York Academy of Sciences, 1979.

3. Russel Merris, *Graph Theory*, John Wiley, 2011.

**22MAT561**

**ADVANCED DATA STRUCTURES AND ALGORITHMS**

**3-0-0-3**

Course Out Comes:

CO-1: Understand the basic concepts of growth functions and various sortings.

CO-2: Understand and the concept of divide and conquer for various sortings.

CO-3: Understand and apply the greedy method for various problems.

CO-4: Understand various definitions of graphs and apply to some algorithms.

CO-5: Understand the concepts of various computational complexity classes.

Pre-requisite: Data Structures and Algorithms.

**Unit-I** Introduction: growth functions – recurrence relation – methods – master method. Sorting:

bubble – insertion sort – selection sort.

**Unit-II** Divide and conquer: quick sort – merge sort – bucket sort – lower bounds – heap sort – comparisons of sorting.

**Unit-III** Greedy algorithm: fractional knapsack problem – task scheduling problem. Dynamic programming: matrix multiplication problem – 0-1 knapsack.

**Unit-IV** Graph algorithms: graph traversal (DFS, BFS with analysis) – biconnected components – strong connectivity; shortest path algorithms (along with analysis) – Dijkstra – Bellman Ford – Floyd Warshall. All pairs shortest path algorithm – minimum spanning tree (with analysis) – Kruskal – Prim's – Baruvka's.

**Unit-V** NP problems: definition, P, NP, NP complete, NP hard & co-NP, examples – P, NP.

### **TEXT BOOK**

1. Goodrich M T and Tamassia R, *Algorithm Design Foundations, Analysis, and Internet Examples*, John Wiley and Sons, 2002.

### **REFERENCES**

1. Baase S and Gelder A V, *Computer Algorithms – Introduction to Design and Analysis*, Pearson Education Asia, 2002.
2. Cormen T H, Leiserson C E, Rivest R L and Stein C, *Introduction to Algorithms*, Prentice Hall of India Private Limited, 2001.
3. Dasgupta S, Papadimitriou C and Vazirani U, *Algorithms*, Tata McGraw-Hill, 2009.
4. Horowitz E, Sahni S and Rajasekaran S, *Fundamentals of Computer Algorithms*, Galgotia, 1998.

Course Out Comes:

- CO-1: Understand the basic concepts of Fuzzy sets
- CO-2: Understand the concepts of arithmetic operations on fuzzy numbers.
- CO-3: Understand the concepts Fuzzy relations.
- CO-4: Understand the concepts of Fuzzy logic.
- CO-5: Understand the concepts of uncertainty and crisp sets.

**Unit-I Fuzzy Sets:** Crisp Sets- an Overview, Fuzzy Sets-Definition and Examples,  $\alpha$ -Cuts and its Properties, Representations of Fuzzy Sets, Extension Principles of Fuzzy Sets, Operations on Fuzzy Sets-Fuzzy Complements, Fuzzy Intersections, Fuzzy Unions, Combinations of Operations, Aggregation Operations.

**Unit-II Fuzzy Arithmetic:** Fuzzy Numbers, Arithmetic Operations on Intervals, Arithmetic Operations on Fuzzy Numbers.

**Unit-III Fuzzy Relations:** Binary Fuzzy relations, Fuzzy Equivalence Relations, Fuzzy Compatibility Relations.

**Unit-IV Fuzzy Logic:** Classical Logic, Multivalued Logic, Fuzzy Propositions, Fuzzy Quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy Propositions, Conditional and Qualified Propositions and Quantified Propositions,.

**Unit-V Uncertainty-Based Information:** Information and Uncertainty, Non Specificity of Crisp Sets – Non Specificity of Fuzzy Sets, Fuzziness of Fuzzy Sets, Uncertainty In Evidence Theory, Principles of Uncertainty.

#### TEXT AND REFERENCE BOOKS:

1. George J. Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic- Theory and Applications*, Prentice Hall of India, 1997.
2. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill, 1997.
3. H.J. Zimmermann, *Fuzzy Sets and its Applications*, Allied publishers, 1991.

Course Out Comes:

- CO-1: Understand the basic concepts of graphs and trees.
- CO-2: Understand and apply the concepts of graph connectivity and shortest path problems.
- CO-3: Understand and apply the concepts of matching problems in job assignments.
- CO-4: Understand the concepts of vertex and edge colorings.

CO-5: Understand the concepts of planar graphs and dual graphs.

**Unit-I** Binomial coefficients, convexity. Inequalities: Jensen's, AM-GM, Cauchy Schwarz. Graphs, subgraphs, connectedness.

**Unit-II** Euler circuits, cycles, trees, bipartite graphs and other basic concepts.

**Unit-III** Vertex colourings. Graphs with large girth and large chromatic number.

**Unit-IV** Extremal graph theory: Dirac's theorem. Ore's theorem. Mantel's theorem. Turan's theorem (several proofs including probabilistic and analytic).

**Unit-V** Kovari- Sosuran theorem with applications to geometry. Erdos Stone theorem. Stability. Andrasfai-Erdos-Sos theorem.

### TEXT AND REFERENCE BOOKS

1. B Bollobas, Modern Graph Theory, Springer
2. D.B. West, *Introduction to Graph Theory*, P.H.I. 2010

**22MAT565**

**INTRODUCTION TO SOFT COMPUTING**

**3-0-0-3**

Course Out Comes:

CO-1: Understand the various types of soft computing techniques

CO-2: Understand the concepts of artificial intelligence.

CO-3: Understand and apply the concepts fuzzy logic in optimization problems.

CO-4: Understand the concepts of neural networks.

CO-5: Understand the concepts of genetic algorithms.

**Unit-I Soft Computing:** Introduction of soft computing, soft computing vs. hard computing, various types of soft computing techniques, applications of soft computing.

**Unit-II Artificial Intelligence:** Introduction, Various types of production systems, characteristics of production systems, breadth first search, depth first search techniques, other Search Techniques like hill Climbing, Best first Search, A\* algorithm, AO\* Algorithms and various types of control strategies.

**Unit-III Fuzzy Logic:** Crisp set and Fuzzy set, basic concepts of fuzzy sets, membership functions. Basic operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations. Propositional logic and Predicate logic, fuzzy If – Then rules, fuzzy mapping rules and fuzzy implication functions, Applications.

**Unit-IV Neural Networks:** Basic concepts of neural networks, Neural network architectures, Learning methods, Architecture of a back propagation network, Applications.

**Unit-V Genetic Algorithms:** Basic concepts of genetic algorithms, encoding, genetic modeling.

**Hybrid Systems:** Integration of neural networks, fuzzy logic and genetic algorithms.

## **TEXT AND REFERENCE BOOKS**

1. S. Rajasekaran and G.A.Vijayalakshmi Pai.. *Neural Networks Fuzzy Logic, and Genetic Algorithms*, Prentice Hall of India.
2. K.H.Lee.. *First Course on Fuzzy Theory and Applications*, Springer-Verlag.
3. J. Yen and R. Langari.. *Fuzzy Logic, Intelligence, Control and Information*, Pearson Education.

**22MAT566**

**Computer Aided Design of VLSI Circuits**

**3-0-0- 3**

Course Out Comes:

CO-1: Understand the basic concepts of VLSI design problems.

CO-2: Understand various definitions of graphs and apply to some algorithms.

CO-3: Understand and apply the placement and partitioning algorithms.

CO-4: Understand and apply the routing algorithms.

CO-5: Understand the concepts of 1D and 2D compactions.

**Unit-I** : Introduction of Design Methodologies and Graph Theory: The VLSI Design Problems- Design Methods –Design Cycle – Physical Design Cycle-Design Styles.

**Unit-II**: Algorithmic and System Design-Structural and Logic Design-Layout Design. Graph terminologies – Data structures for the representation of Graphs – Algorithms: DFS-BFS-Dijkstra’s shortest path algorithm – Prim’s algorithm for minimum spanning trees. Combinatorial Optimization Problems – Complexity Class-P-NP Completeness and NPHardness problems.

**Unit-III** ; Placement, Partitioning and Floor Planning: Types of Placement Problems – Placement Algorithms – K-L Partitioning Algorithm. Optimization Problems in Floor planning - Shape Function and Floor plan Sizing

**Unit-IV**: Routing and Compaction: Types of Routing Problems – Area Routing – Channel Routing – Global Routings.

**Unit-V**: 1D and 2D Compaction. Gate level – Switch level Modeling and Simulations.

## **TEXT BOOK / REFERENCES:**

1. Gerez, “*Algorithms for VLSI Design Automation*”, John Wiley & Sons, 2000.

2. Naveed Sherwani, “*Algorithms for VLSI Physical Design Automation*”, Second Edition, Kluwer Academic Publishers, 1995.
3. Sadiq M Sait and Habib Youssef, “*VLSI Physical Design Automation: Theory and Practice*”, IEET, 1999.
4. M. Sarrafzadeh and C. K. Wong, *An Introduction to VLSI Physical Design*, McGraw-Hill, New York, NY, 1996.
5. Giovanni De Micheli, *Synthesis and Optimization of Digital Circuits*, Tata McGraw Hill, 1994

**22MAT567**

**Cryptography**

**3 0 0 3**

CO-1: Understand the basic concepts of classical ciphers.

CO-2: Understand the concepts of encryptions and pseudorandomness.

CO-3: Understand the concepts private-key encryption.

CO-4: Understand the concepts of ElGamal encryption.

CO-5: Understand the concepts of RSA and DSA signatures.

**Unit-I Classical ciphers:** Cryptanalysis of classical ciphers, Probability theory, Perfect security

**Block ciphers:** DES, AES, Block cipher modes of operation.

**Unit-II Private-key encryption:** Chosen plaintext attacks, Randomised encryption, Pseudorandomness, Chosen ciphertext attacks.

**Unit-III Message authentication codes:** Private-key authentication, CBC-MAC, Pseudorandom functions, CCA-secure private-key encryption.

**Unit-IV Hash function:** Integrity, Pre-image resistance, 2nd pre-image resistance, Collision freeness.

**Key distribution:** Key distribution centres, Modular arithmetic and group theory, Diffie-Hellman key exchange.

**Unit-V Public-key Distribution:** ElGamal encryption, Cramer-Shoup encryption, Discrete logarithm problem.

**Digital Signatures:** RSA signatures, RSA-FDH and RSA-PSS signatures, DSA signatures.

**Text / Reference Books:**

1. Katz and Lindell, Introduction to Modern Cryptography. Second Edition, Chapman & Hall/ CRC Press, 2014.
2. Jonathan Katz and Yehuda Lindell, Introduction to Modern Cryptography, CRC Press.
3. Hans Delfs, Helmut Knebl, "Introduction to Cryptography, Principles and Applications", Springer Verlag.

CO-1: Understand the basic concepts of languages and finite state machine.

CO-2: Understand the concepts of regular language and regular expressions.

CO-3: Familiarise the concepts of various types of grammars.

CO-4: Understand the concepts of context free grammar and language

**Unit-I Fundamentals** : Strings, Alphabet, Language, Operations, Finite state machine, definitions, finite automaton model, acceptance of strings, and languages, deterministic finite automaton and non deterministic finite automaton, transition diagrams and Language recognizers. Finite Automata: NFA with  $\hat{\epsilon}$  transitions - Significance, acceptance of languages. Conversions and Equivalence : Equivalence between NFA with and without  $\hat{\epsilon}$  transitions, NFA to DFA conversion, minimisation of FSM, equivalence between two FSM's, Finite Automata with output-Moore and Melay machines.

**Unit-II Regular Languages** : Regular sets, regular expressions, identity rules, Constructing finite Automata for a given regular expressions, Conversion of Finite Automata to Regular expressions. Pumping lemma of regular sets, closure properties of regular sets (proofs not required).

**Unit-III Grammar Formalism** : Regular grammars-right linear and left linear grammars, equivalence between regular linear grammar and FA, inter conversion, Context free grammar, derivation trees, sentential forms. Right most and leftmost derivation of strings. **Unit-IV Context Free Grammars** : Ambiguity in context free grammars. Minimisation of Context Free Grammars. Chomsky normal form, Greiback normal form, Pumping Lemma for Context Free Languages. Enumeration of properties of CFL (proofs omitted). Push Down Automata : Push down automata, definition, model, acceptance of CFL, Acceptance by final state and acceptance by empty state and its equivalence. Equivalence of CFL and PDA, interconversion. (Proofs not required). Introduction to DCFL and DPDA. **Turing Machine** : Turing Machine, definition, model, design of TM, Computable functions, recursively enumerable languages. Church's hypothesis, counter machine, types of Turing machines (proofs not required).

**Unit-V Computability Theory** : Chomsky hierarchy of languages, linear bounded automata and context sensitive language, LR(0) grammar, decidability of, problems, Universal Turing Machine, undecidability of posts. Correspondence problem, Turing reducibility, Definition of P and NP problems, NP complete and NP hard problems.

### TEXT BOOKS

1. Hopcroft, Motwani and Ullman, *Introduction to Automata Theory Languages and Computation*. Third Edition, 2007, Pearson Education, Addison-Wesley.
1. Peter Linz *An Introduction to Formal Languages and Automata* (Feb 14, 2011), Fifth



Edition Jones & Bartlett.

## REFERENCES

1. Daniel I.A. Cohen, *Introduction to Computer Theory*, John Wiley.
2. John C Martin, *Introduction to languages and the Theory of Computation*, TMH.
3. Lewis H.P. & Papadimitriou *Elements of Theory of Computation* C.H. Pearson /PHI.
- 4 Mishra and Chandrashekar, *Theory of Computer Science – Automata Languages and Computation* 2<sup>nd</sup> Edition, PHI.

**22MAT569**

**ALGORITHMS FOR ADVANCED COMPUTING**

**3-0-0-3**

Course Out Comes:

CO-1: Understand the various classifications

CO-2: Understand the concepts of decision trees

CO-3: Understand and apply the concepts preprocessing techniques for information extraction problems.

CO-4: Understand the concepts of various soft computing techniques.

CO-5: Understand the concepts of various algorithms in networks.

**Unit I:** Issues regarding classification and prediction, Bayesian Classification, Classification by back propagation, Classification based on concepts from association rule mining, Other Classification Methods, Classification accuracy.

**Unit II:** Introduction to Decision trees - Classification by decision tree induction – Various types of pruning methods – Comparison of pruning methods – Issues in decision trees – Decision Tree Inducers – Decision Tree extensions.

**Unit III:** Introduction, Core text mining operations, Preprocessing techniques, Categorization, Clustering, Information extraction, Probabilistic models for information extraction

**Unit IV:** Soft Computing: Rationale, motivations, needs, basics: examples of applications in diverse fields, Basic tools of soft computing: Neural Networks, Fuzzy Logic Systems, and Support Vector Machines, Statistical Approaches to Regression and Classification - Risk Minimization, Support Vector Machine Algorithms.

**Unit V:** Single-Layer Networks: The Perceptron, The Adaptive Linear Neuron (Adaline) and the Least Mean Square Algorithm - Multilayer Perceptrons: The Error Backpropagation Algorithm – The Generalized Delta Rule, Heuristics or Practical Aspects of the Error Backpropagation Algorithm.

Text Books:

• Jiawei Han and Micheline Kamber, “Data Mining: Concepts and Techniques”, Morgan Kaufmann Publishers, 3rd ed, 2010.

• Jared Dean, “Big Data, Data Mining, and Machine Learning: Value Creation for Business Leaders and Practitioners”, Wiley India Private Limited, 2014.

## References Books :

- Lior Rokach and Oded Maimon, “Data Mining and Knowledge Discovery Handbook”, Springer, 2nd edition, 2010.
- Ronen Feldman and James Sanger, “The Text Mining Handbook: Advanced Approaches in Analyzing Unstructured Data”, Cambridge University Press, 2006.
- Vojislav Kecman, “Learning and Soft Computing”, MIT Press, 2010

## Data Science Electives

**22CSC533                      Database Management for Big Data                      (3-0-0-3)**

Course outcomes

CO1: Understand the basic concepts of database and big data.

CO 2.: Understand the database models and its implementation techniques.

CO 3: Ability to learn big data implementation platforms

CO 4: Ability to learn data base technologies associated with big data.

CO5.: Ability to apply Data Intensive tasks using the Map Reduce Paradigm

### Unit 1

Introduction: Overview of DBMS, File vs DBMS, elements of DBMS. Database design: E-R model, Notations, constraints, cardinality and participation constraints

### Unit 2

Relational Data Model: Introduction to relational model, Structure of relational model, domain, keys, tuples to relational models, sql queries. Relational Database Design: Functional dependency, Normalization: 1NF, 2NF, 3NF, BCNF, table joins.

### Unit 3

Introduction to Big Data: Types of Digital Data - Characteristics of Data – Evolution of Big Data - Definition of Big Data - Challenges with Big Data - 3Vs of Big Data - Non Definitional traits of Big Data - Business Intelligence vs. Big Data - Data warehouse and Hadoop environment - Coexistence.

### Unit 4

Big Data Analytics: Classification of analytics - Data Science - Terminologies in Big Data - CAP Theorem - BASE Concept. NoSQL: Types of Databases – Advantages – NewSQL - SQL vs. NoSQL vs NewSQL.

### Unit 5

Introduction to Hadoop: Features – Advantages – Versions - Overview of Hadoop Eco systems - Hadoop distributions - Hadoop vs. SQL – RDBMS vs. Hadoop - Hadoop Components – Architecture – HDFS - Map Reduce: Mapper – Reducer – Combiner – Partitioner – Searching – Sorting - Compression. Hadoop 2 (YARN): Architecture - Interacting with Hadoop Eco systems.

Textbooks:

Silberschatz A, Korth H F and Sudharshan S, “*Database System Concepts*”, Sixth Edition, Tata McGraw-Hill Publishing Company Limited, 2010.

Seema Acharya, Subhashini Chellappan, “*Big Data and Analytics*”, Wiley Publication, 2015.

**References:**

Judith Hurwitz, Alan Nugent, Dr. Fern Halper, Marcia Kaufman, “*Big Data for Dummies*”, John Wiley & Sons, Inc., 2013.

Tom White, “*Hadoop: The Definitive Guide*”, O’Reilly Publications, 2011.

**22CSC534**

**Data Visualization**

**(3-0-0-3)**

Course outcomes

CO1: Able to design visualizations that represent the relationships contained in complex data sets and adapt them to highlight the ideas you want to communicate

CO2:Able to Support the visualizations with written and verbal explanations on their interpretation.

CO3:Able to Use leading open source software packages to create and publish visualizations

CO4: Able to Identify the statistical analysis needed to validate the trends present in data visualizations.

CO5: Enable clear interpretations of big, complex and real world data

**Unit 1**

Goals of data visualization, Data plotting softwares like matplotlib (python) and Gnuplot(available in linux environment), Syntax of the codes in these softwares

**Unit 2**

Different kinds of plots, Plots and subplots, Histogram, Probability density plots, Bar graphs, Pie charts

**Unit 3**

3D data visualization in 2D, Bubble Plot, Color density plot, 2D Histograms, 4D Data visualization in 3D, making animated plots and movies for data

**Unit 4**

Graph and Networks visualization, Introduction to software Graphviz, Syntax in graphviz, Drawing small and big networks in graphviz, Introduction to software Cytoscape, Different plotting layouts in cytoscape, visualizing large datasets in cytoscape with examples

**Unit 5**

Online data visualization, Introduction to D3 JSON, Plotting a dataset online

References: Data Visualizations

Course outcomes

**CO1:** To understand the fundamentals of deep learning

CO2: To know the main techniques in deep learning and the main research in this field.

CO3: Be able to design and implement deep neural network systems,

CO4: Be able to autonomously extend the knowledge acquired during the study course by reading and understanding scientific and technical documentation.

CO5 Identify new application requirements in the field of computer vision.

Unit 1

Introduction to Tensorflow, Installing and learning its basics, Recap of Neural networks, Convolution neural networks(CNN) and Recurrent Neural Networks (RNN)

Unit 2

Autoencoder and Decoders, Introduction to Generative Adversarial networks (GANs)

Unit 3

Introduction to Speech Processing, important neural network architectures used in them

Unit 4

Introduction to Natural Language processing (NLP), Important neural network architectures used in them

Textbooks:

Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press.

Course outcomes

CO1: Understand to apply Logistic regressions.

CO2: Linear discriminant analysis, Nonlinear methods, Isomap, Local linear embedding

CO3: Able to apply Regression trees, Classification trees, comparison of trees and linear models,

Unit 1

Support Vector Machines: Hyperplane, Maximum Margin Classifier, Support Vector Classifiers, Support Vector Machines, One vs One Classification and One vs All Classification, Relationship to Logistic Regression.

Unit 2

Dimensionality reduction, linear methods including PCA, Linear discriminant analysis, Nonlinear methods, Isomap, Local linear embedding, nonlinear PCA, t-SNE

Unit 3

Regression trees, Classification trees, comparison of trees and linear models, Bagging, Random Forests, Boosting.

#### Unit 4

Bayes Theorem, Prior, Likelihood function, Maximum likelihood estimation, Undirected graphical models, Hidden Markov Models.

#### Textbooks:

G. James, R. Tibshirani, An Introduction to Statistical Learning: with applications in R, Springer.

T. Hastie, R. Tibshirani, Elements of Statistical Learning: Data mining, Inference and Prediction, Springer.

#### References:

Kevin Murphy, Machine Learning: A Probabilistic Perspective, MIT Press.