

Central University of Tamil Nadu
School of Mathematics and Computer Sciences
Department of Statistics and Applied Mathematics



M.Sc. Statistics/Applied Mathematics

Syllabus

To Be Implemented from AY 2024-25

M.Sc. Statistics/Applied Mathematics Programme Structure

Table 1: First Year

No	Course Code	Course Title	CBCS Nature	Course Type	Credit	Hours / week	Marks	
							Int	Ext
SEMESTER – I								
1	SAM2011	Real Analysis	CC	Theory	4	4	40	60
2	SAM2012	Linear Algebra	CC	Theory	4	4	40	60
3	SAM2013	Probability Distribution Theory	CC	Theory	4	4	40	60
4	SAM2014	Optimization Techniques	CC	Theory	4	4	40	60
5	SAM2015	Calculus for Several Variables	CC	Theory	3	3	40	60
6	SAM2016	R Programming	CCP	Practical	2	4	100	
7	SAM2017	MATLAB Programming and Practical on SAM2014	CCP	Practical	2	4	100	
Total					23	27		
Total Hours in Semester I: 27x15=405 hours								
SEMESTER – II								
1	SAM2021	Probability Measure Theory	CC	Theory	3	3	40	60
2	SAM2022	Stochastic Processes	CC	Theory	3	3	40	60
3	SAM2023	Differential Equations	CC	Theory	3	3	40	60
4	SAM2024	Numerical Methods	CC	Theory	3	3	40	60
5	SAM2025	Practical on SAM2022 and SAM2024	CCP	Practical	2	4	100	
6	SAM2026	Introduction to PYTHON	CCP	Practical	2	4	100	
7	SAMOE**	Open Elective	OE	Theory	3	3		
8	SAM2027	Internship	Internship		4	*		
Total					23	23+*		
9	SAMVA**	Value Added Course	VAC	Theory	2			
*Internship will be conducted in continuous mode for 160 hrs (1 credit = 40hrs)								
Total Hours in Semester II: 23x15=345+160 (Internship)=505 hours								

Choice of Degree:

- After the Successful completion of first year, the students can choose either M. Sc. Statistics or M. Sc. Applied Mathematics for their degree.

- The students choosing M. Sc. Statistics will have to undertake the courses as per Table 2 for the Second year of study.
- The students choosing M. Sc. Applied Mathematics will have to undertake the courses as per Table 3 for the Second year of study.

Table 2: Second Year (M.Sc. Statistics)

SEMESTER - III								
1	SAM2031	Statistical Inference - I	CC	Theory	4	4	40	60
2	SAM2032	Regression Analysis	CC	Theory	4	4	40	60
3	SAM2033	Multivariate Statistical Analysis	CC	Theory	4	4	40	60
4	SAM2034	Sampling Theory	CC	Theory	3	3	40	60
5	SAM2035	Practical on SAM2032 and SAM2033	CCP	Practical	2	4	100	
6	SAM2036	Practical on SAM2031 and SAM2034	CCP	Practical	2	4	100	
7	SAMEC**	DSE – 1	DSE	Theory	4	4	40	60
8	SAMSS01	Type Setting using LATEX	Soft Skill	Theory	2	2		
Total					25	29		
Total Hours in Semester III: 29x15=435 hours								
SEMESTER - IV								
1	SAM2041	Statistical Inference - II	CC	Theory	4	4	40	60
2	SAMEC**	DSE – 2	DSE	Theory	3	3	40	60
3	SAMEC**	DSE – 3	DSE	Theory	3	3	40	60
4	SAMEC**	DSE – 4: Relevant MOOCS course offered on SWAYAM/NPTEL/e-Pathshala	DSE	Theory	3	3	40	60
5	SAM2042	Project	Project	Project	8	#	40	60
Total					21	13+#		
# 8x40=320 hours (1 credit = 40 hours)								
Total Hours in Semester IV: 13x15=195 (DSE/CC) + 320 (Research Project) = 515 hours								
Total Credits=92								
Total Hours=1860								

Table 3: Second Year (M.Sc. Applied Mathematics)

SEMESTER - III								
1	SAM2032	Regression Analysis	CC	Theory	4	4	40	60
2	SAM2037	Advanced Differential Equations	CC	Theory	4	4	40	60
3	SAM2038	Advanced Mathematical Analysis	CC	Theory	3	3	40	60
4	SAM2039	Fluid Dynamics	CC	Theory	4	4	40	60
5	SAM20310	Practical on SAM2023 and SAM2032	CCP	Practical	2	4	100	
6	SAM20311	Scientific Computing using MATLAB	CCP	Practical	2	4	100	
7	SAMEC**	DSE - 1	DSE	Theory	4	4		
8	SAMSS01	Type Setting using LATEX	Soft Skill	Theory	2	2		
Total					25	29		
Total Hours in Semester III: 29x15=435 hours								
SEMESTER - IV								
1	SAM2043	Mathematical Modeling in Biology	CC	Theory	4	4	40	60
2	SAMEC**	DSE - 2	DSE	Theory	3	3	40	60
3	SAMEC**	DSE - 3	DSE	Theory	3	3	40	60
4	SAMEC**	DSE - 4: Relevant MOOCS course offered on SWAYAM/NPTEL/e-Pathshala	DSE	Theory	3	3	40	60
5	SAM2042	Project	Project	Project	8	#	40	60
Total					21	13+#		
# 8x40=320 hours (1 credit = 40 hours)								
Total Hours in Semester IV: 13x15=195 (DSE/CC) + 320 (Research Project) = 515 hours								
Total Credits=92								
Total Hours=1860								

Multiple Exit and Entry Options

Multiple Exit Options:

- 1) Students can exit the program after successfully completing First Year (Semester I and II) of M.Sc. Statistics/Applied Mathematics. Such students will be awarded **PG Diploma in Statistics and Applied Mathematics**.
- 2) Student's successfully completing first year and second year as per Table 2 will be awarded M.Sc. Statistics.
- 3) Student's successfully completing first year and second year as per Table 3 will be awarded M.Sc. Applied Mathematics.

Multiple Entry Options:

Students can enter the program at the beginning of Semester I after completing THREE years Bachelor Degree in Statistics/Mathematics.

OR

at the beginning of Semester III after completing FOUR year Bachelor Degree in Statistics/First two semesters of M.Sc. Statistics/M. Sc. Applied Statistics for M. Sc. Statistics program.

OR

at the beginning of Semester III after completing FOUR year Bachelor Degree in Mathematics/First two semesters of M.Sc. Mathematics/ M. Sc. Applied Mathematics for M. Sc. Applied Mathematics program.

S. No.	Course Components / Name of the Course	Credits	Percentage
1	Core Courses (CC)	50	54.34
2	Core Courses Practical (CCP)	12	13.04
3	Discipline Specific Elective (DSE)	13	14.13
4	Open Elective (OE)	3	3.26
5	Soft-Skill (SS)	2	2.17
6	Internship	4	4.34
7	Project	8	8.69

ELECTIVE BASKET

List of Open Electives

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMOE01	Basic Statistics	3	3	OE
2	SAMOE02	Essential Mathematical Methods	3	3	OE
3	SAMOE03	Exploratory Data Analysis	3	3	OE

List of Value Added Courses

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMVA01	Introduction to SAS	2	4	VAC
2	SAMVA02	Data Analysis using MS Excel	2	4	VAC
3	SAMVA03	Indian Official Statistics	2	2	VAC
4	SAMVA04	Data Analysis using SPSS	2	4	VAC

ELECTIVE BASKET M. Sc. STATISTICS

List of Electives for DSE – 1

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC01	Machine Learning	4	4	DSE
2	SAMEC02	Biostatistics	4	4	DSE
3	SAMEC03	Statistical Quality Control	4	4	DSE
4	SAMEC04	Game Theory	4	4	DSE
5	SAMEC05	Artificial Intelligence	4	4	DSE
6	SAMEC22	Design and Analysis of Experiments	4	4	DSE

List of Electives for DSE – 2

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC06	Time Series Analysis	3	3	DSE
2	SAMEC07	Generalized Linear Models	3	3	DSE
3	SAMEC08	Demography	3	3	DSE
4	SAMEC09	Econometrics	3	3	DSE
5	SAMEC10	Reliability Theory	3	3	DSE

List of Electives for DSE – 3

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC11	Statistical Methods in Clinical Trials	3	3	DSE
2	SAMEC12	Evolutionary Algorithms	3	3	DSE
3	SAMEC13	Actuarial Statistics	3	3	DSE
4	SAMEC14	Deep Learning	3	3	DSE
5	SAMEC15	Fuzzy Set Theory and Fuzzy Logic	3	3	DSE

ELECTIVE BASKET M. Sc. APPLIED MATHEMATICS

List of Electives for DSE – 1

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC01	Machine Learning	4	4	DSE
2	SAMEC04	Game Theory	4	4	DSE
3	SAMEC05	Artificial Intelligence	4	4	DSE
4	SAMEC16	Classical Mechanics	4	4	DSE

List of Electives for DSE – 2

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC15	Fuzzy Set Theory and Fuzzy Logic	3	3	DSE
2	SAMEC17	Functional Analysis	3	3	DSE
3	SAMEC18	Advanced Numerical Methods	3	3	DSE
4	SAMEC20	Integral Transforms	3	3	DSE

List of Electives for DSE – 3

S. No	Course Code	Course Name	Credit	Hours	Type
1	SAMEC19	Computational Introduction to Number Theory	3	3	DSE
2	SAMEC21	Calculus of Variations and Integral Equations	3	3	DSE
3	SAMEC23	Stochastic Differential Equations	3	3	DSE
4	SAMEC24	Discrete Mathematics	3	3	DSE

M.Sc. Statistics/Applied Mathematics Syllabus in OBE Format

A. Vision

Vision Statement of the Department

Vision Statement

To provide quality education to bring out potentialities in the students
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B. Mission

Mission Statements of the Department

M1	To produce able statisticians and Applied Mathematicians
M2	To impart current knowledge on cross cutting issues in the domain
M3	To equip students with knowledge to work in domain specific targeted industries

C. Program Objective (PO)

After two years of successful completion of the program, the student will

P01	Have a broad background in Statistics and Applied Mathematics, an appreciation of its various sub-disciplines and their inter-relationships; acquire in-depth knowledge about topics chosen from those offered through the department.
P02	Be familiar with a variety of real-life situations where Statistics and Mathematics help accurately explain the underlying abstract or physical phenomena and able to recognize and appreciate the connections between theory and applications
P03	Develop the ability to effectively and aptly use techniques from different sub-disciplines in solving a broad range of real-life problems.
P04	Be Statistically and Mathematically literate . Graduates will recognize the importance and value of discipline.
P05	Have the versatility to work effectively in a broad range of companies (including R and D sectors of financial, pharmaceutical, market research, software development companies, consultancy etc), or analytic, scientific, government, financial, health, teaching and other positions or continue for higher education.
P06	Be able to independently read and analyze Statistical and Mathematical literature including survey articles, scholarly books, and online sources.
P07	Be life-long learner, able to independently expand their expertise when needed, or out of their own interest.
P08	Be able to exhibit ethical and professional behaviour in teamwork

D. Graduate Attributes for M.Sc. Statistics / Applied Mathematics Program

1. In-depth knowledge in sub-disciplines offered in this program
2. Problem Solving in various fields
3. Model Building and Data Analysis
4. Using Computational Software
5. Life-long learner
6. Ethical and professional behaviour in teamwork

E. PO to Mission Statement Mapping

	P01	P02	P03	P04	P05	P06	P07	P08
M1	3	3	3	3	3	3	3	3
M2	3	3	3	3	3	3	3	3
M3	3	3	3	3	3	3	3	3

F(1). Program Specific Outcomes (PSO) M. Sc. Statistics

On the successful completion of the program, the student will be able to

PSO1	Effectively recall basics and display knowledge of conventions.
PSO2	Develop stochastic models for studying real-life phenomena in diverse disciplines.
PSO3	Efficiently interpret and translate the outcomes obtained from the analysis of stochastic models to an environment understandable to a layman.
PSO4	Effectively use necessary computational software.
PSO5	Apply statistical techniques to optimize and monitor real-life phenomena related to industry and business analytics at local and global levels.

F (2). Program Specific Outcomes (PSO) M. Sc. Applied Mathematics

On the successful completion of the program, the student will be able to

PSO1	Effectively recall basics and display knowledge of conventions.
PSO2	Develop Mathematical models for studying real-life phenomena in diverse disciplines.
PSO3	Efficiently interpret and translate the outcomes obtained from the analysis of Mathematical models to an environment understandable to a layman.
PSO4	Effectively use necessary computational software.
PSO5	Apply Mathematical techniques to optimize and monitor real-life phenomena related to industry and business analytics at local and global levels.

G (1). PSO to PO Mapping (M. Sc. Statistics)

	PSO1	PSO2	PSO3	PSO4	PSO5
P01	3	3	3	3	3
P02	3	2	2	2	3
P03	3	3	2	3	3
P04	3	3	2	3	3
P05	3	3	3	3	3
P06	3	2	2	1	2
P07	3	2	2	3	3
P08	1	3	3	1	3

G (2). PSO to PO Mapping (M. Sc. Applied Mathematics)

	PSO1	PSO2	PSO3	PSO4	PSO5
P01	3	3	3	3	3
P02	3	2	2	2	3
P03	3	3	2	3	3
P04	3	3	2	3	3
P05	3	3	3	3	3
P06	3	2	2	1	2
P07	3	2	2	3	3
P08	1	3	3	1	3

H. Question Paper Template

Part – A

Answer **ALL** the questions

(10 x 1 = 10 Marks)

Question nos: 1 to 10

TEN questions – TWO questions from each unit- only MCQ

Part – B

Answer **ALL the** questions

(5 x 3 = 15 Marks)

Question nos: 11-15

FIVE questions – ONE question from each unit

Part – C

Answer **FIVE** questions

(5 x 7 = 35 Marks)

Question nos: 16-20

FIVE questions – ONE question from each unit with internal choice (either or type).

It can be a question with seven marks or with sub-divisions

J. Rubrics for core course practical (CCPR) evaluation:

The split up for CCPR evaluation is as follows:

Component	Marks
Practical Examination	60
Practical Work Record	20
Practical Viva	10
Observation	10
Total	100

SEMESTER-I

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain about the basic analysis on real line and set theory.	Remember
CO 2	Understand the convergence of sequences and series on real numbers and functions.	Understand
CO 3	Apply the concept of sequences of functions in real time applications.	Apply
CO 4	Analyze the concepts of functions, Derivatives, Integration	Analyze
CO 5	Evaluate the real-life applications by means of partitions on real line, sequence of functions and infinite series.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	1	1
CO2	3	3	2	2	3
CO3	3	3	2	2	1
CO4	2	2	2	3	2
CO5	2	2	3	2	3

c. Syllabus

Unit I: Set of real numbers, countable and uncountable sets, Supremum and Infimum of bounded sets, limit points and interior points of a set, open sets, closed sets, dense set and compact sets, Bolzano-Weierstrass Theorem (Statement only) and Heine-Borel Theorem (Statement only).

(10H)

Unit II: Sequences and Series of Real Numbers: Convergent and Divergent of Sequence, Cauchy Sequence, Upper Limit, and Lower Limit of Real Sequences. Cauchy Criterion for Series of Real Numbers, Absolute Convergence, Series of Non-Negative Real Numbers, Geometric Series, The number e , Cauchy Product of Series, Merten's Theorem (statement only), Rearrangement of Series.

(15H)

Unit III: Real valued functions. Limits and continuity of the function, derivative of a function, Mean value theorem, Riemann Integration, Fundamental theorem of calculus, Leibnitz rule.

(10H)

Unit IV: Sequences of Functions: Point-wise Convergence, Uniform convergence, Uniform Convergence and Continuity, Uniform Convergence and Integration, Uniform Convergence and Differentiation, Stone-Weierstrass Theorem. Power Series, radius of convergence.

(15H)

Unit V: Riemann-Stieltjes Integral: Definition, Existence of the Integral, Properties of the Integral, Integration, and Differentiation. (10H)

References:

1. Rudin, W. (1976). Principles of mathematical analysis (Vol. 3). New York: McGraw-hill.
2. Apostol, T. M. (1985). Mathematical Analysis, Narosa Publ. House, New Delhi.
3. Royden H. L.(1988). Real Analysis, 3rd Edition, McMillan Publication Co. Inc.
4. Arora, S., Malik, S. C. (2017). Mathematical Analysis. India: New Age International.
5. Kumaresan, S., Kumar, A. (2014). A Basic Course in Real Analysis. United Kingdom: Taylor and Francis.
6. Nair, M. T. (2022). Calculus of One Variable. India: Springer International Publishing.
7. <https://nptel.ac.in/courses/111/101/111101134/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain the basic concepts of vector spaces, including bases and dimensions, matrix representations of linear transformations and their properties, and inner products of vector spaces.	Understand
CO 2	Create an orthonormal set from a set of linearly independent vectors by employing the Gram-Schmidt orthogonalization process.	Skill
CO 3	Analyze the existence and uniqueness of the solution of a linear system.	Apply
CO 4	Examine the use of bilinear and quadratic forms in the geometric study of conic and quadratic curves.	Analyze
CO 5	Understand the decomposition of a vector space into the Jordan form and Sylvester's law for congruent matrices and also their applications.	Remember

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	1	2
CO2	1	1	2	2	1
CO3	3	3	3	3	3
CO4	2	3	2	1	1
CO5	2	2	1	1	2

c. Syllabus

UNIT I: Vector Spaces, Subspaces, Vector differentiation and matrix differentiation, Linear combinations and span, Linear dependence and independence, Bases and dimension of a vector space, Vector spaces with inner products, Gram-Schmidt orthogonalization, Linear Transformations (LT) and its properties, Representation of LT by matrices. **(12H)**

UNIT II: Invertibility and isomorphisms, Change of bases, Orthogonal transformation, Systems of linear equations - Homogeneous and non-homogeneous systems of linear equations, Existence and uniqueness of solutions; Types of matrices and elementary row operations, Row-reduced echelon matrices. **(12H)**

UNIT III: Gaussian elimination method, Rank of a matrix, Inverses, G-inverse and transposes of a matrix, Moore-Penrose inverse, Eigen values and Eigen vectors of LT, Diagonalization of LT, Properties of Eigen values and eigenvectors, Cayley-Hamilton theorem, Minimal polynomial for LT, Eigen values of matrix polynomials, Positive Definite Matrices. **(12H)**

UNIT IV: Orthogonal projections and the spectral theorem, Similarity transformations, bilinear forms, Quadratic forms - Classification of quadratic forms, Rank, index, and signature of quadratic forms, Reduction of quadratic form into a canonical form. **(12H)**

UNIT V: Decomposition of a vector space into the Jordan form, Singular value decomposition, Cholesky decomposition, Sylvester's law for congruent matrices and its application in Einstein's special theory of relativity, **(12H)**

References:

1. Strang, G. (2005). Linear Algebra and its Applications, 4th Edition, Cengage Learning India Pvt Ltd.
2. Ramachandra Rao, A. and Bhimasankaran, P. (2000). Linear Algebra. 2nd Edition, Hindustan Book Agency.
3. Friedberg, S. H., Insel, A. J., and Spence, L. E. (2002). Linear Algebra, 4th Edition, Prentice-Hall of India.
4. Searle, S. R. (2006). Matrix Algebra Useful for Statistics (Wiley Series in Probability and Statistics), John Wiley and Sons, Inc., New York.
5. Olver, P. J., and Shakiban, C. (2018). Applied Linear Algebra (Undergraduate Texts in Mathematics), 2nd Edition, Springer International Publishing AG, part of Springer Nature.
6. Hadely, G. (2002). Linear Algebra. Narosa Publishing House, India.
7. Harville, D. A. (1977). Matrix Algebra from a Statistician's Perspective, Springer.
8. <https://nptel.ac.in/courses/111/106/111106051/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall the pdf, pmf, cdf, moments, and generating functions of a random variable.	Remember
CO 2	Explain standard discrete and continuous distributions.	Understand
CO 3	Explain and apply moment inequalities to obtain bounds on entity of interest.	Apply
CO 4	Derive distribution of function of random variables.	Analyze
CO 5	Separate mixture of distributions	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

c. Syllabus

UNIT I: Introduction - Sample space and events - Axiomatic approach to probability - Conditional Probability and Independence- Law of multiplication - Law of total probability and Bayes' Theorem, Discrete and continuous random variables - probability mass function and density function - distribution function - Expectation, variance and quantiles. **(12H)**

UNIT II: Probability models for categorical, count and continuous data, Joint probability distributions - marginal and conditional distributions-Independent random variables, Conditional expectation. **(12H)**

UNIT III: Moments and moment generating functions- Sums of independent random variables, Moment Inequalities- Basic, Markov, Chebyshev, Hölder and Jensen inequalities. **(12H)**

UNIT IV: Mixtures of probability distributions - decomposition of mixture type CDF into discrete and continuous CDF's - expectation and variance of mixture distributions. **(12H)**

UNIT V: Distribution of function of random variables - Transformations of univariate random variables - Transformations of bivariate random variables, Applications to random number generation. Sampling distributions: Students't, Chi-square and Snedecors' F. **(12H)**

References:

1. Rohatgi, V. K., and Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley and Sons.
2. Ross, S. M. (2014). A First Course in Probability, India: Pearson India Education Services Pvt. Limited.
3. Casella, G., and Berger, R. L. (2021
4.). Statistical inference. Cengage Learning.
5. Hogg, R. V. McKean, J. W. and Craig, T. T. (2005). Introduction to Mathematical Statistics, Sixth Edition, Pearson Prentice Hall, New Jersey.
6. Dasgupta, A. (2010) Fundamentals of Probability: A First Course, Springer, New York.
7. Ghahramani, S. (2012). Fundamentals of Probability with Stochastic Processes, Pearson education.
8. Walpole, R. E. (2012). Probability and Statistics for Engineers and Scientists, Prentice Hall.
9. <https://online.stat.psu.edu/stat414>
10. <https://nptel.ac.in/courses/111/104/111104032/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Comprehend the techniques and applications of optimization.	Remember
CO 2	Analyze characteristics of a dynamic programming.	Understand
CO 3	Apply basic concepts of mathematics to formulate a nonlinear programming.	Apply
CO 4	Analyze various methods of solving the constrained minimization problem.	Analyze
CO 5	Analyze and appreciate Inventory models for various optimization problems.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	3	2
CO2	3	2	3	2	2
CO3	2	3	3	2	3
CO4	2	1	1	2	3
CO5	1	3	2	3	1

C. Syllabus

UNIT I: Introduction to LPP- Formulation and Graphical Solutions – Simplex method – Degeneracy – Unbounded Solution – Infeasible Solution – BIG-M method – Two-Phase method – Revised Simplex Method – Duality in Linear Programming Problems – Dual Simplex method.

(12H)

UNIT II: Integer Programming – Pure and Mixed Integer programming problems – Cutting Plane Algorithm – Mixed Algorithm With proof. Additive and Zero One algorithm – Branch and Bound method

(12H)

UNIT III: Dynamic Programming – Modelling and solving of recursive equations – Cargo Loading Model – Reliability Model – Warehousing Model – Investment Model. Solving of optimization problems of mathematical nature using dynamic programming models-Non-Linear programming – Kuhn-Tucker conditions – Wolfe's and Beale's method – with proof – Simple applications.

(12H)

UNIT IV: Stochastic programming – Chance constrained optimization problems – E, V and EV models - Queueing models – Definition of transient and Steady-states - Kendall's notations and classification of queueing models - Distributions in queueing systems - Solution of queueing models: Model I: (M/M/1:∞/FCFS): Birth and Death Model. Interrelationship between L_q , L_s , W_q and W_s : Model-II - General Erlangian queueing model (Birth-Death Process) - Model-III: (M/M/1: N/FCFS) and Model IV: (M/M/S/∞/FCFS).

(12H)

UNIT V: Inventory models – Economic order quantity models - Single item and multi-item -Deterministic and Nondeterministic models - inventory models with and without back logs. Stochastic inventory models – Multi product models – Inventory control models in practice.

(12H)

References

1. Taha, H. A. (2013). Operations research: an introduction. Pearson Education India.
2. Rao. S.S. (2004). Engineering Optimization. New Age International (P) Ltd, New Delhi.
3. Kambo, N. S. (1991). Mathematical Programming techniques. Affiliated East-west Press Pvt. Ltd.
4. Sharma, J. K. (2007). Operations Research. Macmillan, New Delhi, 3rd Edition.
5. Manmohan, Kanti Swarup and Gupta(1979). Operations Research – Prentice Hall – New Delhi
6. <https://nptel.ac.in/courses/112/106/112106131/>
7. https://swayam.gov.in/nd2_cec20_ma10/preview

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO1	Learn about conceptual variations in calculus when working with single variables to multiple variables.	Understand
CO2	Determine the extreme values, critical points, and turning (inflection) points of a function of several variables.	Apply
CO3	Learn the applications of the mean value theorem and Taylor's theorem.	Skill
CO4	Evaluate definite integral of given functions using the fundamental theorems of calculus.	Apply
CO5	Demonstrate an understanding of the relationships between multiple integrals (lines, areas, and volumes) using Gauss and Stoke's theorems.	Analyze

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	3	1
CO2	3	2	2	2	2
CO3	3	1	1	2	3
CO4	3	2	1	2	2
CO5	3	2	2	2	3

c. Syllabus

UNIT I: Partial Differentiation: Functions of several variables, differentiability of functions of two variables, Total derivative, Higher order partial derivatives, Directional derivatives and Gradient, Jacobian Matrix, Hessian Matrix. **(9H)**

UNIT II: Implicit Functions and Inverse Functions: Implicit functions, Implicit function theorem, Inverse functions. Inverse function theorem, Change of variables, Functional dependence. **(9H)**

UNIT III: Taylor's Theorems and Applications: Mixed derivative theorem, Taylor's theorem for functions of two variables, Error approximations, Unconstrained and Constrained maxima, and minima of real-valued functions of several variables, Lagrange multipliers. **(9H)**

Unit IV: Vector Differential Calculus: Vector in 2D and 3D spaces, Dot product, Vector product operations, Vector and scalar fields, Curves, Arc length, Curvature, Gradient of a scalar field, curl of a vector field. **(9H)**

UNIT V: Line and Surface Integrals-Definition of line integrals, Integrals with respect to Arc length, properties of line integrals, Green's theorem, Applications, Surface integrals and properties, Gauss divergence theorem and Stoke's theorem(Statement Only).

(9H)

References:

1. Weir, M. D., and Hass, J. (2014). Thomas' Calculus (Early Transcendental), 13th Edition, Pearson Education, Inc.
2. Kreyszig, E. (2011). Advanced Engineering Mathematics, 9th edition, John Wiley and Sons, Inc., United Kingdom.
3. Ghorpade S.R., and Limaye, B.V. (2010). A Course in Multivariable Calculus and Analysis, Springer- Verlag.
4. Kaplan W. (2003). Advanced Calculus, Addison Wesley (Pearson Education, Inc.), Fifth Edition.
5. Marsden J.E., and Tromba A.J. (1996). Vector Calculus, Fourth Edition., W. H. Freeman and Co., New York.
6. Courant R. and John F. (1989). Introduction to Calculus and Analysis, Vol. 2, Springer-Verlag, New York.
7. <https://www.usf.edu/undergrad/academic-success-center/documents/resources-calculus.pdf>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Understand the basics of R Language	Understand
CO 2	Perform parametric methods	Analyze
CO 3	Apply the logical skills for creating data frames.	Apply
CO 4	Use appropriate plots, charts and diagrams for all kinds of data	Apply
CO 5	Write and execute the code by loops and conditional statements.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	3	3
CO2	3	3	3	3	2
CO3	3	2	2	3	3
CO4	3	3	3	3	3
CO5	3	2	1	3	2

c. Syllabus

UNIT I: Introduction to R - A programming language and environment for data analysis and graphics. Syntax of R expressions: Vectors and assignment, vector arithmetic, generating regular sequence, logical vector, character vectors, Index vectors; selecting and modifying subsets of dataset, Data objects: Basic data objects, matrices, partition of matrices, arrays, lists, factors and ordered factors, creating and using these objects; Functions – Elementary functions and summary functions, applying functions to subsets of data. **(12H)**

UNIT II: Discrete and continuous distributions –Calculate PDF, CDF and generation of random numbers for Uniform, Normal, Gamma, Exponential, Beta, F, Poisson, Binomial. **(12H)**

UNIT III: Data frames: The benefits of data frames, creating data frames, combining data frames, Adding new classes of variables to data frames; Data frame attributes. Importing data files: import. Data function, read. Table function; exporting data: export. Data function, cat, write, and write. Table functions; outputting results - sink function, formatting output-options, and format functions; Exporting graphs- export. Graph function. **(12H)**

UNIT IV: Graphics in R: creating graphs using plot function, box plot, histogram, line plot, stem and leaf plot, pie chart, bar chart multiple plot layout, plot titles, formatting

plot axes. Interactively adding information of plot-Identifying the plotted points, adding trend lines to current scatter plot, adding new data to current plot, adding text and legend-Partition plot. **(12H)**

UNIT V: Loops and conditional statements: Control Statements; if statement, if else Statement. Looping statement; for loop, repeat, while loop developing simple programs in R for data analysis tasks, saving programs, executing stored programs, defining a binary operator, assignment with in function. **(12H)**

References:

1. Chambers, J. M. (1998). Programming with data: A guide to the S language. Springer Science and Business Media.
2. Venables, W., and Ripley, B. D. (2000). S programming. Springer Science and Business Media.
3. Everitt, B. S. (2019). A handbook of statistical analyses using S-Plus. CRC Press.
4. Dalgaard, P. (2002). Statistics and computing: Introductory Statistics with R. Springer.
5. Maindonald, J., and Braun, J. (2006). Data analysis and graphics using R: an example-based approach (Vol. 10). Cambridge University Press.
6. <https://pll.harvard.edu/subject/r>
7. <https://nptel.ac.in/courses/111/104/111104100/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
C01	Introduction to MATLAB, Recall the concepts of Optimization	Understand
C02	Commands on MATLAB, Visualization, Solving LPP-Simplex and Dual	Apply
C03	Matrix operations, Non-algebraic equations using MATLAB and solve constrained/unconstrained optimization problems	Skill
C04	Transportation and Assignment optimization.	Apply
C05	Formulate and solve optimization-design problems	Analyze

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
C01	3	2	2	3	1
C02	3	2	2	2	2
C03	3	1	1	2	3
C04	3	2	1	2	2
C05	3	2	2	2	3

c. Syllabus

UNIT I: Basics of MATLAB, Reviews on special variables and constants, elementary mathematical functions, general-purpose commands, Reviews on matrices and vectors and their creation, Matrix and array operations, Use of built-in functions, Script and function files, Significant digits, precision, accuracy, and floating-point number representation. **(12H)**

UNIT II: Language-specific features (branching and looping), Creation of polynomials and operations on them, zeros (roots) of polynomial equations, Function handles, Inline functions, and anonymous functions, 2-D and 3-D plots and Animation, Data analysis.

(12H)

UNIT III: Solving a linear system, Finding Eigen values and eigenvectors, Matrix factorizations, Curve fitting and interpolation, Numerical integration, Solving ordinary differential equations, Nonlinear algebraic equations, Optimization -Development, Characteristics, formulation of LPP, Graphical, Simplex method, Big M Method, Duality-Dual Simplex method. **(12H)**

UNIT IV: Transportation and Assignment problems: Formulation, Initial Feasible solution, Unbalanced transportation, Degeneracy, Assignment problem, Travelling Salesman problem and Optimal solution. **(12H)**

UNIT V: Introduction to CPM-Network diagram-Critical Path-Job slack-Time estimates estimation- project due different from earliest completion time, PERT-Scheduling networks, Expected length estimates-Visualization -Optimal solution. **(12H)**

References:

1. Quarteroni, A., Saleri, F., and Gervasio, P. (2014). Scientific Computing with MATLAB and Octave (Texts in Computational Science and Engineering), 4th Edition, Springer Nature.
2. Pratap, R. (2010). Getting Started with MATLAB (A Quick Introduction for Scientists and Engineers), Oxford University Press, Inc., New York.
3. Higham, D. J., and Higham, N. J. (2005). MATLAB Guide, 2nd Edition, The Society for Industrial and Applied Mathematics (SIAM), Philadelphia, USA.
4. Chapman, S. J. (2017). Essentials of MATLAB Programming, Cengage Learning-Engineering, 3rd Edition.
5. Manmohan, Kanti Swarup and Gupta(1979). Operations Research-Prentice Hall-New Delhi
6. Taha,H.A (2013).Operations Research: An Introduction, Pearson Education India
7. Sharma.J.K(2007): Operations Research, Macmillan, New Delhi,3rd Edition

SEMESTER II

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain the random variable and its expectation.	Remember
CO 2	Understand the concepts related to class of sets such as fields, sigma fields, Borel fields and solve related problems	Understand
CO 3	Apply the convergence theorems to solve problems related to the sequence of random variables	Apply
CO 4	Analyze the measure-theoretic definition of a random variable and random vector and solve problems related to their distributions	Analyze
CO 5	Solve the problems related to the central limit theorem.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	1	2	2	2
CO2	3	2	3	2	2
CO3	3	1	3	1	3
CO4	2	1	1	2	3
CO5	3	3	2	3	2

c. Syllabus

Unit I: Classes of sets: Sequence of sets, limit of sequence of sets, field, σ -field, σ -field generated by a class, Borel σ -field. Probability measure, Probability space, properties of probability measure. Lebesgue and Lebesgue – Stieltjes measures on $\mathbb{R}$. (9H)

Unit II: Measurable function, random variable, the distribution function of a random variable, simple random variable, elementary random variable, limit of the sequence of random variables. Method of obtaining a random variable as a limit of sequence of simple random variables. (9H)

Unit III: Expectation of a random variable, independence. Characteristic function, simple properties. Inversion theorem and uniqueness property (Statement only). (9H)

Unit IV: Monotone convergence theorem, Fatou's Lemma, Dominated Convergence theorem, Borel - Cantelli Lemma, and their applications. Almost sure convergence, character property, convergence in probability, uniqueness of limit, Yule-Slutsky results and preservation under continuous transform (Statements only), convergence in r^{th} mean. (9H)

Unit V: Convergence of sequence of random variables, Convergence in distribution, (9H)

continuity theorem (Statement only), Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sure convergence (Statement only), Lyapunov's, Lindeberg-Feller Theorems on CLT (Statement only).

References:

1. Bhat, B. R. (2019). Modern Probability Theory. United Kingdom: New Academic Science.
2. Karr, A. F. (1993). Probability. Germany: Springer New York.
3. Billingsley, P. (2012). Probability and Measure. Italy: Wiley.
4. Athreya K. B. and Lahiri S. (2006). Probability Theory vol 41, Trim series, (Hindustan Book Agency).
5. Feller, W. (1968). An Introduction to Probability Theory and Its Applications, Volume 1. India: Wiley.
6. Loeve, M. (2012). Probability Theory I. United States: Springer New York.
7. <https://nptel.ac.in/courses/111/101/111101005/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Apprehend the concept of stochastic process, its specifications, and analyze the classification of states; construct Markov Chain for real world situations.	Remember
CO 2	Understand Continuous time Markov processes and obtain the birth and death processes.	Understand
CO 3	Determine renewal process, renewal function, distribution of arrival and inter arrival times and renewal policy under varied conditions.	Apply
CO 4	Understand the concept of branching processes and determine covariance and spectral density of stationary random processes.	Analyze
CO 5	Apply the Martingales concept in finance related analysis.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	3	3	2
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO4	2	2	1	3	2
CO5	1	1	1	1	2

c. Syllabus

UNIT I: Stochastic processes and their classification-Brownian Motion- Markov chain- Examples (Random walk, Gambler's ruin problem)- classification of states of a Markov Chain-Recurrence-Basic limit theorem of Markov Chains-Absorption probabilities and criteria for recurrence. (9H)

UNIT II: Markov chains continuous in time – General pure birth processes and Poisson process, birth and death processes, finite state continuous time Markov chains. (9H)

UNIT III: Renewal processes – Definition and examples – key renewal theorem – Study of residual life time process – Stationary process, weakly stationary and strongly stationary processes. (9H)

UNIT IV: Branching processes discrete in time – Generating functions relations – Mean and variance – Extinction probabilities – Concept of Age dependent Branching process. (9H)

UNIT V: Martingales in discrete time– Conditional expectations- Super martingales and sub martingales – Martingale convergence theorem and its applications. **(9H)**

References:

1. Karlin, S. (2014). A first course in stochastic processes. Academic press.
2. Medhi, J. (2009). Stochastic Processes, 3rd Edition. New age International.
3. Bhat, B. R. (2004). Stochastic models: analysis and applications. New Age International.
4. Jones, P. W., and Smith, P. (2001). Stochastic Processes: An Introduction. Arnold Texts in Statistics.
5. Cinlar, E. (1975). Introduction to stochastic processes Prentice-Hall. Englewood Cliffs, New Jersey (420p).
6. Williams, D. (1991). Probability with martingales. Cambridge university press.
7. Cox, D. R., and Miller, H. D. (1983). The theory of stochastic processes (Vol. 134). 3rd Edition, Chapman and Hall.
8. Ross, S. M. (1983). Stochastic Process. Wiley.
9. <https://nptel.ac.in/courses/111/102/111102111/>
10. <https://www.stat.auckland.ac.nz/~fewster/325/notes/325book.pdf>
11. [https://stats.libretexts.org/Bookshelves/Probability_Theory/Probability_Mathematical_Statistics_and_Stochastic_Processes_\(Siegrist\)](https://stats.libretexts.org/Bookshelves/Probability_Theory/Probability_Mathematical_Statistics_and_Stochastic_Processes_(Siegrist))

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain the basics of Ordinary Differential Equations (ODEs), Partial Differential Equations (PDEs) along with their classifications.	Remember
CO 2	Understand the existence and uniqueness of solution for first order ODEs and solving procedures of first and second order ODE	Understand
CO 3	Apply various techniques to solve PDEs.	Apply
CO 4	Analyse the solution nature of ODEs, PDEs.	Analyze
CO 5	Model physical phenomena using ODEs and PDEs.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	2	1
CO2	3	2	3	3	2
CO3	2	3	2	3	3
CO4	3	2	2	2	3
CO5	3	2	2	3	3

c. Syllabus

Unit I: First order ordinary differential equation (ODE)-The method of successive approximations, Lipschitz condition, Convergence of successive approximations, Existence and Uniqueness of solutions for first order initial value problem. **(10H)**

Unit II: Second order linear ODE - General solution of homogeneous equations, non-homogeneous equations, Wronskian, Method of variation of parameters, Boundary value problems, Sturm-Liouville problems. **(10H)**

Unit III: First order partial differential equation (PDE), Quasilinear PDE of the first order, Integral surfaces passing through a given curve, Surfaces orthogonal to the given system, Classification of integrals **(8H)**

Unit IV: Compatible systems of first order PDE, Charpit's method, Method of Characteristics, Nonlinear partial differential equation for first order. **(8H)**

Unit V: Second order PDE- Origin and Classification, linear second and higher order PDE with constant and variable coefficients, Characteristics curve of the second order PDE. **(9H)**

References

1. Braun, M. (1993). Differential Equations and Their Applications: An Introduction to Applied Mathematics. Fourth Edition. Germany: World Publishing Company.
2. Coddington, E. A. (2012). An Introduction to Ordinary Differential Equations. United Kingdom: Dover Publications.
3. Simmons, G. F. (2003). Differential Equations: With Applications and Historical Notes. India: Tata McGraw-Hill.
4. John, F. (2013). Partial Differential Equations. Germany: Springer New York.
5. Evans, L. C. (2022). Partial Differential Equations. United States: American Mathematical Society.
6. https://onlinecourses.nptel.ac.in/noc24_ma02/preview

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Study some direct and iterative methods for solving systems of simultaneous algebraic equations.	Remember
CO 2	Analyze the difference between numerical differentiation and integration.	Analyze
CO 3	Understand various types of polynomial and spline interpolation to construct interpolating polynomials for given data.	Apply
CO 4	Explain the finite difference solution for a one-dimensional initial and boundary value ordinary and partial differential equations.	Understand
CO 5	Interpret the difference between single-step and multi-step methods for initial-value ordinary differential equations.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	2	2	3	3	3
CO2	3	1	2	1	1
CO3	3	3	3	2	3
CO4	1	2	1	1	2
CO5	2	3	2	3	2

c. Syllabus

UNIT I: Linear System-Gaussian elimination with pivoting and scaling, LU decomposition; Vector and matrix norms, Error analysis and system condition, Iterative methods- Jacobi and Gauss-Seidel method; Eigen value problem- Power method, QR method.

(9H)

UNIT II: Nonlinear equations-One-point iteration approach, Newton-Raphson method, Newton's method; Lagrange's interpolation, Inverse interpolation, Accuracy of interpolation, Newton's divided differences interpolation, Errors in Lagrange's and Newton's divided differences interpolation, Relationship between derivatives and divided differences.

(9H)

UNIT III: Least squares approximation, Interpolation by splines, Numerical differentiation based on interpolation and divided differences, Newton-Cotes integration methods-Trapezoidal and Simpson rules, Gaussian quadrature. **(9H)**

UNIT IV: Error estimation in trapezoidal rule, Simpson rules, and Gaussian quadrature; Quadrature rules for multiple integrals, Single and multi-point methods-Taylor series, Euler's, Modified Euler's, and Runge-Kutta methods; Finite difference methods. **(9H)**

UNIT V: Consistency, order, stability, and convergence; Steady-state two-dimensional (2D) Laplace equation, Finite difference solution of the Laplace equation, Unsteady 1D parabolic diffusion equation, Explicit and implicit schemes, Unsteady 1D convection hyperbolic equation, Explicit schemes for convection equation. **(9H)**

References:

1. Phillips, G. M. M., and Taylor, P. J. (1996). Theory and Applications of Numerical Analysis, 2nd Edition, Elsevier.
2. Isaacson, E., and Keller, H. B. (1994). Analysis of Numerical Methods, 1st Edition, Dover Publication.
3. Conte, S. D. and Boor, C. (1981). Elementary Numerical Analysis: An Algorithmic Approach, 3rd Edition, McGraw-Hill.
4. Lange, K. (2010). Numerical Analysis for Statisticians (Statistics and Computing), 2nd Edition, Springer-Verlag New York Inc.
5. Sastry, S. S. (2012). Introductory Methods of Numerical Analysis, 5th Edition, Prentice Hall India (PHI) Learning Private Limited, New Delhi, India.
6. https://onlinecourses.nptel.ac.in/noc24_ma34/preview

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Identify the communication classes of a Markov chain.	Remember
CO 2	Construct transition probability matrix and use of Markov chain.	Analyze
CO 3	Formulate the execution of numerical algorithms for direct and iterative methods.	Understand
CO 4	Apply working knowledge of MATLAB software to develop scripts and functions for various interpolation and numerical integration methods.	Apply
CO 5	Formulate the execution of numerical algorithms for single-step and multi-step methods using MATLAB software.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	3	3
CO2	2	3	2	2	3
CO3	2	3	2	2	3
CO4	2	2	1	3	2
CO5	2	3	2	3	2

c. Syllabus

Unit I: Introduction to Monte Carlo simulations using R, Simulating Gambler's ruin problem, identifying a random walk model using R, Classification of the states and identifying the communication classes of a Markov chain. **(12H)**

Unit II: Constructing Transition Probability Matrix, Problems on continuous-time Markov chain, finding the probability of a random variable from Poisson distribution, finding the Stationary distribution. Estimation of extinction probability. **(12H)**

UNIT III: Direct and iterative methods for solving system of linear equations: Experiment on the Gauss Elimination Method (GEM), Development of algorithm on GEM using partial pivot technique, LU factorization experiment, developing an algorithm on the Gauss-Seidel iterative method, Experiment on testing the ill-conditioned and well-conditioned behaviour of a system of linear equations. **(12H)**

UNIT IV: Interpolation and numerical differentiation and integration: Lagrange interpolation experiment. Experiment with numerical differentiation, single and double integration, and compare them with exact differentiation and integration, developing an algorithm for the composite trapezoid rule, writing code for the composite Simpson's rules. **(12H)**

UNIT V: Single and multi-step numerical methods: Develop script and function files for the Taylor series method, Experiment with Euler's and modified Euler's methods, Create code for the Runge-Kutta methods, Create finite-difference approximation code for boundary value problems. **(12H)**

References

1. Karlin, S. (2014). A first course in stochastic processes. Academic press.
2. Medhi, J. (2009). Stochastic Processes, 3rd Edition. New age International.
3. Bhat, B. R. (2004). Stochastic models: analysis and applications. New Age International.
4. Williams, D. (1991). Probability with martingales. Cambridge university press.
5. Chapra, S. C. (2012). Applied Numerical Methods with MATLAB for Engineers and Scientists, 3rd Edition, The McGraw-Hill Companies, Inc., New York.
6. Yang, W. Y., Cao, W., Chung, T., and Morris, J. (2005). Applied Numerical Methods Using MATLAB, John Wiley and Sons, Inc., New Jersey.
7. Quarteroni, A., Saleri, F., and Gervasio, P. (2014). Scientific Computing with MATLAB and Octave (Texts in Computational Science and Engineering), 4th Edition, Springer Nature.
8. W.Chun(2016), Core Python Programming, 2016, Pearson.
9. Kenneth A. Lambert (2015). Introduction to Python, Cengage.
10. https://onlinecourses.nptel.ac.in/noc24_cs20/preview

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand and use the essential modules in Python.	Remember
CO 2	Use classes and objects in application programs and visualize data.	Understand
CO 3	Deal with Tuples.	Apply
CO 4	Apply suitable programming constructs and built-in data structures to solve a problem.	Analyze
CO 5	Understand the library functions.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	2	1
CO2	3	3	2	3	2
CO3	2	2	3	2	3
CO4	3	2	2	1	2
CO5	2	2	3	2	1

c. Syllabus

UNIT 1: Introduction to Python-Problem Solving: Definition and Steps, Problem Analysis Chart, Developing an Algorithm, Flowchart and Pseudocode. Python Programming Fundamentals-Introduction to python Interactive and Script Mode Indentation Comments Variables-Words- Data Types Operators and their precedence Expressions Built-in Functions Importing from Packages. **(12H)**

UNIT II: Control Structures-Decision Making and Branching: if, if-else, nested if, multi-way if-else-if statements Looping: while loop, for loop else clauses in loops, nested loops break, continue and pass statements. Lists: Create Access, Slicing, Negative indices, and List methods. **(12H)**

UNIT III: List comprehensions-Tuples: Create, Indexing and slicing, Operations on tuples Dictionary: Create, add, and replace values, Operations on dictionaries Sets: Creation and operations. **(12H)**

UNIT IV: Strings and Regular Expressions-Strings: Comparison, Formatting, Slicing, Splitting, Stripping Regular Expressions- Matching, Search and replace, Patterns. **(12H)**

UNIT V: Functions and Files, Functions Parameters and Arguments, Positional arguments, Keyword arguments, Parameters with default values Local and Global scope of variables Functions with Arbitrary arguments Recursive Functions Lambda Function. Files: Create, Open, Read, Write, Append and Close tell and seek methods. Modules and Packages – Built – In modules User-Defined modules Overview of Numpy and Pandas packages.

(12H)

References:

1. Matthes, E. (2023). Python crash course: A hands-on, project-based introduction to programming. no starch press.
2. Brown, M. C. (2001). Python: The complete reference. McGraw-Hill Professional.
3. Guttag, J. V. (2016). Introduction to computation and programming using Python: With application to understanding data. MIT press.
4. Mark Lutz (2007). Learning Python, 3rd Edition.
2. Vamsi Kurama (2017), Python Programming: A Modern Approach, Pearson.
8. Allen Downey,(2017),Think Python, 2nd Edition, Green Tea Press.
9. W.Chun(2016), Core Python Programming, 2016, Pearson.
10. Kenneth A. Lambert (2015). Introduction to Python, Cengage.

Students are expected to undergo continuous 20 Days (160 Hours) of internship in Industry/Government Autonomous Bodies/Research Institutes/Universities and Affiliated Colleges/Public Sector Units (PSU's) after completion of end semester examination of Semester II. Students have to get approval from the department faculty committee. Students have to submit a (a) report of work done and (b) attendance certificate, signed by the supervisor in the host institute. Evaluation will be done by the supervisor in the host institute out of 100 Marks.

SEMESTER III

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Recall basic terms in frequentists approach to Statistical inference.	Remember
CO 2	Explain the concept of Methods of estimation.	Understand
CO 3	Compare estimators and tests.	Analyze
CO 4	Explain the concept of Testing of Hypothesis	Apply
CO 5	Derive estimators, tests and confidence intervals. Implement the inference procedures on data.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

C. Syllabus

UNIT I: Sufficiency principle, factorization theorem, minimal sufficiency, minimal sufficient partition, minimal sufficient statistics, minimal sufficient statistic for exponential family, power series family, curved exponential family, and Pitman family, completeness, bounded completeness, ancillary statistics, Basu's theorem and its applications, conditionality principle. **(12H)**

UNIT II: Problem of point estimation, properties of good estimators, minimum variance unbiased estimator, Rao-Blackwell theorem and Lehmann-Scheffe theorem and their applications. A necessary and sufficient condition for an estimator to be UMVUE, Fisher information and information matrix, Cramer-Rao inequality. **(12H)**

UNIT III: Methods of estimation: Method of moments and its properties, Method of maximum likelihood and its properties, Method of scoring and its application, Method of minimum chi-square and its properties, Method of least squares. **(12H)**

UNIT IV: Problem of testing of Hypothesis, Simple and composite hypotheses. Randomized and non-randomized tests, most powerful test, Neyman-Pearson Lemma and its applications. Monotone likelihood ratio property, UMP test, power function of a test, existence of UMP test, UMP test for one-sided alternatives. Concept of p-value.

(12H)

UNIT V: Interval estimation: Problem of confidence intervals, relation with testing of hypotheses problem, UMA confidence intervals, shortest length confidence intervals. Likelihood ratio test and its applications.

(12H)

References:

1. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015). Introduction to Probability Theory and Mathematical Statistics -3rd edition, John Wiley and sons.
2. Lehmann, E. L. (1983). Theory of Point Estimation - John Wiley and sons.
3. Rao, C. R. (1973). Linear Statistical Inference and its Applications, 2nd edition, Wiley.
4. Kale, B.K. and Muralidharan, K. (2015). Parametric Inference: An Introduction, Alpha Science International Ltd.
5. Mukhopadhyay, P. (2015). Mathematical Statistics, Books and Allied (p) Ltd.
6. Casella, G. and Berger, R. L. (2001). Statistical Inference, 2nd edition, Duxbury press.
7. <https://nptel.ac.in/courses/103/106/103106120/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO1	Recall the basics of linear regression model	Remember
CO2	Explain parameter estimation, testing of hypothesis and confidence intervals in various regression models.	Understand
CO3	Perform parameter estimation and testing of hypothesis. Implement variable selection methods.	Apply
CO4	Detect problems of multicollinearity and outliers in data.	Analyze
CO5	Compare regression models and interpret the results.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	3	3
CO5	1	2	3	1	3

c. Syllabus

UNIT I: Multiple regression model - least squares estimate (LSE) - Properties of LSE - Hypothesis testing - confidence and prediction intervals - General linear hypothesis testing; Dummy variables and their use in regression analysis. **(12H)**

UNIT II: Residuals and their properties - residual diagnostics; Transformation of Variables: VST - Box-Cox power transformation; Variable Selection Procedures: R-square - adjusted R-square - Mallows' Cp - forward, backward and stepwise selection methods – AIC - BIC. **(12H)**

UNIT III: Multicollinearity: Consequences - detection and remedies - ridge regression; Autocorrelation: sources – consequences – detection - Durbin-Watson test – remedies - Parameter estimation using Cochrane-Orcutt method. **(12H)**

UNIT IV: Nonlinear regression models: Nonlinear least squares - Transformation to a linear model - Parameter estimation in a nonlinear system - Statistical inference in nonlinear regression; Polynomial regression model - piecewise polynomial fitting; Nonparametric regression: kernel and locally weighted regression. **(12H)**

UNIT V: Robust Regression: Influential observations – leverage – outliers - methods of detection of outliers and influential observations; estimation in the presence of outliers - M-estimator - Huber loss function - breakdown point - influence function – efficiency - Asymptotic distribution of M-estimator (Statement only) - Mallows’ class of estimators.

(12H)

References:

1. Draper, N. R., and Smith, H. (1998). Applied regression analysis (Vol. 326). John Wiley and Sons.
2. Weisberg, S. (2005). Applied linear regression (Vol. 528). John Wiley and Sons.
3. Kutner, M., Nachtsheim, C. J., Neter, J., and Li, W. (2005). Applied linear statistical models. McGraw-Hill. New York, 7.
4. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley and Sons.
5. Cook R.D. and WiesbergS. (1982). Residuals and Influence in Regression. Chapman and Hall.
6. Birkes, D., and Dodge, Y. (2011). Alternative methods of regression. John Wiley and Sons.
7. Huber, P. J. and Ronchetti, E. M.(2011).Robust Statistics, Wiley, 2nd Edition.
8. Seber, G. A., and Wild, C. J. (2003). Nonlinear regression. New Jersey: John Wiley and Sons.
9. https://onlinecourses.nptel.ac.in/noc24_ma19/preview
10. <https://online.stat.psu.edu/stat504/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Select appropriate methods of multivariate data analysis, given multivariate data and study objectives	Remember
CO 2	Understand likelihood based, as well as minimum expected cost based, discriminant analysis.	Understand
CO 3	Know the theories of PCA and factor analysis (FA), and be able to apply these methods to real data.	Apply
CO 4	Interpret results of multivariate data analysis.	Analyze
CO 5	Understand the fundamental difference between univariate and multivariate analysis. Design/perform hypothesis testing -and be able to apply MANOVA and understand multivariate regression.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	3	2
CO2	3	2	3	2	2
CO3	2	3	3	2	3
CO4	2	1	1	2	3
CO5	1	3	2	3	1

C. Syllabus

UNIT I: Singular and non-singular Multivariate normal distributions and their properties - Marginal and conditional distributions - Characteristic function and moments - Distribution of linear combinations of multivariate normal vector - Determination of mean and variance -covariance matrix of multivariate normal distribution.

(12H)

UNIT II: Random Sampling from multivariate normal distribution - Maximum likelihood estimators of the parameters of multivariate normal distribution - distribution of sample mean vector and sample dispersion mean vector - Necessary and sufficient condition for a quadratic form to be distributed as chi-square - Inference concerning the sample mean vector when covariance matrix is known.

(12H)

UNIT III: Generalized T² statistic and its distribution - Hotelling's T² statistic and its distribution - Two sample problems with unequal covariance matrices likelihood ratio criterion and its applications - Mahalanobis D² statistic and its distribution - Applications of Hotelling's T² Statistic - Invariance property of T² statistic - Relationship between T² and D² statistics - Behrens-Fisher Problem.

(12H)

UNIT IV: Wishart distribution - Sampling distribution of sample covariance matrix - Properties of Wishart distribution - Wilk's criterion - Generalized variance (Concept only) - Sampling distribution of simple sample correlation coefficient - Sampling distribution of partial and multiple correlation coefficients in null case (without derivation) - Tests concerning simple, partial and multiple correlation coefficients - Discriminant function (concept only) - Fisher's discriminant function. Cluster analysis. **(12H)**

UNIT V: Problem of classification - Two populations and k populations - Principal components and determination - Factor analysis – estimation of factor loadings - Canonical variables and canonical correlations - Derivation of canonical correlation coefficients. **(12H)**

References:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis (Third Edition). Wiley-Inter science, New York.
2. Johnson, R.A. and D.W. Wichern. (2013). Applied Multivariate Statistical Analysis (Sixth Edition), Pearson New International Edition.
3. Kendall, M.G., Stuart, A. and Ord, K.J. (1973): The Advanced Theory of Statistics. (Fourth Edition), Vol. 2, Charles Griffin company Ltd.
4. Kotz, S., Balakrishnan, N. and Johnson, N.L. (2000): Continuous Multivariate Distribution Models and Applications (Second Edition). Vol. 1, Wiley-Inter science, New York.
5. Mardia, K.V., Kent, J.T and Bibby, J.M. (1979): Multivariate Analysis. Academic Press, New York.
6. Morrison, D.F. (2004): Multivariate Statistical Methods (Fourth Edition). Duxbury Press, New York.
7. Rao, C.R. (2001): Linear Statistical Inference and its Applications (Second Edition). Wiley-Inter Science, New York.
8. Rencher, A.C. (2002): Methods of Multivariate Analysis (Second Edition). Wiley Interscience, New York
9. <https://online.stat.psu.edu/stat505/>
10. <https://nptel.ac.in/courses/111/104/111104024/>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand need of Sample survey	Understand
CO 2	Decide appropriate sampling strategy	Apply
CO 3	Compute sample size for sample surveys	Analyze
CO 4	Use ratio and regression methods for estimation	Remember
CO 5	Recall sampling strategies	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	3	1
CO2	2	3	2	1	2
CO3	2	2	2	3	3
CO4	2	3	2	1	3
CO5	1	3	3	1	2

c. Syllabus

UNIT I: Population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Non-probability and probability sampling, basic principles of sample survey, Sample size determination, Simple random sampling. **(9H)**

UNIT II: Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations. Systematic sampling and modified systematic sampling. **(9H)**

UNIT III: Probability proportional to size sampling. Horvitz Thompson's estimator of a finite population total/mean. Expressions for variance of Horvitz Thompson's estimator and their unbiased estimators. **(9H)**

UNIT IV: Use of auxiliary information in sample surveys, Ratio, product and regression methods of estimators, sampling variance and efficiency of the estimators. multivariate ratio estimator. **(9H)**

UNIT V: Cluster sampling (equal clusters only) estimation of population mean and variance, comparison (with and without randomly formed clusters). Relative efficiency of cluster sampling with SRS in terms of intra-class correlation. Concept of two-stage sampling, double sampling. **(9H)**

References:

1. Cochran W.G. (1984). Sampling Techniques, (3rd Ed.), Wiley Eastern.
2. Sukhatme,P.V., Sukhatme,B.V. Sukhatme,S. Asok,C.(1984). Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics
3. Murthy M.N. (1977). Sampling Theory and Statistical Methods, Statistical Pub. Society, Calcutta.
4. Des Raj and Chandhok P. (1998). Sample Survey Theory, Narosa Publishing House. B. Sc. Honours (Statistics) 17
5. Singh D., Chaudhary F.S. (1986). Theory and Analysis of Sample Survey Designs, New Age International (P) Ltd.
6. <https://online.stat.psu.edu/statprogram/stat506>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall syntax for implementing multivariate and regression analysis techniques.	Remember
CO 2	Compare and evaluate the performance of different multivariate and regression techniques.	Analyze
CO 3	Decide which multivariate and regression techniques are useful for the data in hand.	Understand
CO 4	Apply multivariate and regression techniques on data.	Apply
CO 5	Interpret the results of multivariate and regression techniques.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	3	3
CO2	2	3	2	2	2
CO3	3	3	2	2	3
CO4	1	3	1	3	3
CO5	1	1	3	1	1

c. Syllabus

UNIT I: Multiple and partial Correlation, Multivariate Normal Distribution, Random sample generation from Multivariate Normal Distributions, Hotelling's T^2 one-sample and two-sample tests. Discriminant Analysis: Fishers best discriminant function, testing whether given discriminant is good enough for discrimination purpose. **(12H)**

UNIT II: Principal Components Analysis: dimension reduction, percentage variation explained by principal components, scree plot, Factor Analysis: M-factor orthogonal model, maximum likelihood estimation, principal component method. Canonical correlation analysis: Finding canonical variable pairs, extraction of canonical correlation. **(12H)**

UNIT III: Cluster Analysis: distance matrix, single linkage complete linkage, average linkage and k-means algorithms. Multiple linear regression: Parameter estimation by Least squares method, Testing overall goodness of fit of the model-ANOVA, R-square and Adjusted R-square, Testing individual significance of regression coefficients. **(12H)**

UNIT IV: Diagnostic Analysis of Multiple linear regression model: Computation of model residuals, Residual plots for checking the validity of assumptions; Multicollinearity - Diagnosing Multicollinearity-correlation matrix, VIF, eigen system analysis, Effect of Multicollinearity on Least squares estimator, Remedies: Parameter estimation by Ridge Estimator. **(12H)**

UNIT V: Autocorrelation: Diagnosing Autocorrelation-Graph of Residuals Vs. Time - Durbin-Watson Test, Effect of Autocorrelation on Least squares estimator, Remedies-Parameter estimation by Cochrane-Orkutt Method; Variable selection: Variable selection using all subset methods- R-square - Adjusted R-square – Mallows' Cp – AIC – BIC, Variable selection using Stepwise procedures – Forward Selection – Backward elimination – Stepwise method; Robust Regression: Diagnosing influential observations using hat diagonal elements, scaled residuals, Cook's Distance, DFBETAS and DFFITS, Effect of Influential observations on Least squares estimator, Parameter estimation by M-Estimator. **(12H)**

References:

1. Draper, N. R., and Smith, H. (1998). Applied regression analysis (Vol. 326). John Wiley and Sons.
2. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley and Sons.
3. Cook R.D., andWiesberg S. (1982). Residuals and Influence in Regression. Chapman and Hall.
4. Birkes, D., and Dodge, Y. (2011). Alternative methods of regression. John Wiley and Sons.
5. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis (Third Edition). Wiley-Inter science, New York.
6. Johnson, R.A. and D.W. Wichern. (2013). Applied Multivariate Statistical Analysis (Sixth Edition), Pearson New International Edition.
7. Mardia, K.V., Kent, J.T and Bibby, J.M. (1979): Multivariate Analysis. Academic Press, New York.
8. Morrison, D.F. (2004): Multivariate Statistical Methods (Fourth Edition). Duxbury Press, New York.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Acquire knowledge about problems on estimation	Remember
CO 2	Solve problems based on Testing of Hypothesis and construct confidence interval	Understand
CO 3	Compute sample size for sample survey	Analyze
CO 4	Analyze problems on Stratified random sampling and Systematic sampling	Apply
CO 5	Estimate population mean and variance for cluster sampling	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

C. Syllabus

UNIT I: Problems of point estimation, unbiased estimators, minimum variance unbiased estimator, Estimation by method of moments for the binomial, Poisson, Exponential and Normal distributions, Computing Maximum likelihood estimator. **(12H)**

Unit II: Computation of Type- I and Type-II errors, Application of NP lemma, Construction of Most Powerful test and Uniformly Most Powerful test, Likelihood ratio test for one-sample and two-sample testing problem, Monte Carlo significance test. **(12H)**

Unit III: Problems based on Selection of sample and determination of sample size, Simple random sampling, Estimation of mean and variance under SRSWR, SRSWOR and their comparison, Estimation of population proportion **(12H)**

UNIT IV: Stratified random sampling- Proportional allocation and Optimum allocation, Comparison of Stratified random sampling with SRS, Problems based on Systematic sampling with $N = nk$, Comparison of Systematic sampling with Stratified and SRSWOR. **(12H)**

UNIT V: Problems based on Cluster sampling, Estimation of population mean and its variance, Relative efficiency of Cluster sampling with SRS. PPS sampling and two stage sampling. **(12H)**

References:

1. Rohatgi, V.K. and Saleh, A. K. MD. E. (2015). Introduction to Probability Theory and Mathematical Statistics -3rd edition, John Wiley and sons.
2. Lehmann, E. L. (1983). Theory of Point Estimation - John Wiley and sons.
3. Rao, C. R. (1973). Linear Statistical Inference and its Applications, 2nd edition, Wiley.
4. Cochran W.G. (1984). Sampling Techniques, (3rd Ed.), Wiley Eastern.
5. Murthy M.N. (1977). Sampling Theory and Statistical Methods, Statistical Pub. Society, Calcutta.
6. Des Raj and Chandhok P. (1998). Sample Survey Theory, Narosa Publishing House. B. Sc. Honours (Statistics)
7. Singh D., Chaudhary F.S. (1986). Theory and Analysis of Sample Survey Designs, New Age International (P) Ltd.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Illustrate some applications of linear algebra concepts to linear homogenous and non-homogenous differential equations.	Remember
CO 2	Interpret the definitions of ordinary and singular (regular and irregular) points to study the method of Frobenius for the solution of second-order differential equations.	Analyze
CO 3	Apply the knowledge of Laplace's equation and its properties to solve the different boundary value problems of ordinary differential equations.	Apply
CO 4	Illustrate the application of partial differential equations to study the behaviour of the motion of vibrating strings by using the Sturm-Liouville problem.	Skill
CO 5	Explain the method of separation of variables to solve one-dimensional heat, wave, and Laplace equations.	Understand

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	3	2
CO2	2	1	1	1	1
CO3	1	2	2	2	3
CO4	3	2	3	1	2
CO5	2	3	2	2	3

c. Syllabus

UNIT I: System of first order differential equations, Algebraic properties of solutions of linear equations, Application of linear algebra to differential equations, Eigen value and Eigenvector method, Solutions of linear non-homogeneous equations, Power series solution of second order linear differential equations - regular singular points, the method of Frobenius.

(12H)

UNIT II: Laplace Equation - Boundary value problems, Maximum and minimum, Principles for Laplace equation, Uniqueness and continuity theorems, Dirichlet problem for a circle, Neumann problem for a circle.

(12H)

Unit III: Theory of Green's function for Laplace's equation, One-dimensional wave equation, Vibrations of a finite string, Vibrations of an infinite string, Vibration of a semi-infinite String. (12H)

UNIT IV: D'Alembert's solution, Separable method, Existence and uniqueness of solution, Riemann method, Duhamel's principle for wave equations, Heat conduction problem in a finite rod, Heat conduction problem for an infinite rod. (12H)

UNIT V: Separable method for one-dimensional heat equation, Existence and uniqueness of the solution, Duhamel's principle for heat equations, Hadamard's definition of well-posedness. (12H)

References:

1. Braun, M. (1993). Differential Equations and Their Applications, 4th Edition, Springer-Verlag New York Inc.
2. Coddington, E. A. (2002). An Introduction to Ordinary Differential Equations (Dover Books on Mathematics), Prentice Hall India Learning Private Limited.
3. John, F. (1978). Partial Differential Equations, 2nd Edition, Springer-Verlag, American Mathematical Society.
4. Evans, L. C. (2010). Partial Differential Equations (Graduate Studies in Mathematics), 2nd Edition, American Mathematical Society.
5. Logan, J. D. (2015). Applied Partial differential Equations, 3rd Edition, Springer Nature Switzerland AG.
6. Simmons, G. F. (1991). Differential Equations with Applications and Historical Notes, 2nd Edition, Tata McGraw-Hill Edition.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain and discuss the concepts of complex numbers, and measures.	Remember
CO 2	Understand the basic context of the analytic function, measurable function.	Understand
CO 3	Work on contour Integration and Cauchy residue theorem, Lebesgue integration.	Apply
CO 4	Analyze the concept of convergence theorems and determine the nature of the singularities.	Analyze
CO 5	Evaluate mathematical problems with the knowledge of complex analysis and sequence of measurable functions.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	1	1	2	2
CO2	3	2	2	2	2
CO3	3	2	2	3	2
CO4	3	2	3	2	3
CO5	2	3	2	3	3

c. Syllabus

Unit I: Complex Numbers, Basic algebraic properties, complex conjugates, geometric representation of complex numbers, powers, and roots of complex numbers. Functions of a complex variable, limits, continuity. **(9H)**

Unit II: Differentiability of a function, Analytic functions. Necessary and Sufficient conditions for the differentiability of a function, Cauchy-Riemann equations. Elementary functions. Conformal mapping (for linear transformation). **(9H)**

Unit III: Contours and contour integration. Cauchy's theorem, Cauchy integral formula. Power Series, term by term differentiation, Taylor series, Laurent series, Zeros, singularities, poles, essential singularities, Residue theorem and its applications. **(9H)**

Unit IV: Measure: Length of Open and Closed Set, Outer Measure, Measurable Sets, Regularity, Borel and Lebesgue Measurability, Abstract Measure, Measurable Functions: Simple Measurable Functions, Sequence of Measurable Functions and their convergence. **(9H)**

Unit V: Lebesgue Integration: Integrals of simple functions, Integrals of Non-Negative Functions, Convergence Theorems (Statement only), Integration of Series, Riemann and Lebesgue Integrals, Product Measure, Fubini's Theorem (Statement only). **(9H)**

References:

1. Brown, J. W., and Churchill, R. V. (2009). Complex variables and applications. McGraw-Hill,
2. De Barra, G. (2003). Measure Theory and Integration, 2nd Edition. United Kingdom: Elsevier Science.
3. Royden, H. L. (1988). Real Analysis, 3rd Edition. United Kingdom: Macmillan.
4. Billingsley, P. (2012). Probability and Measure. Italy: Wiley.
5. Rudin, W. (1987). Real and Complex Analysis. Germany: McGraw-Hill.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the basic concepts of fluid dynamics and methods of describing fluid motion.	Remember
CO 2	Analyze the stress-strain rate relationship in fluid flow.	Understand
CO 3	Apply Bernoulli's principle, conservation of mass, conservation of momentum, and conservation of energy equations to solve some simple fluid flow problems.	Apply
CO 4	Explain Blasius and Kutta-Joukowski's theorems and their applications.	Analyze
CO 5	Illustrate dimensional analysis, the law of similarity, and boundary layer theory to solve fluid flow problems.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	3	2	1
CO2	2	2	2	1	1
CO3	2	3	3	2	2
CO4	3	2	1	1	3
CO5	2	1	1	3	2

c. Syllabus

UNIT I: Continuum hypothesis, Forces acting on a fluid, Analysis of the relative motion near a point, Methods of describing fluid motion, Translation, rotation and rate of deformation, Differentiation following the motion of the fluid, Classification of fluids, Transport theorem. (12H)

UNIT II: Conservation laws - Equation of continuity, Euler's equation, Equations of motion (Navier-Stokes equations), Energy equation; Streamlines, Equation of state, Isentropic fluids, Vorticity, Theory of stress and rate of strain, Relationship between them, Kelvin's circulation theorem, Helmholtz's theorem. (12H)

UNIT III: Rotational and irrotational flows, Bernoulli's equation, Momentum theorem and its applications, Two dimensional irrotational flow of an incompressible fluid, Stokes' stream function, Axisymmetric flows. (12H)

UNIT IV: Gravity waves, Damping of gravity waves, Flow in a pipe, Potential flow, Complex potential, Blasius theorem, Kutta-Joukowski theorem, D'Alembert paradox, Dimensional analysis, Law of similarity and the Reynolds number, Flow between two parallel flat plates. (12H)

UNIT V: Couette flow, Poiseuille flow, Torque and drag on a sphere due to a uniform flow, Flow with small Reynolds numbers, Stoke's law, Unsteady motion of a flat plate, Boundary layers, Prandtl's boundary layer equations, Solution for steady flow on a flat plate of infinite length.

(12H)

References:

1. Batchelor, G. K. (2000). An Introduction to Fluid Dynamics (Cambridge Mathematical Library), Cambridge University Press, 2nd Edition, United Kingdom.
2. Chorin, A. J., and Marsden, J. E. (2000). A Mathematical Introduction to Fluid Mechanics (Texts in Applied Mathematics), 3rd Edition, Springer-Verlag.
3. Landau, L. D., and Lifshitz, E. M. (1987). Fluid Mechanics (Volume 6 of Course of Theoretical Physics), Pergamon Press, 2nd Edition, New York.
4. O'Neill, M. E., and Chorlton, F. (1986). Ideal and Incompressible Fluid Dynamics (Mathematics and Its Applications), Ellis Horwood Ltd., Publisher.
5. White, F. M. (2007). Fluid Mechanics, McGraw-Hill Education (India) Private Limited, 9th Edition (Standard Edition).
6. Yuan, S. W. (1988). Foundations of Fluid Mechanics, Printice-Hall of India Private Limited.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall the concepts of ODE and PDE. Recall syntax for implementing regression analysis techniques.	Remember
CO 2	Understand the concepts of the general and particular solution of DE. Compare and evaluate the performance of different regression techniques.	Understand
CO 3	Apply suitable method to find the numerical solutions DE of the real time applications. Decide which regression techniques are useful for the data in hand.	Apply
CO 4	Formulate practical design problems, and apply algorithms of social problems. Apply regression techniques on data.	Analyze
CO 5	Formulate the physical models and find the numerical solution. Interpret the results of regression techniques.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	3	3
CO2	3	3	3	3	2
CO3	3	2	3	2	2
CO4	2	2	3	3	2
CO5	2	2	3	3	2

c. Syllabus

UNIT I: Multiple linear regression: Parameter estimation by Least squares method, testing overall goodness of fit of the model-ANOVA, R-square and Adjusted R-square, Testing individual significance of regression coefficients. **(12H)**

UNIT II: Diagnostic Analysis of Multiple linear regression model: Computation of model residuals, Residual plots for checking the validity of assumptions; Multicollinearity - Diagnosing Multicollinearity-correlation matrix, VIF, eigen system analysis, Effect of Multicollinearity on Least squares estimator, Remedies: Parameter estimation by Ridge Estimator. **(12H)**

UNIT III: Autocorrelation: Diagnosing Autocorrelation-Graph of Residuals Vs. Time - Durbin-Watson Test, Effect of Autocorrelation on Least squares estimator, Remedies-Parameter estimation by Cochrane-Orkutt Method; Variable selection: Variable selection using all subset methods- R-square - Adjusted R-square – Mallows' Cp – AIC – BIC, Variable selection using Stepwise procedures – Forward Selection – Backward elimination – Stepwise method; Robust Regression: Diagnosing influential observations using hat diagonal elements, scaled residuals, Cook's Distance, DFBETAS and DFFITS, Effect of Influential observations on Least squares estimator, Parameter estimation by M-Estimator. **(12H)**

UNIT IV: First-order differential equations-Numerical Solution.Methods of Direct integration, separable method, integrating factor. Plotting successive approximations for the first-order differential equation. **(12H)**

UNIT V: Second-order homogeneous differential equations: Formulation, Auxiliary equations, roots, general solution. Second-order non-homogeneous differential equations: Particular integral, general solution. **(12H)**

References:

1. Draper, N. R., and Smith, H. (1998). Applied regression analysis (Vol. 326). John Wiley and Sons.
2. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley and Sons.
3. Cook R.D., and Wiesberg S. (1982). Residuals and Influence in Regression. Chapman and Hall.
4. Birkes, D., and Dodge, Y. (2011). Alternative methods of regression. John Wiley and Sons.
5. Logan, J. D. (2011). A First Course in Differential Equations. Germany: Springer.
6. Coddington, E. A. (1961). An Introduction to Ordinary Differential Equations. India: Prentice-Hall.
7. Braun, M. (1992). Differential Equations and Their Applications: An Introduction to Applied Mathematics. United States: Springer New York.

a. a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO1	Learn about the roots, error analysis, solving ODE, PDE	Remember
CO2	Understand the concepts in curve fitting	Understand
CO3	Apply suitable m files to solve ODE, PDE, BVP	Apply
CO4	Analyze the least square methods and interpolation	Analyze
CO5	Formulate the mathematical models and obtain the numerical solution	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	3	2
CO2	3	2	2	2	2
CO3	3	2	2	2	3
CO4	3	2	2	2	2
CO5	3	2	2	2	3

c. Syllabus

UNIT I: Eigen value problem: Eigen value and eigenvectors, Eigen value problem for the homogeneous system, developing an algorithm power method. Methods for root approximations. **(12 H)**

UNIT II: Curve fitting and Interpolation: Error Analysis, Methods of Curve Fitting, nonlinear least square method, Taylor series and calculation of functions, Interpolation, and Newton's polynomials. **(12 H)**

UNIT III: Solving ordinary differential equations (ODE) the motion of a simple pendulum and nonlinear motion of a damped pendulum, Developing an algorithm to find the vibration of the elastic string, Stiff problems. **(12 H)**

UNIT IV: Boundary value problems (BVP), Shooting methods, Finite difference methods, Delay-differential equations. **(12 H)**

UNIT V: Partial differential equations(PDE), Solving the Laplace Equation inside a Rectangular Region, Vibration String, Experiment on one-dimensional Heat Conduction Problem. **(12 H)**

References:

1. Mathews, J. H., and Fink, K. D. (2004). *Numerical methods using MATLAB* (Vol. 4). Upper Saddle River, NJ: Pearson prentice hall.
2. Higham, D. J., and Higham, N. J. (2005). *MATLAB Guide*, 2nd Edition, The Society for Industrial and Applied Mathematics (SIAM), Philadelphia, USA.
3. Rao V. Dukkipati. (2010). *MATALAB: An Introduction with Applications*, New Age International Publishers.
4. Wilson, H. B., Turcotte, L. H., and Halpern, D. (2003). *Advanced Mathematics and Mechanics Applications Using MATLAB*, Chapman and Hall/CRC, 3rd Edition.
5. Quarteroni, A., Saleri, F., and Gervasio, P. (2014). *Scientific Computing with MATLAB and Octave* (Texts in Computational Science and Engineering), 4th Edition, Springer Nature.
6. Chapra, S. C. (2012). *Applied Numerical Methods with MATLAB for Engineers and Scientists*, 3rd Edition, The McGraw-Hill Companies, Inc., New York.
7. Gupta, R. S. (2015). *Elements of numerical analysis*. Cambridge University Press
8. <https://guides.libraries.uc.edu/c.php?g=461109andp=3152742>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain the Latex document structure and beamer presentation.	Remember
CO 2	Understand Latex and beamer coding.	Understand
CO 3	Apply coding to create tables, equations and insert figures.	Apply
CO 4	Analyze the suitable coding for mathematical expression.	Analyze
CO 5	Prepare research reports, presentations, and articles.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	1	2	2	1
CO2	2	1	2	2	1
CO3	2	2	2	3	1
CO4	3	2	2	3	3
CO5	3	3	3	2	2

C. Syllabus

Unit I: Introduction, Installation: Beginning typesetting - LaTeX. Basics for document structure, and preamble preparation. (6H)

Unit II: Latex commands: font colour, font size, make title, the syntax for beginning document, new page, sectioning (6H)

Unit III: Tables and Figures: Create Tables, Insert figures, enumeration list, itemized list, font effects, and insert equations. (6H)

Unit IV: References: Insert - Manual - BibTex, cite reference, Drafting a research manuscript. (6H)

Unit V: Introduction to Beamer, Installation, Workflow for creating Beamer presentation, Guidelines, creating frames, structuring the presentations. (6H)

References:

1. Griffiths, D. F., Higham, D. J. (2016). Learning LaTeX. United States: Society for Industrial and Applied Mathematics.
2. Lamport, L. (2001). Latex: A Document Preparation System : User's Guide and Reference Manual. United States: Addison-Wesley.
3. Erickson, M., Bindner, D. (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. United Kingdom: Taylor and Francis.
4. Kottwitz, S. (2021). LaTeX Beginner's Guide - Second Edition: Create Visually Appealing Texts, Articles, and Books for Business and Science Using LaTeX. India: Packt Publishing.
5. Tantau, T., Wright, J., Miletic, V. (2016). The BEAMER Class: User Guide for Version 3.49. (n.p.): 12th Media Services.
6. <https://guides.nyu.edu/LaTeX/resources>

SEMESTER IV

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO1	Learn about asymptotic inference and its application	Understand
CO2	Apply Bayesian inference to solve the problem	Apply
CO3	Learn the applications of sequential inference	Skill
CO4	Evaluate importance of different non-parametric inference.	Analyse
CO5	Apply different non-parametric test on real data	Apply

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	3	1
CO2	2	3	2	2	2
CO3	3	1	3	2	3
CO4	1	2	1	3	2
CO5	3	3	2	2	3

c. Syllabus

Unit I: Asymptotic Inference: Review of convergence in probability and convergence in distributions; consistent estimators; Consistent and Asymptotic Normal (CAN) estimators, Cramer family and cramer – Huzur bazaar theorem (statement only), Fisher inequality. BAN estimator, asymptotic relative efficiency (ARE). **(12H)**

Unit II: Bayesian estimation: prior distributions, posterior distribution. Bayes estimators, limit of Bayes estimators, highest posterior density credible regions. Minimax estimators and their relationships with Bayes estimators. **(12H)**

Unit III: Sequential Analysis: Need for sequential tests. Wald's SPRT, ASN, OC function. Stein's two stage fixed length confidence interval. Illustrations with Binomial and Normal distributions. Elements of sequential estimation. Robust estimation. **(12H)**

Unit IV: Nonparametric Methods I: Formulation of the problems, order statistics and their distributions. Tests and confidence intervals for population quantiles. Sign test. Test for symmetry, signed rank test. **(12H)**

Unit V: Nonparametric Methods II: Wilcoxon-Mann-Whitney test, Kruskal-Wallis test. Run test, Kolmogorov-Smirnov Goodness-of – Fit Test, Equality of k independent samples. **(12H)**

References:

1. Lehmann E. L. (1975): Non parametrics: Statistical Methods Based on Ranks, Springer, New York
2. Casella G. and Berger R.L. (2002): Statistical Inference, Wadsworth, a part of Cengage Learning, Delhi
3. Daniel W.W. (1990) Applied Nonparametric Statistics, 2 nd Edition, PWS- KENT.
4. Ghosh J.K. and Ramamoorthi R.V. (2003) Bayesian Nonparametrics, Springer, New York
5. Gibbons, J. D., and Chakraborti, S. (2014). Nonparametric statistical inference: revised and expanded. CRC press.
6. Hollander, M., Wolfe, D. A., and Chicken, E. (2013). Nonparametric statistical methods. John Wiley and Sons.
7. Berger, J.O (1985): Statistical Decision Theory and Bayesian Analysis (Second Edition), Springer Verlag, New York
8. Bernardo J M and A.F.M. Smith (2000) : Bayesian Theory, John Wiley and Sons, New York
9. <https://online.stat.psu.edu/stat415/>

Students have to undertake a research project under the guidance of a faculty member of the Department. A student will be evaluated by Project Evaluation Committee based on the project presentation and project report for 60 Marks. Students have to report to their respective guide daily. Internal Marks out of 40 will be awarded by the project guide based on the day-to-day performance. Project Report should be accompanied with a Plagiarism Check Report (Max. 10 %) certified by the project guide.

Specifications for project report

-
1. Cover page – Content in color on white background
 2. Main Heading font size – 16 points.
 3. Sub Heading – 14 points.
 4. Content – 12 points.
 5. Line Spacing – 1.5 points
 6. Font – Time New Roman
 7. Page Size – A4
 8. Binding – Soft binding
 9. No. of copies to be submitted – 3 (one copy will be returned to the candidate after evaluation).
-

Format for Plagiarism Check Report

CENTRAL UNIVERSITY OF TAMIL NADU
DEPARTMENT OF STATISTICS AND APPLIED MATHEMATICS
PLAGIARISM CHECK REPORT

Name of the Student	
Reg. No	
Title of Project	
Name of Guide	
Similarity content (%) (up to 10% acceptable)	
Plagiarism detection tool applied	
Date of Plagiarism check	

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1. Name:
 2. Designation:
 3. Signature:
 4. Date:
-

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand basic knowledge about biological systems in order to model them and also use techniques and tools of applied mathematics to describe and solve various biological problems.	Remember
CO 2	Examine the modelling foundations (defining goals, identifying variables, parameters, and assumptions) of simple discrete and continuous models of biological phenomena.	Understand
CO 3	Formulate the mathematical models based on exponential and logistic growth models for the cell cycle, cell division, and tumor cell.	Apply
CO 4	Apply the concepts of linear stability and phase plane analysis to predict the behaviour of living systems.	Analyze
CO 5	Demonstrate an understanding of powerful mathematical tools such as ODEs and PDEs and apply them to modelling infectious disease (SI, SIR, SEIR, and HIV) models and various processes in biological systems.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	1	2
CO2	3	2	3	1	1
CO3	3	3	2	1	2
CO4	2	2	1	2	2
CO5	3	3	3	3	3

c. Syllabus

UNIT I: Introduction, motivation and background biology, Continuous growth models, Insect outbreak model - Spruce Budworm, Delay models; Tumor cell growth, Model with spatial Heterogeneity, Tumor cell spreading dynamics in vitro - Parameter estimation. **(12H)**

UNIT II: Models with age distribution, Logistic-type model - Chaos, Discrete delay models: Fishery management model, Predator-Prey models, Analysis of predator-prey model with limit cycle periodic behavior, Threshold phenomena, Lotka-Volterra systems. **(12H)**

UNIT III: Competition models, Mutualism or Symbiosis, Waves in biology, Spiral waves, Traveling wave trains in reaction diffusion systems, Spiral wave solutions of $\lambda - \omega$ reaction diffusion systems, Enzyme kinetics. **(12H)**

UNIT IV: Law of mass action, Basic model for the dynamics of nerve membranes, Infectious Diseases; Simple epidemic models (SI, SIR, SEIR, and HIV), Classical Kermack-McKendrick model, Biological oscillators, Singular perturbation analysis for biological applications. **(12H)**

UNIT V: Analysis of the phase shift equation and application to the coupled Belousov-Zhabotinskii Reactions, Reaction diffusion equations, Models for animal dispersal, Pattern formation in biological systems, Cell-chemotaxis model mechanism. **(12H)**

References:

1. Murray, J. D. (2002). Mathematical Biology I: An Introduction (Interdisciplinary Applied Mathematics), 3rd Edition, Springer-Verlag Berlin Heidelberg, New York.
2. Murray, J. D. (2003). Mathematical Biology II: Spatial Models and Biomedical Applications, (Interdisciplinary Applied Mathematics), 3rd Edition, Springer-Verlag Berlin Heidelberg, New York.
3. Edelstein-Keshet, L. (2005). Mathematical Models in Biology (Classics in Applied Mathematics), Society for Industrial and Applied Mathematics (SIAM), Philadelphia, New York.
4. Logan, J. D., and Wolesensky, W. (2009). Mathematical Methods in Biology, 1st Edition, John Wiley and Sons Inc.
5. Chou, C. S., and Friedman, A. (2016). Introduction to Mathematical Biology: Modelling, Analysis, and Simulations, 1st Edition, Springer International Publishing Switzerland.

Discipline Specific Elective

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Have a good understanding of the fundamental issues and challenges of machine learning: data, model selection, model complexity, etc.	Remember
CO 2	Have an understanding Network protocols, analysis of Web traffic, Computer security, Bioinformatics and Machine Learning	Understand
CO 3	Appreciate the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised and un-supervised learning.	Apply
CO 4	Be able to design and implement various machine learning algorithms in a range of real-world applications.	Analyze
CO 5	Get exposure to a wide variety of mathematical concepts used in computer science discipline like probability, Graph Theory for solving problems, sampling and estimation.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	3	2
CO2	3	2	3	2	2
CO3	2	3	3	2	3
CO4	2	1	1	2	3
CO5	1	3	2	3	1

C. Syllabus

UNIT I: Introduction to Machine Learning, Different Forms of Learning, Linear Regression, Ridge Regression, Lasso, Bayesian Regression, Regression with Basis Functions.

(12H)

UNIT II: Instance-Based Classification, Linear Discriminant Analysis, Logistic Regression, Large Margin Classification, Kernel Methods, Support Vector Machines, Multi-class Classification, Classification and Regression Trees.

(12H)

UNIT III: Neural Networks: Multi-layer Networks, Back-propagation, Multi-class Discrimination, Training Procedures, Localized Network Structure, Deep Learning. Graphical Models: Hidden Markov Models, Bayesian Networks, Markov Random Fields, Conditional Random Fields.

(12H)

UNIT IV: Ensemble Methods: Boosting - Adaboost, Gradient Boosting, Bagging -Simple Methods, Random Forest, Clustering: K-Medoids, CLARA, DENCLUE,DBCSAN. **(12H)**

UNIT V: Learning Associative rules-Mining Frequent Patterns - basic concepts -Apriori algorithm, FP- Growth algorithm, Associationbased Decision Trees- Simple problems **(12H)**

References:

1. C. Bishop, Pattern Recognition and Machine Learning, Springer - Verlag,2006.
2. T. Mitchell, Machine Learning, McGraw Hill Education, 2017.
3. R. O. Duda, P. E. Hart and D. G. Stork, Pattern Classification, Wiley-Blackwell;2nd edition, 2000.
4. T. Hastie, R. Tibshirani and J. Friedman, Elements of Statistical Learning, 2ndEdition, Springer, 2009.
5. Han, Jiawei, Jian Pei, and Micheline Kamber. Data mining: concepts and techniques. Elsevier, 2011.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the functions survival distributions	Remember
CO 2	Analyze epidemiologic and clinical data	Apply
CO 3	Understand the concept of censoring	Understand
CO 4	Derive simple and general epidemic models.	Analyze
CO 5	Learn natural selection, mutation and estimation of linkage in heredity	Skill

B. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

C. Syllabus

UNIT I: Functions of survival time - survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shape hazard function; Tests of goodness of fit for survival distributions.

(12H)

UNIT II: Analysis of epidemiologic and clinical data - studying association between a disease and a characteristic: types of studies in epidemiology and clinical research - prospective study - retrospective study - cross-sectional data; dichotomous response and dichotomous risk factor - 2x2 tables; expressing relationship between a risk factor and a disease; inference for relative risk and odds ratio for 2x2 table - sensitivity - specificity and predictivity; Cox proportional hazard model.

(12H)

UNIT III: Type I and type II censoring schemes with biological examples - estimation of mean survival time and variance of the estimator for type I and type II censored data - numerical examples. Nonparametric methods for estimating survival function and variance of the estimator.

(12H)

UNIT IV: Competing risk theory - indices for measurement of probability of death under competing risks and their interrelations; Estimation of probabilities of death under competing risks by maximum likelihood; Theory of independent and dependent risks.

(12H)

UNIT V: Simple and general epidemic models-random variable technique-Basic biological concepts in genetics - Mendels law, Hardy-Weinberg equilibrium - random mating, distribution of allele frequency - approach to equilibrium for X-linked genes, natural selection, mutation, genetic drift, equilibrium - natural selection and mutation, detection and estimation of linkage in heredity.

(12H)

References:

1. Collett, D. (2023). Modelling survival data in medical research. CRC press.
2. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., and Granger, C. B. (2015). Fundamentals of clinical trials. springer.
3. Indrayan, A., and Malhotra, R. K. (2017). Medical biostatistics. CRC Press.
4. Lee, E. T., and Wang, J. (2003). Statistical methods for survival data analysis (Vol. 476). John Wiley and Sons.
5. Deshpande, J. V., and Purohit, S. G. (2015). Lifetime Data: Statistical Models and Methods (Vol. 16). World Scientific Publishing Company.
6. Daniel, W. W., and Cross, C. L. (2018). Biostatistics: a foundation for analysis in the health sciences. Wiley.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Know the concepts and scope of Quality control.	Remember
CO 2	Construct variable and attribute control charts for detecting large and smaller shifts in the production process.	Understand
CO 3	Compute process capability measures for analyzing production process	Apply
CO 4	Evaluate the performance of sampling plans using OC, ASN, ATI, AOQ functions under various sampling inspection situations.	Analyze
CO 5	Understand the concept of variable sampling plans using single and double variable sampling plan.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	2	2	3	3	2
CO2	2	2	3	3	3
CO3	3	3	3	3	2
CO4	3	3	3	3	3
CO5	2	3	3	2	3

c. Syllabus

Unit I: Quality and Quality system: Quality, Quality improvement and productivity, specification and requirement - Quality characteristics, standard and measurements - Concepts of quality control, quality assurance, quality circle, and quality system - Scope of quality control and quality system.

(12H)

Unit II: Shewhart Control Charts for $\bar{X}$, R, np, p, c and their uses, OC and ARL of Control Charts, Control Charts based on C.V., Modified Control Charts, CUSUM procedures, use of V-mask, Derivation of ARL.

(12H)

Unit III: Decision Interval Schemes for CUSUM charts. Economic Designs of Control Charts, Pre-control, Relative Precision and Process Capability analysis and Gauge capability analysis, Multivariate Control charts and HotellingT².

(12H)

Unit IV: Basic Concepts of Acceptance Sampling, Single, Double, Multiple and Sequential Sampling Plans for Attributes, Curtailed and Semi Curtailed Sampling. Dodge-Romig Tables-LTPD and AOQL protection (Single Sampling Plan only). MIL-STD-105D.

(12H)

Unit V: Variable Sampling: Assumptions, Single and Double Variable Sampling Plans. Application of Normal and Non-central t- Distributions in Variable Sampling. Continuous Sampling Plans: CSP-1, CSP-2 and CSP-3. Special Purpose Plans: Chain Sampling Plans, Skip-lot Plans.

(12H)

References:

1. Montgomery, D. C. (1985). Introduction to statistical quality control. John Wiley and Sons.
2. Schilling, E. G., and Neubauer, D. V. (2017). Acceptance sampling in quality control. Chapman and Hall/CRC.
3. Burr, I. W. (1976). Statistical quality control methods (Vol. 16). CRC Press.
4. Mittag, H. J., and Rinne, H. (2018). Statistical methods of quality assurance. Routledge.
5. Wetherill, G. B. (2013). Sampling inspection and quality control (Vol. 129). Springer.
6. Ramsey, P. (1991). Process Quality Control: Troubleshooting and Interpretation of Data.
7. Halpern, S. (1979). An Introduction to Quality Control and Reliability. Prentice Hall of India.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Identify strategic situations and represent them as games.	Remember
CO 2	Solve simple games using various techniques.	Understand
CO 3	Analyse matrix games and Linear Programming.	Apply
CO 4	Recommend and prescribe which strategies to implement	Analyze
CO 5	Examine Games in coalitional form	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	2	3
CO2	2	3	3	2	2
CO3	2	2	2	3	2
CO4	3	3	2	1	2
CO5	3	3	3	2	3

C. Syllabus

UNIT I: Introduction - The Formulation of Two-Person, Zero-Sum Games- Solving simple Games - A Prototype Example – Games with Mixed Strategies – Graphical Solution Procedure – Solving by Linear Programming. (12H)

UNIT II: Combination games –Definition of Combinatorial game – The fundamental theorem for combinatorial games – Nim–Hex and other games – Tree games – Grundy functions – Bogus Nim–Sums. (12H)

UNIT III: Two Person Zero – Sum games – Games in normal form – Saddle points and equilibrium pairs Max-min and Minimum – Mixed Strategies – 2 x 2 matrix games – 2 x n, m x 2, and 3 x 3 matrix games – Linear Programming. (12H)

UNIT IV: The Simplex Method the fundamental theorem of duality solution of two person – Slack variables perfect canonical linear programming problem – the Simple method – Pivoting – The perfect phase of the simplex method –The Big M method – Bland's rules to prevent cycling –Duality and the Simple method – Solution of game metrics. (12H)

UNIT V: Games in coalitional form – The imputation of set and the core – Linear production games –Dominance – D-core – Stable sets – Shapley value – Nucleolus – Bargaining games. (12H)

References:

1. Binmore, K. (1992). Fun and Games: A Text on Game Theory, Heath, Lexington, MA.
2. Chatterjee, K., and W. F. Samuelson. (2001). Game Theory and Business Applications, Kluwer Academic Publishers, Boston.
3. Forgo, F., Szep, J. and F. Szidarovsky. (1999). Introduction to the Theory of Games Concepts, Methods, Application, Kluwer Academic Publishers, Boston.
4. Hillier, F.S. and G. J. Lieberman. (2008). Introduction to Operations Research Concepts and Cases. (Eighth Edition). Tata McGraw-Hill Publishing Company Limited, New Delhi
5. Mendelson, E. (2004). Introducing Game Theory and its Applications. CRC Press.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Demonstrate fundamental understanding of the history of artificial intelligence (AI) and its foundations.	Remember
CO 2	Apply basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation, and learning.	Understand
CO 3	Demonstrate awareness and a fundamental understanding of various applications of AI	Apply
CO 4	Demonstrate proficiency developing applications in an 'AI language', expert system shell, or data mining tool.	Analyze
CO 5	Demonstrate an ability to share in discussions of AI, its current scope and limitations, and societal implications.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	3	3
CO2	2	3	2	3	2
CO3	3	2	2	2	3
CO4	2	1	3	1	1
CO5	3	2	1	1	3

c. Syllabus

UNIT I: The foundations of AI - The History of AI- Intelligent agents- Agent based system. Searching for solution- Uninformed/Blind search - Informed/Heuristic search - A* search - Hill-climbing search -Constraint satisfaction problem. (12H)

UNIT II: Knowledge-based agents – propositional logic – propositional theorem proving – propositional model checking – agents based on propositional logic. First-order logic – syntax and semantics – knowledge representation and engineering – inferences in first-order logic – forward chaining – backward chaining – resolution. (12H)

UNIT III: The planning problem - Planning with state space search - Partial order search - Planning with propositional logic - Planning and acting in the real world, Adversarial planning. (12H)

UNIT IV: Uncertainty-Probabilistic reasoning - Semantics of Bayesian network - Approximate inference in Bayesian network, Exact inference in Bayesian network - Probabilistic reasoning over time. (12H)

UNIT V: Learning from observation - Knowledge in learning - Statistical learning methods - Reinforcement learning. Game Playing and CSP - Game theory – optimal decisions in games – alpha-beta search – monte-carlo tree search – stochastic games – partially observable games. Constraint satisfaction problems – constraint propagation – backtracking search for CSP – local search for CSP – structure of CSP

(12H)

References:

1. Russell, S. J., and Norvig, P. (2021), “Artificial Intelligence – A Modern Approach”, Fourth Edition, Pearson Education.
2. Pool, D. and Mackworth, A. (2011). Artificial Intelligence: Foundations of Computational agents. Cambridge University.
3. Dan W. Patterson(20027), “Introduction to AI and ES”, Pearson Education.
4. Kevin Night, Elaine Rich, and Nair B.(2008), “Artificial Intelligence”, McGraw Hill.
5. Patrick H. Winston(2006), "Artificial Intelligence", Third Edition, Pearson Education.
6. Deepak Khemani(2013), “Artificial Intelligence”, Tata McGraw Hill Education.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Forecast using time series data.	Remember
CO 2	Find autocorrelation, auto-covariance, and partial autocorrelation.	Understand
CO 3	Fit time series data using AR, MA, and ARMA models.	Apply
CO 4	Fit time series data using ARIMA and SARIMA models.	Analyze
CO 5	Explain spectral analysis.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	2	1
CO2	2	3	2	3	2
CO3	1	3	2	3	3
CO4	2	3	2	2	2
CO5	3	2	3	2	2

c. Syllabus

UNIT I: Exploratory Time Series Analysis: Forecasting trend and seasonality based on smoothing. Methods of Exponential and moving average smoothing, Holt-Winter method; Types and implications of interventions; Outliers, additive and innovational outliers, procedure for detecting outliers. (9H)

UNIT II: Stationary Stochastic models: weak and strong stationarity, Deseasonaliing and detrending an observed time series, Auto-covariance, autocorrelation function (ACF), partial autocorrelation function (PACF) and their properties, Conditions for stationary and invertibility. (9H)

UNIT III: Models for Time Series: Time series data, Trend, seasonality, cycles and residuals, Stationary, White noise processes, Autoregressive (AR), Moving Average (MA), Autoregressive and Moving Average (ARMA). (9H)

UNIT IV: Autoregressive Integrated Moving Average (ARIMA) processes, Choice of AR and MA periods. Introduction to Seasonal ARIMA model, Volatility modelling. (9H)

UNIT V: Spectral analysis and decomposition: Spectral analysis of weakly stationary process, Periodogram and correlogram analysis, Spectral decomposition of weakly AR process and representation as a one-sided MA process–necessary and sufficient conditions, implication in prediction problems.

(9H)

References:

1. N. T. Thomopoulos, Applied Forecasting Methods, Prentice Hall, 1980.
2. G. E. P. Box, G. M. Jenkins and G. C. Reinsel, Time Series Analysis–Forecasting and Control, Pearson Education, 2004.
3. P. J. Brockwell and R. A. Davis, Introduction to Time Series and Forecasting, Springer, 2002.
4. D. C. Montgomery and L. A. Johnson, Forecasting and Time Series analysis, McGraw Hill, 1977.
5. Chan, N. H. (2004). Time series: applications to finance. John Wiley and Sons.
6. <https://www.coursera.org/learn/practical-time-series-analysis>.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall the basics of generalized linear models.	Remember
CO 2	Explain parameter estimation, testing of hypothesis in GLM.	Understand
CO 3	Implement Logistic regression, Poisson regression and NB-2 models for data analysis.	Apply
CO 4	Analyze the results of different models.	Analyze
CO 5	Compare and interpret the results of GLM.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	3	3
CO5	1	2	3	1	3

c. Syllabus

UNIT I: Generalized linear models: concept of generalized linear model - Link function - ML estimation - Quasi-likelihood estimation - large sample tests about parameters - goodness of fit - analysis of deviance- Residual analysis - types of residuals: raw, Pearson, deviance, Anscombe, quantile; residual plots. Variable selection: AIC – BIC. (9H)

UNIT II: Logistic regression: logit - probit - cloglog model for dichotomous data with single and multiple explanatory variables - ML estimation - large sample tests about parameters - Hosmer-Lemeshow test - ROC curve. (9H)

UNIT III: Multilevel logistic regression, Logistic regression for Nominal response: Baseline Category model and ordinal response: Proportional odds model. (9H)

UNIT IV: Poisson regression: ML and Quasi-likelihood estimation of parameters - testing significance of coefficients – goodness-of-fit - power family of link functions - over dispersion: Types – causes – remedies; Negative Binomial regression: NB-2 model. (9H)

UNIT V: Generalized linear mixed models (GLMM): Structure of the model - consequences of having random effects - estimation by maximum likelihood - marginal versus conditional models - estimation by generalized estimating equations and conditional likelihood - tests of hypothesis: LRT - asymptotic variance - Wald and score test. (9H)

References:

1. Hosmer Jr, D. W., Lemeshow, S., and Sturdivant, R. X. (2013). Applied logistic regression (Vol. 398). John Wiley and Sons.
2. Agresti, A. (2012). Categorical data analysis (Vol. 792). John Wiley and Sons.
3. Christensen, R. (2006). Log-linear models and logistic regression. Springer Science and Business Media.
4. Hilbe, J. M. (2011). Negative binomial regression. Cambridge University Press.
5. McCulloch, C. E., and Searle, S. R. (2004). Generalized, linear, and mixed models. John Wiley and Sons.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand need of population studies.	Remember
CO 2	Calculate different types of mortality rates.	Apply
CO 3	Construct Life table.	Skill
CO 4	Measure different types of mortality rates.	Understand
CO 5	Explain different measures of Nuptiality analysis	Remember

B. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

C. Syllabus

UNIT I: Population Theories: Coverage and content errors in demographic data, Population structure and characteristics, Balancing equations and Chandrasekharan-Deming formula, Adjustment of age data, use of Myer and UN indices, Population composition, dependency ratio. (9H)

UNIT II: Introduction and sources of collecting data on vital statistics, errors in census and registration data, Measurement of population, rate and ratio of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates. (9H)

UNIT III: Stationary and Stable population, Central Mortality Rates and Force of Mortality. Life(Mortality) Tables: Assumption, description, construction of Life Tables and Uses of Life Tables, Abridged Life Tables, Concept and construction of abridged life tables by Reed-Merrell method, Greville's method and King's Method. (9H)

UNIT IV: Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR). (9H)

UNIT V: Nuptiality Analysis: Crude Marriage Rate (CMR), General Marriage Rate (GMR), Age-Specific Marriage Rate (ASMR), Total Marriage Rate (TMR), Mean Age at Marriage, Singulate Mean Age at Marriage (SMAM), Population Projections, Uses of Projections, Techniques of Projection.

(9H)

References:

1. Pathak, K. B., and Ram, F. (1992). Techniques of demographic analysis. Himalaya Publishing House.
2. Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
3. Biswas, S. (1988): Stochastic Processes in Demography and Application, Wiley Eastern Ltd.
4. Bhende, A. A., and Kanitkar, T. (1978). Principles of population studies, Himalaya Publishing House.
5. Keyfitz N., Beckman John A.: Demography through Problems S-Verlag New york.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the basic concepts of Econometrics, methodology in Econometric theory	Remember
CO 2	Derive Generalized Least square estimators and verifying the validity of essential assumptions.	Understand
CO 3	Forecast from Dynamic models and Evaluate order of Autocorrelation. Determine Simultaneous equations models for real world problems	Apply
CO 4	Obtain and evaluate estimators applying Indirect least squares method, two-stage least squares method, K-Class estimators LIML and FIML.	Analyze
CO 5	Develop computer programmes for construction and evaluation of Econometric models	Apply

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	3	3	2
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO4	2	2	1	3	2
CO5	3	1	1	1	2

C. Syllabus

UNIT I: Nature and scope of Econometrics - Illustrative examples Production and cost analysis - Theory and analysis of consumer demand specification - Estimation of demand function - Price and income elasticity of demand - Price elasticity's of supply - Torquivists model of demand for inferior goods models building bias in construction of models.

(9H)

UNIT II: Single equation linear model static case - Ordinary least square model and generalized least squares model: Introduction - estimation and prediction - Problem of multicollinearity and heteroscedasticity – Causes, consequences and solutions of and estimation.

(9H)

UNIT III: Autocorrelation: Causes, consequences and testing for auto-correlated disturbances - Autoregressive series of order 1 (AR(1)) - Lagged variables and distributed log methods - Errors in variable models and Instrumental variables. Economical Forecasting – long term and short term.

(9H)

UNIT IV: Simultaneous equations model- Concept, structure and types - Identification Problem with restrictions on variance and covariance - Rank and order conditions of identifiability –Methods of estimation- Indirect least square method, two-stage least squares method of estimation and Estimation of Limited Information Maximum Likelihood (LIMH). **(9H)**

UNIT V: K-Class estimators - Full information estimators - Full Information Maximum Likelihood (FIMH) - Three stage least squares estimators (3-SLS) and its Properties - Comparison of various estimation methods. **(9H)**

References:

1. Castle, J. and Shephard, N. (2009). The Methodology and Practice of Econometrics. OUP Oxford publications.
2. Gujarati, D.N. and Sangeetha (2007). Basic Econometrics (Third Edition). McGraw Hill Publisher, New York.
3. Goldberger, A.S. (1964): Econometrics theory. John Wiley and Sons, New Delhi. 16
4. Kelejion, H. H. and Oates, W.E. (1988). Introduction to Econometrics, Principles and Applications. Harper and Row Publishers Inc., New York.
5. Maddala, G.S. and Kajal Lagari (2009). Introduction to Econometrics. John Wiley and Sons.
6. Madnani, G.M.K. (2008): Introduction to Econometrics: Principles and Applications. Oxford and IBH Publishing.
7. Wooldridge, J. (2012). Introduction Econometrics: A Modern Approach. Cengage Learning. 3.4 DEMOGRAPHY

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Know about the concepts of Reliability	Remember
CO 2	Get idea about some life time distributions.	Understand
CO 3	Analyze IFR, IFRA, NBU, DMRL and NBUE classes and their duals	Analyze
CO 4	Analyze Reliability estimation based on failure time.	Analyze
CO 5	Examine Probability growth models.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	2	2
CO2	3	2	2	3	3
CO3	3	2	2	3	3
CO4	1	3	3	2	2
CO5	2	1	1	2	1

C. SYLLABUS

UNIT I: Reliability concepts and measures – components and systems – Coherent systems and their reliability – cuts and paths – modular decomposition – bounds on system reliability – structural reliability importance of components. **(9H)**

UNIT II: Life time distributions – reliability function – hazard rate - common life time distributions –exponential, gamma, normal, Weibull, Rayleigh– estimation of parameters and testing of hypotheses in these distributions. **(9H)**

UNIT III: Notions of ageing – IFR,DFT, IFRA, NBU, DMRL and NBUE classes and their duals –implications – closures of these classes under formation of coherent systems. **(9H)**

UNIT IV: Reliability estimation based on failure times under various censored life tests and tests with replacement of failed items – stress-strength reliability and its estimation-reliability for Series and parallel circuits. **(9H)**

UNIT V: Reliability growth models – probability plotting techniques – Hollander-Proschan and Deshpande tests for exponentiality – tests for HPP vs NHPP with repairable systems - Basic ideas of accelerated life testing. **(9H)**

References:

1. Bain, L.J. and Engelhardt. (1991): Statistical Analysis of Reliability and Life Testing Models. CRC Press.
2. Barlow, R.E., and Proschan, F. (1981): Statistical Theory of Reliability and Life Testing (Second Edition). Holt, Rinehart and Winston, New York.
3. Blischke, W.R. and Murthy, D.N.P. (2000): Reliability–Modeling, Prediction and Optimization. John Wiley and Sons, New York.
4. Lawless, J.F. (2011): Statistical Models and Methods for Lifetime Data (Second Edition). John Wiley and Sons,
5. Nelson, W.B. (2005): Applied Life Data Analysis. John Wiley and Sons, New York.
6. Singpurwalla, N.D. (2006): Reliability and Risk – A Bayesian Perspective. John Wiley and Sons, New York.
7. Zacks, S. (2011): Introduction to Reliability Analysis. Springer London, Limited.

SAMEC11 STATISTICAL METHODS IN CLINICAL TRIALS 3 Credits

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Know the phases of clinical trials and epidemiological designs.	Remember
CO 2	Understand the Disease-Exposure association and diagnostic testing in clinical studies.	Understand
CO 3	Check model assumptions for Estimation of Means and proportions to analyze the clinical data.	Apply
CO 4	Design the different phases of clinical trials	Analyze
CO 5	Estimate survival function of the data	Skill

a) Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	2	2	3	3	3
CO2	2	3	1	3	2
CO3	2	1	2	3	2
CO4	3	3	3	3	3
CO5	2	3	3	2	3

c. Syllabus

UNIT I: Introduction to clinical trials: the need and ethics of clinical trials - bias and random error in clinical studies - conduct of clinical trials - overview of Phase I-IV trials - multi-center trials.

(9H)

UNIT II: Data management: data definitions - case report forms - database design - data collection systems for good clinical practice - concept of blinding/masking in clinical trials; Bioavailability – pharmacokinetics - pharmaco-dynamics - two compartment model.

(9H)

UNIT III: Design of clinical trials: parallel vs. cross-over designs - cross-sectional vs. longitudinal designs - review of factorial designs - objectives and endpoints of clinical trials.

(9H)

UNIT IV: Design of Phase I trials - design of single-stage and multi-stage Phase II trials - design and monitoring of Phase III trials with sequential stopping.

(9H)

UNIT V: Design of bio-equivalence trials - Inference For 2x2 crossover designs: Classical methods of interval hypothesis testing for bioequivalence - Bayesian methods - nonparametric methods; Reporting and analysis: analysis of categorical outcomes from Phase I - III trials - analysis of survival data from clinical trials.

(9H)

References:

1. Jennison, C., and Turnbull, B. W. (1999). Group sequential methods with applications to clinical trials. CRC Press.
2. Chow, S. C., and Liu, J. P. (2008). Design and analysis of clinical trials: concepts and methodologies (Vol. 507). John Wiley and Sons.
3. Chow, S. C., and Liu, J. P. (2008). Design and analysis of bioavailability and bioequivalence studies. CRC press.
4. Clayton, D., and Hills, M. (2013). Statistical models in epidemiology. OUP Oxford.
5. Daniel, W. W., and Cross, C. L. (2018). Biostatistics: a foundation for analysis in the health sciences. Wiley.
6. Fleiss, J. L. (2011). Design and analysis of clinical experiments. John Wiley and Sons.
7. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., and Granger, C. B. (2015). Fundamentals of clinical trials. Springer.
8. Marubini, E., and Valsecchi, M. G. (2004). Analysing survival data from clinical trials and observational studies (Vol. 15). John Wiley and Sons.
9. Piantadosi, S. (2017). Clinical trials: a methodologic perspective. John Wiley and Sons.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the basics and need of Evolutionary algorithms.	Remember
CO 2	Design Single Objective Optimization.	Understand
CO 3	Discover innovative knowledge through optimization.	Apply
CO 4	Design and parameterization for multi-objective applications.	Analyze
CO 5	Solve some real-world MOPs and their solution using MOEAs.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	3	3	2
CO2	2	3	1	2	3
CO3	2	2	3	1	2
CO4	3	3	3	2	2
CO5	2	1	2	3	1

c. Syllabus

UNT I: Introduction to Optimization; Single Objective Optimization (SOP); Deterministic Optimization Methods (Gradient Descent, LP and QP); Stochastic Optimization Methods (random search, Stimulated Annealing, Evolutionary Algorithms); Difficulties in Single Objective Optimization; Difficulties with Classical Optimization Algorithms; Need for Evolutionary Algorithms. **(9H)**

UNITII: Evolutionary Algorithm; EA operators (Selection, Recombination and Mutation operators); Single Objective Optimization (SOP) using EAs; Design and Parameterization for Single Objective Applications; Problem Formulation and representation issues for different real world engineering SOPs; Some competent EAs. **(9H)**

UNITIII: Constrained SOP; Discovery of innovative knowledge through Optimization; Difficulties in EAs; No free lunch theorem; Enhancing efficiency of EAs through incorporation of domain specific information and hybridization with expressly designed algorithms. **(9H)**

UNITIV: Introduction to Multi-Objective Optimization (MOP); Concept of Pareto Optimality; Issues in Multi- Objective Optimization; Multi-objective evolutionary approaches; Design and parameterization for multi-objective applications. **(9H)**

UNITV: Constrained Multi-Objective Optimization; Dynamic Optimization; Robust Optimization; some real-world MOPs and their solution using MOEAs. **(9H)**

References:

1. Eiben, A. E., and Smith, J. E. (2015). Introduction to evolutionary computing. Springer-Verlag Berlin Heidelberg.
2. Deb. (2005). Multi-objective Optimization Using Evolutionary Algorithms, Wiley.
3. Koza, J.R. et al. (2003). Genetic Programming. Kluwer, Norwell, MA.
4. Caello, C.A., Van Veldhuitzen, D.A. and Lamont, G. (2002). Evolutionary Algorithms for Solving Multi-Objective Problems, New York.
5. Butz, M.V. (2002). Anticipatory Learning Classifier Systems. Kluwer, Norwell, MA.
6. Abd Samad, M. F. (2014). Evolutionary computation in system identification: review and recommendations. Int Rev AutomControl(IREACO), 7(2), 208-216.
7. Jin, Y.C. (Ed). (2005). Knowledge incorporation in evolutionary computation. Springer, New York.
8. Riolo, R. and Worzel, B. (Eds). (2003). Genetic programming theory and practice, Norwell, MA.
9. Sarker, R., Mohammadian, M. and Yao, X. (Eds). (2002). Evolutionary Optimization, Kluwer, Norwell, MA

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the risk models for insurance.	Understand
CO 2	Use different types of life table.	Apply
CO 3	Find annuity, future value, present value, and compound interest.	Apply
CO 4	Calculate premium for different cases.	Analyze
CO 5	Find policy expenses, claim amount distributions, stop-loss Insurance	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	1	1
CO2	2	3	3	1	2
CO3	2	3	2	3	2
CO4	2	3	2	1	3
CO5	3	2	1	1	3

c. Syllabus

Unit I: Introduction to Insurance Business, Insurance and utility theory, Risk models for Insurance: Individual and aggregate Risk models for short term, aggregate claims distribution, compound Poisson distribution and its applications. Survival function and Life tables: Survival function, Distribution function, Density functions and Force of mortality. Time-until-death random variable and Curtate-future lifetime random variable.

(9H)

Unit II: Life tables, Select and ultimate life tables. Assumptions for fractional ages and some analytical laws of mortality. Life Insurance: Principles of compound interest: Nominal and effective interest rates and force of interest and discount, compound interest, accumulation factor, continuous compounding. Insurance payable at the moment of death and at the end of the year of death, level benefit insurance, Whole life insurance, endowment insurance, deferred insurance and varying benefit insurance. Recursion equations and commutation functions.

(9H)

Unit-III: Compound Interest, Interest compounded continuously, Annuities: Annuities certain, Annuity contingent, Annuity perpetual, ordinary annuity, Annuity deferred, Annuity due paid immediately, Continuous and Discrete life annuities, Life annuities with monthly payments and apportionable annuities. Recursion equations, Sinking fund, Amortization of principal, net premium: Fully continuous and discrete premiums, True monthly payment premiums, apportionable premiums and accumulation type benefits. Insurance model including expenses.

(9H)

Unit-IV: Net premium reserves: Continuous and discrete net premium reserves, reserves on a semi continuous basis, reserves based on true monthly premiums, reserves on an apportion able or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions. (9H)

Unit V: Some practical considerations: Premiums that include expenses-general expenses Type's of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss Insurance. (9H)

References:

1. Robin Cunningham, Thomas N. Herzog, Richard L. Models for Quantifying Risk, 4th Edition, ACTEX Publications, 2011.
2. Browers, Newton L et al., Actuarial Mathematics 2nd . Society of Actuaries, 1997.
3. Dickson, David C. M., Hardy, Mary R. and Waters, Howard R., Actuarial Mathematics for life contingent risks, International series on actuarial science, Cambridge 2009.
4. Deshmukh S. R., An Introduction to Actuarial Statistics, University Press, 2009
5. Narang, Uma, Insurance Industry in India: Features, Reforms and Outlook, New Century Publications
6. Borowiak, D.S. and A. F. Shapiro. (2013). Financial and Actuarial Statistics: An Introduction (Second Edition). CRC press.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Able to understand the mathematics behind functioning of artificial neural networks	Remember
CO 2	Able to analyze the given dataset for designing a neural network based solution	Understand
CO 3	Able to carry out design and implementation of deep learning models for signal/image processing applications	Apply
CO 4	Able to design Auto Encoders.	Analyze
CO 5	Learn about Deep Generative models.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	2	3
CO2	2	3	2	3	3
CO3	3	3	3	2	2
CO4	1	2	2	1	3
CO5	2	1	3	3	1

c. Syllabus

UNIT I: Learning algorithms, Maximum likelihood estimation, Building machine learning algorithm, Neural Networks Multilayer Perceptron, Back-propagation algorithm and its variants Stochastic gradient decent, Curse of Dimensionality. **(9H)**

UNIT II: Introduction to Deep Learning and Architectures, Machine Learning Vs. Deep Learning, Representation Learning, Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU, Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders. **(9H)**

UNIT III: Architectural Overview – Motivation - Layers – Filters – Parameter sharing – Regularization, Popular CNN Architectures: Res Net, Alex Net, Transfer Learning - Transfer learning Techniques, Variants of CNN: Dense Net, PixelNet. Sequence Modeling – Recurrent and Recursive Nets, Recurrent Neural Networks, Bidirectional RNNs – Encoder-decoder sequence to sequence architectures - BPTT for training RNN, Long Short Term Memory Networks. **(9H)**

UNIT IV: Auto Encoders - Under complete Auto encoders – Regularized Auto encoders – stochastic Encoders and Decoders – Contractive Encoders. **(9H)**

UNIT V: Deep Generative Models-Deep Belief networks – Boltzmann Machines – Deep Boltzmann Machine - Generative Adversarial Networks, Applications of DL. **(9H)**

References:

1. Heaton, J. (2018). Ian Good fellow, Yoshua Bengio, and Aaron Courville: Deep learning: The MIT Press, 2016, 800 pp, ISBN: 0262035618. Genetic programming and evolvable machines, 19(1-2), 305-307.
2. Patterson, J., and Gibson, A. (2017). Deep learning: A practitioner's approach. " O'Reilly Media, Inc."
3. Michelucci, U. (2018). Applied deep learning. A Case-Based Approach to Understanding Deep Neural Networks.
4. Murphy, K. P. (2012). Machine learning: a probabilistic perspective. MIT press.
5. Alpaydm, E. (2014). Introduction to Machine Learning, (Adaptive Computation and Machine Learning)almohreraladbi.
6. Zacccone, G., and Karim, M. R. (2018). Deep Learning with TensorFlow: Explore neural networks and build intelligent systems with Python. Packt Publishing Ltd.
7. Gulli, A., and Pal, S. (2017). Deep learning with Keras. Packt Publishing Ltd.
8. Chollet, F. (2021). Deep learning with Python. Simon and Schuster.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Have knowledge on Fuzzy sets and Membership Functions.	Remember
CO 2	Decide the difference between crisp set and fuzzy set theory.	Understand
CO 3	Make applications on Fuzzy logic membership function and fuzzy inference systems.	Apply
CO 4	Able to make decision under Fuzzy States and Fuzzy Actions.	Analyze
CO 5	Apply Fuzzy pattern recognition, Image processing and Syntactic Recognition.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	2	2	3
CO2	1	2	1	3	3
CO3	3	2	1	2	2
CO4	2	3	3	3	3
CO5	2	3	2	2	1

C. Syllabus

UNIT I: Uncertainty and Imprecision – Statistics and Random Processes – Uncertainty in Information – Fuzzy Sets and membership – Chance versus Ambiguity - Classical Sets – Fuzzy Sets – Sets as Points in Hyper-cubes - Classical Relations and Fuzzy Relations: Cartesian Product – Crisp Relations – Fuzzy Relations – Fuzzy Tolerance and Equivalence Relations - Membership Functions. (9H)

UNIT II: Fuzzy-to-Crisp Conversions: Lambda-Cuts for Fuzzy Sets – Lambda-Cuts for Fuzzy Relations – Defuzzification Methods - Fuzzy Arithmetic, Numbers, Vectors and the Extension Principle - Extension Principle – Fuzzy Numbers – Interval Analysis in Arithmetic – Approximate Methods of Extension – Fuzzy Vectors. (9H)

UNIT III: Classical Logical and Fuzzy Logic: Classical Predicate Logic – Fuzzy Logic – Approximate Reasoning – Fuzzy Tautologies, Contradictions, Equivalence, and Logical Proofs – Other Forms of the Implication Operation – Other Forms of the Composition Operation - Fuzzy Rule-Based Systems: Natural Language – Linguistic Hedges – Rule-Based Systems – Graphical Techniques of Inference. (9H)

UNIT IV: Fuzzy Nonlinear Simulation: Fuzzy Relational Equations – Partitioning – Nonlinear Simulation Using Fuzzy Rule-Based Systems – Fuzzy Associative Memories (FAMs) – Fuzzy Decision Making: Fuzzy Synthetic Evaluation – Fuzzy Ordering – Preference and Consensus – Multi-objective Decision Making – Fuzzy Bayesian Decision Method – Decision Making under Fuzzy States and Fuzzy Actions. **(9H)**

UNIT V: Fuzzy Classification: Classification by Equivalence Relations – Cluster Analysis – Cluster Validity – Classification Metric – Hardening the Fuzzy- Similarity Relations from Clustering. Fuzzy Pattern Recognition: Feature Analysis – Partitions of the Feature Space – Single Sample Identification – Fuzzy Statistics- Multi-feature Pattern Recognition – Image Processing – Syntactic Recognition. **(9H)**

References

1. George, A. and Anastassiou. (2010). Fuzzy Mathematics: Approximation Theory. Springer.
2. George J. Klir and Tina A. Folge.(1988). Fuzzy Set, Uncertainty, and Information. PrenticeHall, Inc, USA.
3. Klir, G.J. and B. Yuan. (1995). Fuzzy sets and Fuzzy logic Theory and Applications. Prentice-Hall Inc., (Reprint 2003).
4. Nanda. S and Das. N.R. (2010). Fuzzy Mathematical Concepts. Narosa Publishing House, Pvt, Ltd, New Delhi 110002.
5. Nguyen, H.T., Prasad, N.R., Walker, A.L. and Walker, E.A. (2003). A First Course in Fuzzy and Neural Control. Chapman Hall/CRC press.
6. Nguyen, H.T. and Walker, E.A. (2005). A First Course in Fuzzy Logic (Third Edition). CRC Press.
7. Ross, T.J. (2009). Fuzzy Logic with Engineering Applications (Third Edition). John Wiley and Sons.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand the basic mechanical concepts for a dynamic system of particles and also the effect of coordinate transformation and visualize the tensor analysis as a linear transformation.	Remember
CO 2	Formulate the equations of motion for dynamics of system of particles using Lagrangian and Hamiltonian theories of classical mechanics.	Analyze
CO 3	Analyze the basic concepts of particles dynamics and the Hamilton-Jacobi formulation of mechanics.	Apply
CO 4	Apply the canonical transformations for calculating conserved quantities of the mechanical systems using the Hamilton-Jacobi equations and Liouville's theorem.	Skill
CO 5	Explain the symmetry group in the quantum mechanics of particle systems and their types.	Understand

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	3	1	2
CO2	2	3	2	3	1
CO3	3	2	3	2	3
CO4	3	2	1	2	1
CO5	2	1	2	1	2

c. Syllabus

UNIT I: Mechanics of a particle, Mechanics of a system of particles, Generalized coordinates, Constraints, Virtual displacement, Virtual work, Principle of virtual work, D'Alembert's principle. **(12H)**

UNIT II: Velocity-dependent potentials and the dissipation function, Energy and momentum, Derivation of Lagrange's equations and its applications, Integrals of the motion, Routhian function, Energy function and the conservation of energy. **(12H)**

UNIT III: Small oscillations for conservative mechanical system, Hamilton's principle, Hamilton's equations, Derivation of Lagrange's equations from Hamilton's equation, Other variational principles. **(12H)**

UNIT IV: Phase space, Liouville's theorem, Hamilton principal function, Hamilton-Jacobi equation, Hamilton-Jacobi method, Separability, Differential forms and generating functions, Canonical transformations, Examples of Canonical transformations. **(12H)**

UNIT V: Harmonic oscillator, Symmetric approach to canonical transformations, Special transformations, Lagrange and Poisson Brackets, Symmetry groups of mechanical systems, More general transformations. **(12H)**

References:

1. Greenwood, D. T. (1977). Classical Dynamics, Prentice-Hall International Series in Dynamics, Dover Publications, Inc., New York.
2. Goldstein, H. (2018). Classical Mechanics, 2nd Edition, Narosa Publishing House.
3. Synge, J. L., and Griffith, B. A. (1963). Principles of Mechanics, 3rd Edition, McGraw-Hill Book Company, Inc.
4. Arnold, A. I. (1997). Mathematical Methods of Classical Mechanics: 60 (Graduate Texts in Mathematics), 2nd Edition, Springer-Verlag New York Inc., New York.
5. Lanczos, C. (1970). Variational Principles of Mechanics, University of Toronto Press, 4th Edition.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain different normed linear spaces, operators.	Remember
CO 2	Understand the basic context of finite and infinite dimensional spaces.	Understand
CO 3	Work on operators and functional.	Apply
CO 4	Analyze the fundamental theorems on Banach spaces, Hilbert spaces and determine the nature of the singularities.	Analyze
CO 5	Solve mathematical problems by the knowledge of functional analysis.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	1	2
CO2	3	2	2	1	2
CO3	3	2	2	1	2
CO4	3	2	1	1	2
CO5	3	1	2	1	3

c. Syllabus

UNIT I: Normed linear space; Banach spaces and basic properties; Riesz lemma, best approximation property; quotient space, Bounded linear operators and their properties, dual space, adjoint of a bounded linear operator. **(9H)**

UNIT II: Inner product space and projection theorem; Hilbert space, Orthonormal bases; Bessel inequality and Parseval's formula; Riesz-Fischer theorem, Orthogonal complement. **(9H)**

UNIT III: Bounded operators on Hilbert spaces and basic properties; Space of bounded operators and dual space; Riesz representation theorem; Adjoint of operators on a Hilbert space. **(9H)**

UNIT IV: Self-adjoint, Normal and Unitary Operators; Examples of unbounded operators; Convergence of sequence of operators, Finite dimensional Spectral theorem. **(9H)**

UNIT V: Hahn-Banach Extension theorem; Uniform boundedness principle; closed graph theorem and open mapping theorem. Some applications. **(9H)**

References

1. B.V. Limaye, Functional Analysis, Second Edition, New Age International, 1996.
2. E. Kreyzig, Introduction to Functional Analysis with Applications, Wiley, 2007.
3. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
4. A.E. Taylor and D.C. Lay, Introduction to Functional Analysis, Second Edition, Wiley, 1980.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Describe different numerical techniques for solving complex nonlinear equations and system of equations.	Remember
CO 2	Explain the various interpolation techniques on curves and surfaces for approximating functions and estimate local errors in the interpolating polynomials.	Understand
CO 3	Apply the knowledge of advanced numerical methods in order to solve different types of problems such as optimization problems, transportation and stochastic problems.	Apply
CO 4	Know about Sobolev, Hilbert and their specifications as well as and also Riesz representation and Lax-Milgran theorem.	Analyze
CO 5	Use a variety of numerical methods to compute solutions to higher-order initial and boundary value ordinary and partial differential equations.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	2	2	1	3	2
CO2	3	3	3	2	2
CO3	3	3	2	1	3
CO4	3	1	1	1	1
CO5	2	2	2	2	1

c. Syllabus

UNIT I: Muller's and Bairstow's methods for complex equations, Successive-Over-Relaxation (SOR) method, Nonlinear eigenvalue problem, Householder method for non-symmetrical matrices, Approximation of Chebyshev polynomials and Chebyshev series, Pade approximation, Minimax approximations. **(9H)**

UNIT II: Minimizing a function of several variables, Bezier and B-splines curves, Interpolating on a surface, Conjugate gradient method, Linear and nonlinear programming, Some optimization problems - Transportation and stochastic problems, Weak formulation of boundary value problems (BVPs) **(9H)**

UNIT III: Ritz-Galerkin approximation, Error estimates, Piecewise polynomial spaces, Relationship to difference methods, Review of Sobolev and Hilbert spaces, Weak derivatives, Sobolev norms and associated spaces, Riesz representation theorem, Symmetric and non-symmetric variational formulation of elliptic and parabolic BVPs, Lax-Milgram Theorem. **(9H)**

UNIT IV: Higher order boundary value ordinary and partial differential equations - Equilibrium and propagation methods, Problems for Laplace, Poisson, diffusion, and wave equations in multidimensional space, Finite-Element Analysis (FEA) - Domain discretization, Finite element application in one and two dimensions. **(9H)**

UNIT V: Rayleigh-Ritz, Collocation, and Galerkin methods, the finite element, Triangular finite elements, Rectangular elements, The Interpolant, Averaged Taylor polynomials, Error representation, Bounds for the Interpolation error. **(9H)**

References:

1. Hoffman, J. D. (2001). Numerical Methods for Engineers and Scientists, 2nd Edition, CRC Press (Taylor and Francis Group).
2. Brenner, S. C., and Scott, L. R. (2007). The Mathematical Theory of Finite Element Methods (Texts in Applied Mathematics), Springer-Verlag, 3rd Edition.
3. Chapra, S. C., and Canale, R. P. (2021). Numerical Methods for Engineers, Applied Mathematics Series, 8th Edition, McGraw-Hill, Inc.
4. Johnson, C. (1988). Numerical Solution of Partial Differential Equations by the Finite Element Method, Cambridge University Press.
5. Lange, K. (2010). Numerical Analysis for Statisticians (Statistics and Computing), 2nd Edition, Springer-Verlag New York Inc.
6. Jain, M. K., Iyengar, S. R. K., and Jain, R. K. (2005), Numerical Methods for Scientific and Engineering Computation, 4th Edition, New Age International Private Limited Publishers.

A. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Express the concept of numbers, congruence and all the basics facts on number theory	Remember
CO 2	Understand the techniques to compute with large integers, distribution of primes, finite and discrete probability distributions.	Understand
CO 3	Apply mathematical ideas and concepts within the context of computational number theory.	Apply
CO 4	Analyze the number theoretic techniques.	Analyze
CO 5	Solve computational problems in number theory.	Skill

B. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	01	2	1	2
CO2	3	2	2	1	2
CO3	3	2	2	3	3
CO4	3	2	2	1	2
CO5	3	3	3	3	3

C. Syllabus

Unit I: Basic properties of the integers-Divisibility and primality, Ideals and greatest common divisors, Some consequences of unique factorization; Congruence's - Definitions and basic properties, Solving linear congruence's, Residue classes, Euler's phi function, Fermat's little theorem, Arithmetic functions and Mobius inversion. **(9H)**

Unit II: Computing with large integers -Asymptotic notation, Machine models and complexity theory, Basic integer arithmetic, Computing in $\mathbb{Z}_n$, Faster integer arithmetic. Euclid's algorithm- The basic and extended Euclidean algorithms, computing modular inverses and Chinese remaindering, Speeding up algorithms via modular computation, Rational reconstruction and applications. **(9H)**

Unit III: The distribution of primes - Chebyshev's theorem on the density of primes, Bertrand's postulate, Mertens' theorem, the sieve of Eratosthenes, The prime number theorem. Quadratic residues and quadratic reciprocity; Quadratic residues, the Legendre symbol, the Jacobi symbol. **(9H)**

Unit IV: Computational problems related to quadratic residues; Computing the Jacobi symbol, testing quadratic residuosity, Computing modular square roots, The quadratic residuosity assumption. **(9H)**

Unit V: Finite and discrete probability distributions -Finite probability distributions: basic definitions, Conditional probability and independence, Random variables, Expectation and variance, Some useful bounds, The birthday paradox, Hash functions, Statistical distance, Discrete probability distributions. **(9H)**

References:

1. Victor Shoup, A computational introduction to number theory and algebra Cambridge University Press, Cambridge, 2005.
2. T. M. Apostol, Introduction to Analytic Number Theory, Springer-Verlag, New York, 1976.
3. D. Bressoud and S. Wagon, A course in Computational Number Theory, Key College Publishing, Emeryville, CA; in cooperation with Springer-Verlag, New York, 2000.

A. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Explain the definition and existence of Laplace transform, Fourier transform, Z, and Mellin transforms.	Remember
CO 2	Understand the basic properties of Laplace transform, Fourier transform, Z and Mellin transforms.	Understand
CO 3	Apply the appropriate transform to solve initial value problems, boundary value problems, signal processing	Apply
CO 4	Analyze the suitable transform to solve ODEs, PDEs and Difference equations.	Analyze
CO 5	Solve real time mathematical models by suitable transforms.	Skill

B. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	3	2	1	2
CO2	3	2	2	1	2
CO3	2	2	2	3	3
CO4	2	2	2	3	3
CO5	2	3	3	3	2

C. Syllabus

Unit I: The Fourier Transform: Algebraic Properties, Convolution, Translation, Modulation. Analytical Properties of Fourier transforms, Transform of Derivatives, and Derivatives of Transform. **(9H)**

Unit II: Fourier Transform: Parseval Formula, Inversion theorem, Plancherel's theorem, Application to Solving Ordinary and Partial Differential Equations. **(9H)**

Unit III: The Laplace transform: Algebraic Properties of Laplace Transform, Transform of Derivatives and Derivatives of Transform. The Inversion Theorem, Evaluation of inverse transforms by residue, Application to solving PDE and Integral Equation. **(9H)**

Unit IV: The Z-Transform: Properties of the region convergence of the Z-transform. Inverse Z-Transform for Discrete-Time Systems and Signals, Signal Processing and Linear System. **(9H)**

Unit V: The Mellin transform: Properties and Evaluation of Transforms, Convolution Theorem for Mellin Transforms. Solving integral equations by Mellin Transform. **(9H)**

References:

1. Bhatta, D., Debnath, L. (2015). Integral Transforms and Their Applications, Third Edition. United Kingdom: Taylor and Francis.
2. Pathak, R. S. (2017). Integral Transforms of Generalized Functions and Their Applications. Netherlands: CRC Press.
3. Titchmarsh, E. C. (1986). Introduction to the Theory of Fourier Integrals. United States: Chelsea Publishing Company.
4. Watson, E. J. (1981). Laplace Transforms and Applications. United Kingdom: Van Nostrand Reinhold.
5. Jury, E. I. (1964). Theory and Application of the Z-transform Method. United Kingdom: Wiley.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recognize the various form of Volterra and Fredholm integral equations.	Remember
CO 2	Understand the solving techniques of integral equations, Brachistochrone and Isoperimetric problems.	Understand
CO 3	Apply the ideas to convert Volterra Equation to ODE and boundary value problem to integral equation.	Apply
CO 4	Analyze the variation problems with fixed boundaries, functional in the form of integrals.	Analyze
CO 5	Evaluate the real-time application governed by integral equations.	Skill

b. Mapping of Program Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	2	2
CO2	3	2	2	2	3
CO3	3	3	3	2	2
CO4	3	2	2	3	2
CO5	3	3	2	2	3

C. Syllabus

UNIT I: Special kinds of Kernel, Classification of integral equation, Convolution integral, Relation between differential and integral equations, Classification, Conversion of Volterra Equation to ODE, Conversion of IVP and BVP to Integral Equation. **(9H)**

UNIT II: Fredholm integral equations, Solution of Fredholm integral equation-decomposition method, direct computation, Adomain decomposition, successive approximation and successive substitution methods. **(9H)**

UNIT III: Volterra Integral equations, Solution of Volterra integral equation- successive approximation method, Adomian decomposition method, series solution, successive substitution method, resolvent kernel, Volterra integral equation of first kind, Integral equations with separable kernels. **(9H)**

UNIT IV: Introduction, problem of Brachistochrone, Isoperimetric problem, Variation and its properties, Variational problems with the fixed boundaries, Euler's equation, Functionals in the form of integrals, Functionals involving more than one dependent variables and their first derivatives, the system of Euler's equations, Functionals depending on the higher derivatives of the dependent variables, Functionals containing several independent variables, Variational problems in parametric form. **(9H)**

UNIT V: Variational problems with moving boundaries, one sided variations, variational problems with subsidiary conditions, Isoperimetric problems, Numerical methods for solving variational problems, Rayleigh – Ritz method, Galerkin's Method. **(9H)**

References

1. Gelfand, I. M., and Fomin, S. V. (1963). Calculus of Variations Prentice-Hall. Inc., Englewood Cliffs.
2. Kanwal, R. P. (2013). Linear integral equations. Springer Science and Business Media.
3. Elsgolts, L. (2003) Differential Equations and the Calculus of Variations. University Press of the Pacific.
4. Corduneanu, C. (2008). Integral Equations and Applications. United Kingdom: Cambridge University Press.
5. Weinstock, R. (2018). Calculus Of Variations With Applications To Physics And Engineering. First Edition, United States: Creative Media Partners, LLC.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall the principles of the Design of Experiment.	Remember
CO 2	Explain procedure of CRD and RBD.	Apply
CO 3	Explain and apply LSD and BIBD.	Analyze
CO 4	Conduct factorial and confounding experiments	Skill
CO 5	Conduct split plot designs	Understand

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	2	3
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	3	3	2	1	3
CO5	1	3	3	2	3

c. Syllabus

UNIT I: Principles of Experimental Design: Need for designed experiments, how data are obtained, difference between data obtained from designed experiments and sampling, randomization, replication and blocking-the need for them and how to achieve these principles in an experiment. (12H)

UNIT II: Analysis of different designs, their strengths and when to employ which design, completely randomized design, fixed effects and random effects, randomized block design-without and with interaction, Analysis with missing observations. (12H)

UNIT III: Latin Square design, repeated LSS; incomplete block designs, balanced incomplete block design (BIBD). (12H)

UNIT IV: Analysis of covariance, factorial designs- 2^k factorial experiments, confounding, 2^{k-1} fractional factorial experiments, response surface method to determine optimum factor level combination with data obtained from a 2^k factorial design, partially balanced incomplete block design (PBIBD). (12H)

UNIT V: Split-Plot Designs: Analysis of a Split-Plot Design with Complete Blocks, Whole-Plot Analysis, Contrasts Within and Between Whole Plots, Split-Split-Plot Designs, Split-Plot Confounding. (12H)

References:

1. D. C. Montgomery, Design and Analysis of Experiments, fifth edition, John Wiley, 2008.
2. M.N. Das, and N. C. Giri, Design and Analysis of Experiments, second edition, Wiley Eastern, 1991.
3. A. Dey, Incomplete Block Designs, Hindustan Book Agency, 2010.
4. Hinkelmann, K., and Kempthorne, O. (2007). Design and analysis of experiments, volume 1: Introduction to experimental design (Vol. 1). John Wiley and Sons.
5. Davies, O. L. (1956), Design and Analysis of Industrial Experiments, 2nd edition Hafner Publishing Company, New York.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall the fundamental concepts of Ito Integral.	Remember
CO 2	Understand the Filtering problem, Markov property.	Apply
CO 3	Apply Ito's lemma to obtain solution to stochastic differential equations.	Analyze
CO 4	Analyze the existence and uniqueness of solution for stochastic differential equations.	Skill
CO 5	Handle real time application using stochastic differential equations.	Understand

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	2	2	1
CO2	3	2	3	3	2
CO3	2	3	2	3	3
CO4	3	2	2	2	3
CO5	3	2	2	3	3

c. Syllabus

UNIT I: Probability spaces, Random variables, Stochastic processes, Brownian motion. Ito Integrals: Construction and properties of Ito integrals, Extension of the Ito integral. (9H)

UNIT II: Ito Formula: One - dimensional Ito Processes, The one-dimensional Ito formula, The multidimensional Ito formula, Examples, The Martingale representation theorem. (9H)

UNIT III: Stochastic Differential Equations: Example and solution methods, The law of iterated logarithm (Statement only), existence and uniqueness results- weak and strong solutions. (9H)

UNIT IV: Filtering Problem: Introduction, The 1-Dimensional Linear Filtering Problem, The 1-dimensional Kalman-Bucy filter (Statement only), Example - Noisy observations of a constant process, Noisy observations of a Brownian motion, and Noisy observations of a population growth. The Multidimensional Linear Filtering Problems: The Multi-Dimensional Kalman-Bucy Filter (Statement only). (9H)

UNIT V: Time homogeneous Ito Diffusion, Basic properties, Markov Property, The Strong Markov Property – The Generator of an Ito Diffusion – Graph of Brownian motion, The Dynkin Formula – The Characteristic Operator, Brownian motion on the unit circle.

(9H)

References:

1. Oksendal, B. (2013). Stochastic differential equations: an introduction with applications. Springer Science and Business Media.
2. Kloeden, P. E., Platen, E., Kloeden, P. E., and Platen, E. (1992). Stochastic differential equations (pp. 103-160). Springer Berlin Heidelberg.
3. Cyganowski, S., Kloeden, P., and Ombach, J. (2001). From elementary probability to stochastic differential equations with MAPLE®. Springer Science and Business Media.
4. Friedman, A. (1975). Stochastic differential equations and applications. In Stochastic differential equations (pp. 75-148). Berlin, Heidelberg: Springer Berlin Heidelberg.
5. Henderson, D., and Plaschko, P. (2006). Stochastic Differential Equations In Science And Engineering (With Cd-rom). World Scientific.
6. <https://youtu.be/3IKuKrvLSnU?si=Jggm0p82rSCtz3mu>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand logic and predicate calculus.	Remember
CO 2	Understand the concepts of counting principles and Combinatorics.	Apply
CO 3	Address the challenges of the relevance of lattice theory.	Analyze
CO 4	Analyze the algebraic structures.	Skill
CO 5	Solve real time applications using graphs and Boolean algebra.	Understand

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	2	1
CO2	3	2	3	3	2
CO3	2	3	2	3	3
CO4	3	2	2	2	3
CO5	3	2	2	3	3

c. Syllabus

UNIT I: Logic and Predicate: Introduction-Statements and Notation-Connectives, Tautologies, Two State Devices and Statement logic, Equivalence, Implications, Normal forms, The Theory of Inference for the Statement Calculus. The Predicate Calculus - Inference Theory of the Predicate Calculus.

(9H)

UNIT II: Algebraic Structures: Algebraic systems – Semi groups and monoids – Groups – Subgroups – Homomorphism's – Normal subgroup and cosets – Lagrange's theorem – Definitions and examples of Rings and Fields.

(9H)

UNIT III: Combinatorics: Mathematical induction – Strong induction and well ordering – The basics of counting – The pigeonhole principle – Permutations and combinations – Recurrence relations – Solving linear recurrence relations – Generating functions – Inclusion and exclusion principle and its applications.

(9H)

UNIT IV: Lattices and Boolean Algebra: Partially Ordered Relations -Lattices as Posets – Hasse Digram – Properties of Lattices. Boolean algebra - Boolean Functions-Representation and Minimization of Boolean Functions – Karnaugh map – McCluskey algorithm.

(9H)

UNIT V: Basic Concepts of Graph Theory and Trees: Planar and Complete graph - Matrix representation of Graphs – Graph Isomorphism – Connectivity–Cut sets-Euler and Hamilton Paths–Shortest Path algorithms. Trees – properties of trees – distance and centers in tree –Spanning trees and algorithms- Tree traversals.

(9H)

References:

1. Tremblay, J. P., and Manohar, R. (1975). *Discrete mathematical structures with applications to computer science*. McGraw-Hill, Inc..
2. Rosen, K. H., and Krithivasan, K. (1999). *Discrete mathematics and its applications* (Vol. 6). New York: McGraw-Hill.
3. Lipschutz, S., and Lipson, M. (1997). *Discrete Mathematics*, Schaum's Outlines.
4. West, D. B. (2001). *Introduction to graph theory* (Vol. 2). Upper Saddle River: Prentice hall.
5. Deo, N. (2017). *Graph theory with applications to engineering and computer science*. Courier Dover Publications.

**Open Electives
(To be offered in Semester
II to the students from
other Departments)**

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall data representation, central tendency and dispersion.	Remember
CO 2	Explain bi-variate data, correlation and regression analysis.	Understand
CO 3	Do testing of hypothesis for parameters.	Apply
CO 4	Learn to calculate the probability of an event.	Skill
CO 5	Decide appropriate sample survey design.	Analyze

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	2	1
CO2	1	3	2	1	2
CO3	2	3	2	3	3
CO4	3	3	2	1	3
CO5	3	2	3	3	3

c. Syllabus

UNIT I: Definition and scope of Statistics, representation data. Measures of Central Tendency: Mean, Median, Mode; Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation. Skewness, and Kurtosis. (9H)

UNIT II: Bivariate data, Scatter diagram, Karl-Pearson Correlation Coefficient, Coefficient of Determination, Spearman's Rank Correlation. linear regression, Principle of least squares. (9H)

UNIT III: Testing of Hypothesis, Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region, Power of the Test, z-test, t-test, F-test, Chi-square test for independence of attributes and Goodness-of-Fit. (9H)

UNIT IV: Probability: Definitions, random experiments, sample space, events. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications (9H)

UNIT V: Complete enumeration versus sampling, Sampling and Non-Sampling errors. Types Of Sampling: Non-Probability and Probability Sampling, Simple Random Sampling with and without replacement. (9H)

References:

1. S. C. Gupta, Fundamentals of Statistics, 7th Edition, Himalaya Publishing House, 2018.
2. R. V. Hogg, A. Craig and J. W. McKean, 6th Edition, Introduction to Mathematical Statistics, 2006.
3. A. M. Gun, M. K. Gupta and B. Dasgupta, Fundamentals of Statistics (Vol-I and II), World Press, 2016.
4. Gupta, S. C., and Kapoor, V. K. (2020). Fundamentals of mathematical statistics. Sultan Chand and Sons.
5. Kelley, T. L. (1947). Fundamentals of statistics (No. 2). Harvard University Press.
6. <https://online.stat.psu.edu/statprogram/reviews/statistical-concepts>
7. S. C. Gupta, Fundamentals of Statistics, 7th Edition, Himalaya Publishing House, 2018.
8. R. V. Hogg, A. Craig and J. W. McKean, 6th Edition, Introduction to Mathematical Statistics, 2006.
9. A. M. Gun, M. K. Gupta and B. Dasgupta, Fundamentals of Statistics (Vol-I and II), World Press, 2016.
10. Gupta, S. C., and Kapoor, V. K. (2020). Fundamentals of mathematical statistics, Sultan Chand and Sons.
11. Kelley, T. L. (1947). Fundamentals of statistics (No. 2). Harvard University Press.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Gain confidence in the applying mathematical methods that are essential for solving practical problems in various fields such as the physical, chemical, biological, etc.	Understand
CO 2	Use Green functions and other special functions.	Apply
CO 3	Interpret the solution of a differential equation using the Laplace and Fourier transform methods.	Skill
CO 4	Recall various concepts in group theory and linear algebra.	Remember
CO 5	Understand some basic models for population dynamics and evolutionary genetics.	Analyze

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	2	3
CO2	1	1	2	1	1
CO3	2	2	2	3	2
CO4	3	1	1	1	1
CO5	3	3	3	2	2

c. Syllabus

UNIT I: Ordinary and Partial Differential Equations-General features of Ordinary Differential Equations (ODEs) and Partial Differential Equations (PDEs), Classification of ODE and PDEs, Initial and boundary value ODEs and PDEs, Higher-order equations and systems, Homogeneous and Nonhomogeneous linear systems, Linear differential equations with constant and periodic coefficients, Series solution of ODEs, Separation of variables and other methods for PDEs.

(9H)

UNIT II: Fourier Series and Integral Transforms-The Fourier coefficients, Discrete Fourier series, Generalized Fourier series, Complex Fourier series, The Hamilton-Jacobi theory, Fourier integral, Fourier and Laplace transform, Initial value problems with discontinuous and impulsive forcing functions, Solution of differential equation by Laplace and Fourier transform methods.

(9H)

UNIT III: Special Functions and Numerical Methods-Legendre functions, Bessel functions, Hankel functions, Hermite functions, The Gamma function and related functions, Green's functions, Eigen value problems, Eigen function expansions, Phase plane interpretations, Sturm-Liouville theory, Roots of non-linear equations, Roots of a system of non-linear equations, Numerical differentiation and integration, Numerical solution of differential equations.

(9H)

UNIT IV: Group Theory and Linear Algebra Concepts - Representation of Groups, Symmetry and physics, Discrete groups, Direct products, Symmetric groups, Continuous groups, Lorentz groups, Space groups, Lorentz covariance of Maxwell's equations, Vector spaces, Subspaces, Row and column spaces, Null spaces, Spanning sets, Basis and dimensions, Linear independence and dependence, Determinants, Matrices, Orthogonality, Normalization, Eigen values and Eigen vectors, Diagonalization.

(9H)

UNIT V: Basic models in population dynamics - exponential growth model, logistic growth model; Predator-prey models, Simple epidemic models (SI, SIR, SEIR), Basic model for the dynamics of nerve membranes, Tumor cell growth model with spatial heterogeneity, Canonical transformations, Symmetric approach to canonical transformations, Symmetry groups of mechanical systems, Basic concepts of population genetics - Genetic material, Alle frequency distribution, Mendel's experiment, Hardy-Weinberg equilibrium.

(9H)

References:

1. Hoffman, J. D. (2001). Numerical Methods for Engineers and Scientists, 2nd Edition, CRC Press (Taylor and Francis Group).
2. Jordan, D. W., and Smith, P. (2008). Mathematical Techniques: An Introduction for the Engineering, Physical, and Mathematical Sciences, 4th Edition, Oxford University Press.
3. Arfken, G. B., and Weber, H. J. (2005). Weber Mathematical Methods for Physicists, Academic Press, Elsevier.
4. Perko, L. (1991). Differential Equations and Dynamical Systems (Texts in Applied Mathematics), 3rd Edition, New York Berlin Heidelberg Springer-Verlag.
5. Sharma, R. D., and Jain, R. (2019). Theory and Problems of Linear Algebra. Dreamtech Press.
6. Ramadevi, P., and Dubey, V. (2019). Group Theory for Physicists: With Applications. Cambridge University Press.
7. Logan, J. D., and Wolesensky, W. (2009). Mathematical Methods in Biology, 1st Edition, John Wiley and Sons Inc.
8. Murray, J. D. (2003). Mathematical Biology II: Spatial Models and Biomedical Applications, (Interdisciplinary Applied Mathematics), 3rd Edition, Springer-Verlag Berlin Heidelberg, New York.
9. Arnold, A. I. (1997). Mathematical Methods of Classical Mechanics: 60 (Graduate Texts in Mathematics), 2nd Edition, Springer-Verlag New York Inc., New York.
10. Burger, R. (2011). Some Mathematical Models in Evolutionary Genetics. In: Chalub, F., Rodrigues, J. (eds) The Mathematics of Darwin's Legacy. Mathematics and Biosciences in Interaction. Springer, Basel.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Know about missing data handling and MLE.	Remember
CO 2	Get knowledge on Bayesian Estimation.	Understand
CO 3	Perform Outlier Detections.	Apply
CO 4	Analyze Feature selection Algorithms.	Analyze
CO 5	Examine PCA, Canonical Correlation and Factor Analysis.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	2	3	2	3	1
CO2	3	2	3	2	3
CO3	2	3	1	2	2
CO4	1	2	3	3	2
CO5	3	1	2	3	3

c. Syllabus

UNIT I: Introduction To Exploratory Data Analysis: Data Analytics lifecycle, Exploratory Data Analysis (EDA)– Definition, Motivation, Steps in data exploration, The basic data types Data Type Portability, Preprocessing-Traditional Methods and Maximum Likelihood Estimation 4 hours Introduction to Missing data, Traditional methods for dealing with missing data, Maximum Likelihood Estimation – Basics, Missing data handling, Improving the accuracy of analysis.

(9H)

UNIT II: Preprocessing Bayesian Estimation - Introduction to Bayesian Estimation, Multiple Imputation-Imputation Phase, Analysis and Pooling Phase, Practical Issues in Multiple Imputation, Models for Missing Notation Random Data Summarization and Visualization - Statistical data elaboration, 1-D Statistical data analysis, 2-D Statistical data Analysis, N- D Statistical data analysis.

(9H)

UNIT III: Outlier Analysis Introduction, Extreme Value Analysis, Clustering based, Distance Based and Density Based outlier analysis, Outlier Detection in Categorical Data- Feature Subset Selection.

(9H)

UNIT IV: Feature selection algorithms: filter methods, wrapper methods and embedded methods, Forward selection backward elimination, Relief, greedy selection, genetic algorithms for features selection.

(9H)

UNIT V: Dimensionality Reduction - Introduction, Principal Component Analysis(PCA), Kernel PCA, Canonical Correlation Analysis, Factor Analysis, Multi-dimensional scaling, Correspondence Analysis.

(9H)

References

1. Aggarwal, C. C. (2015). Data mining: the textbook (Vol. 1). New York: springer.
2. Koch, I. (2013). Analysis of multivariate and high-dimensional data (Vol. 32). Cambridge University Press.
3. Michael Jambu. (2014). Exploratory and multivariate data analysis. Academic Press Inc. 1990. Cambridge University Press.
4. Charu Aggarwal, C. (2015). Data Classification Algorithms and Applications. CRC press.

Value Added Courses (To be offered in Semester II)

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Recall syntax of data statement and proc statements in SAS	Remember
CO 2	Create and manipulate data sets in SAS	Understand
CO 3	Use Control structures in SAS programs	Apply
CO 4	Investigate SAS data libraries	Analyze
CO 5	Generate reports and handle errors	Skill

B. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	3	3
CO2	2	3	1	3	3
CO3	2	2	1	3	3
CO4	2	2	1	3	3
CO5	1	2	3	3	3

c. Syllabus

UNIT I: Introduction to SAS - Common structure of SAS – Getting familiar with interface with Base SAS System - Accessing Data - read data file- FORMATTED, LIST, and COLUMN, INFILE statement -control processing, column and line pointer controls, and trailing @ controls, Combine SAS data sets using the DATA step. **(12H)**

UNIT II: Data Structures, temporary and permanent SAS data sets, Create and manipulate SAS data values, DATA Step statements - export data, Control specific observations and variables for processing output. **(12H)**

UNIT III: PROC step - Investigate SAS data libraries using base SAS utility procedures - Sort observations in a SAS data set - Conditionally execute SAS statements - Use assignment statements in the DATA step - Modify variable attributes using options and statements in the DATA step. **(12H)**

UNIT IV: Modify variable attributes -options and statements in the DATA step - Accumulate subtotals and totals - DATA step statements, manipulate character data, numeric data, and SAS data values, convert character data to numeric and vice versa, Construct Structure- DO LOOPS, SAS arrays. **(12H)**

UNIT V: Generating Reports: Generate list reports using the PRINT and REPORT procedures, Generate summary reports and frequency tables using base SAS procedures; Enhance reports through the use of labels, SAS formats, user-defined **(12H)**

formats, titles, footnotes, and SAS System reporting options, HTML reports - ODS statement; Error handling.

References:

1. Delwiche, L. D., and Slaughter, S. J. (2019). The little SAS book: a primer. SAS institute.
2. Cody, Ronald P. and Jeffrey K. Smith (2006). Applied Statistics and the SAS Programming Language, Fifth Edition, Upper Saddle River, NJ: Pearson Prentice Hall.
3. SAS. Institute. (2018). SAS Certification Prep Guide: Base Programming for SAS9. SAS Institute.
4. Cody, R. (2021). Getting Started with SAS Programming: Using SAS Studio in the Cloud. United Kingdom: SAS Institute.
5. Messineo, M. (2017). Practical and Efficient SAS Programming: The Insider's Guide. United States: SAS Institute.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand need of this analysis tool.	Remember
CO 2	Handle data and do proper management, and filter.	Understand
CO 3	Represent data by different graphical techniques using Excel	Apply
CO 4	Do descriptive data analysis using MS Excel.	Apply
CO 5	Test a hypothesis for parameters using MS Excel.	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	1	3	2
CO2	3	3	2	1	2
CO3	2	3	2	3	3
CO4	3	3	2	1	3
CO5	2	2	3	2	3

c. Syllabus

UNIT I: Introduction to MSEXCEL. Cell formatting, conditional formatting, Data manipulation using EXCEL: sort and filter, find and replace, text to columns, remove duplicate, data validation, consolidate, what-if-analysis. Create and format worksheet and workbook- data format and validation – advanced conditional formatting and filtering.

(12H)

UNIT II: Working with Multiple Worksheets and Workbooks. Create and manage tables – filter and sort a table, remove duplicate records – create and modify pivot table. Recording Macros - Running Macros – Deleting Macros.

(12H)

UNIT III: Summarize data by using functions, conditional operations by using functions, format and modify text by using functions. Creating different types of charts, Formatting chart objects, Changing the chart type, showing and hiding the legend, showing and hiding the data table.

UNIT IV: Rand and rand between function, Logical functions: if, and, or, not. Lookup functions: h lookup, v lookup, Formula Errors Descriptive analysis using Excel- Measures of central tendency, Measures of dispersion, correlation coefficients, Calculation of partial correlation matrix, Regression lines.

(12H)

UNIT V: Normal distribution in Excel, Sample t-Test, Two sample t-Test, computing PMF/PDF, CDF and quantiles of the well-known distributions. **(12H)**

References:

1. Held, B., Moriarty, B., and Richardson, T. (2019). Microsoft Excel Functions and Formulas. Stylus Publishing, LLC.
2. Alexander, M., and Kusleika, R. (2016). Excel 2016 Formulas. John Wiley and Sons.
3. Salkind, N. J. (2015). Excel statistics: A quick guide. Sage Publications.
4. Schmuller, J. (2013). Statistical analysis with Excel for dummies. John Wiley and sons.
5. Kennedy, W. J., and Gentle, J. E. (2021). Statistical computing. Routledge.

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Have knowledge on CSO and NSSO.	Remember
CO 2	Know different method of collection of official statistics.	Understand
CO 3	Analyze the impact of Agricultural and Industrial statistics.	Apply
CO 4	Study about Index numbers.	Analyze
CO 5	Examine the financial Statistics	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PS01	PS02	PS03	PS04	PS05
CO1	3	2	3	2	3
CO2	2	3	3	2	2
CO3	2	2	2	3	2
CO4	3	3	2	1	2
CO5	3	3	3	2	3

C. SYLLABUS

UNIT I: Statistical System in India: Central and State Government Organizations, Functions of Central Statistical Organization (CSO), National Sample Survey Organization (NSSO) - Sampling fundamentals – sampling and non-sampling errors - large scale sample surveys. (7H)

UNIT II: Official statistics: Meaning, methods of collection, limitations and reliability. Principal publications containing data on the topics such as population, agriculture, industry, trade, prices, labour and employment, transport and communications - Banking and finance. (7H)

UNIT III: System of Collection of Agricultural Statistics - Crop forecasting and estimation - Productivity, fragmentation of holdings - Support prices - Buffer stocks - Impact of irrigation projects – Industrial statistics. (5H)

UNIT IV: Index Numbers - Price, Quantity and Value indices. Price Index Numbers: Construction, Uses, Limitations, Tests for index numbers - Consumer Price Index, Wholesale Price Index and Index of Industrial Production – Construction of index numbers and uses. (6H)

UNIT V: National Income – Measures of national income - Income, expenditure and production approaches – Applications in various sectors in India - Wage Statistics – Trade Statistics – Financial Statistics. (5H)

References:

- 1) Saluja, M.R (1972): Indian official statistical systems: Statistical publishing society, Calcutta and The Indian Econometric Society, Hyderabad.
- 2) Central Statistical Organisation (1995), Statistical System in India, Ministry of Statistics and Programme Implementation, India
- 3) Central Statistical Organisation (1999), Guide to Official Statistics, Ministry of Statistics and Programme Implementation, India.
- 4) Goon A. M., Gupta M. K., and Dasgupta. B. (2001), Fundamentals of Statistics, Vol. 2, World Press, India.
- 5) Bhaduri, A. (1990). Macroeconomics: The Dynamics of Commodity Production, Macmillan India Limited, New Delhi.
- 6) <https://mospi.gov.in/142-present-indian-statistical-system-organisation>

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

	Course Outcome	Level
CO 1	Understand SPSS software data entry, import, recode, group data	Remember
CO 2	Perform Exploratory data analysis	Understand
CO 3	Use statistical tools for parametric and non-parametric analysis	Analyze
CO 4	Explain General linear model and multiple regression analysis	Apply
CO 5	Work on some Multivariate techniques, Classification and forecasting	Skill

b. Mapping of Program Specific Outcomes with Course Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	1	1
CO2	2	3	2	1	2
CO3	2	3	2	3	3
CO4	2	3	2	1	3
CO5	1	2	3	1	3

C. SYLLABUS

UNIT I: SPSS: Data editor, output viewer, syntax editor, Data view window, SPSS Syntax, Data creation, importing data, Variable types and defining variables, creating a codebook in SPSS, Computing variables, Recoding, Sorting, Grouping and splitting data, Insert variable and cases, merge variable and cases.

(12H)

UNIT II: Exploratory Data Analysis: Interval scale data, options with missing values, Descriptive statistics, Diagrammatic representation- Simple bar diagram, Multiple bar diagram, Pie diagram, Frequency tables and Histogram, scatter plot and Box plot, Correlation.

(12H)

UNIT III: Testing of hypothesis: Parametric- one sample, two sample, comparing means, Non parametric: Mann- Whitney U test, Wilcoxon signed rank test, Kruskal Wallis test, Friedman test, Chi-square test, Analysis of Variance: one way and Two way ANOVA.

(12H)

UNIT IV: General Linear Model, Repeated Measures, residuals and outliers, Simple linear regression, Multiple linear regression, variables selection, stepwise multiple linear regression

(12H)

UNIT V: Factor analysis, Principal Component analysis, Classification, Clustering, Discriminant analysis, Forecasting, Structural equation modeling.

(12H)

References:

1. Huizingh, E. (2007). Applied Statistics with SPSS, SAGE.
2. Carver, R.H. and Nash, J. G. (2011). Doing Data Analysis with SPSS, Cengage.
3. Gray, C. D., Kinnear, P. R. (2011). IBM SPSS Statistics 19 Made Simple, Taylor and Francis.
4. Burns, R. and Burns, R. P., (2008). Business Research Methods and Statistics using SPSS, SAGE.
5. Jeremy J. Foster. (2000). Data analysis using SPSS for windows, SAGE.