

UNIVERSITY OF DELHI

CNC-II/093/1/EC-1273/25/

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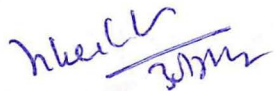
NOTIFICATION

Sub: Amendment to Ordinance V

(ECR 38-14, 38-15 and 38-16/ dated 17.01.2025)

Following addition made to Appendix-II-A to the Ordinance V (2-A) of the Ordinances of the University regarding the Syllabi of the following Programmes for Semester-VII and Semester-VIII under the Faculty of Mathematical Sciences based on Undergraduate Curriculum Framework 2022, are notified herewith for the information of all concerned:

1. BSc. (Hons.) Statistics for Sem-VII and Sem-VIII – As per **Annexure-1**
2. BSc. (Hons.) Mathematics for Sem-VII and Sem-VIII – As per **Annexure-2**
3. BSc. (Hons.) Computer Science for Sem-VII and Sem-VIII – As per **Annexure-3**


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Department of Statistics

B.Sc.(H), Statistics Semester-VII

Category I

DISCIPLINE-SPECIFIC CORE COURSE – 19: MULTIVARIATE ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Analysis	4	3	0	1	-	Knowledge of Probability Distributions and Statistical Inference.

Learning Objectives

The learning objectives include:

- To study Bivariate Normal Distribution along with their properties.
- To study Multivariate Normal Distribution with their properties along with its applications analysis.
- Concepts of Multiple and partial correlation coefficients along with their interpretation.
- Analysis of multivariate data using discriminant analysis, principal component analysis, factor analysis and cluster analysis.

Learning Outcomes:

After completing this course, students should be able to:

- Understand the basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- Understand the Multiple and partial correlation coefficients.
- Analyze the multivariate data using dimension reduction techniques like principal component analysis, factor analysis and cluster analysis.
- Apply the classificatory method namely discriminant analysis.

SYLLABUS OF DSC-19

Theory

UNIT 1

Bivariate Normal Distribution

(15 hours)

Probability density function of Bivariate Normal Distribution (BVN). Moment generating function, marginal distribution, conditional distribution of BVN and properties of BVN. Introduction of random vector, probability mass function, probability density functions of random vector, distribution function, mean vector, dispersion matrix, marginal distributions and conditional distributions of random vector.

UNIT 2**Multivariate Normal Distribution****(15 hours)**

Probability density function of Multivariate Normal distribution (MVN). Moment generating function, marginal and conditional distribution of MVN. Properties of MVN. Sampling distribution of sample mean vector and sample variance-covariance matrix. Regression planes. Multiple and partial correlation coefficients with their properties and interpretations.

UNIT 3**Multivariate Data Analysis****(15 hours)**

Dimension reduction techniques: Eigenvalues and Eigenvectors Principal component analysis and its applications, factor analysis and its applications, cluster analysis and its applications. Classification technique: Discriminant analysis and its applications.

PRACTICAL/LAB WORK: (30 HOURS)**List of Practical:**

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression plane.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant Analysis.
10. Factor Analysis.
11. Cluster Analysis

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anderson, T.W. (2009). An Introduction to Multivariate Statistical Analysis, 3rd Ed., John Wiley & Sons.
- Johnson, R.A. and Wichern, D.W. (2015). Applied Multivariate Analysis, 6th Ed., Prentice Hall. (** Note publication Pearson Education India)
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2016). An Outline of Statistical Theory, Volume II, World Press.
- Applied multivariate data analysis, second edition, Brian.S.Everett and Graham Dunn, Oxford University Press, 2001

SUGGESTED READINGS:

- S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons, 2020.
- Kshirsagar, A.M. (1972). Multivariate Analysis, 1st Ed., Marcel Dekker.
- Muirhead, R.J. (2005). Aspects of Multivariate Statistical Theory, John Wiley. (**reprint)
- Arora, S. and Bansal, L. (1968). New Mathematical Statistics, 1st Ed., Vanita Printers.
- Rao, C. R. (2009). Linear Statistical Inference, Second Edition, John Wiley & Sons.
- Approaching multivariate analysis -A practical introduction, second edition, Pat Dugard, John Todman and Harry Staines, Routledge, 2010.
- An R and S-plus companion to multivariate analysis, Brian Everitt, Springer texts in Statistics, Springer, 2010. (**reprint in 2010)

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course for B.Sc. (H) Statistics
Semester-VII

DISCIPLINE SPECIFIC CORE COURSE – 5A: FINANCIAL STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Financial Statistics	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Stochastic processes, Calculus and Probability theory and Financial markets

Learning Objectives

The learning objectives include:

- To study the Financial Statistics which deals primary and secondary financial markets and the mathematical models used by these markets?
- To study the Stochastic Calculus, this is the study of infinitesimal changes in stochastic processes and the methods of dealing with such changes over time.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Primary financial markets and their products such as equity, bonds and cash deposits
- Secondary financial markets and their products such as futures, forwards and options (American and European)
- Stochastic calculus- Stochastic differentiation and integration
- Stochastic differential equations and methods of solving them
- Applications of stochastic differential equations in formulating models to price various secondary financial markets products.
- Hedging techniques

SYLLABUS OF DSE- 5a**Theory****UNIT I (15 hours)**

Introduction to investment and markets, Cash flows. Net present value, Future value, Internal rate of return, criteria for project appraisal, Basic theory of interest, different interest rates and their relationships, discount rates, bonds-pricing and yields, yield curves, spot rates, spot rate curves, Zero- coupon bonds, perpetual bonds and discount bonds, Introduction to derivatives, Tools Needed for Option Pricing: Forward contracts, spot price, forward price, future price, Call and put options, binary one period model, Pricing derivatives: Arbitrage relations and perfect financial markets, Pricing futures, Put call parity for European and American options, Relationship between strike price and option price.

UNIT II (15 hours)

Discrete Stochastic Processes- Binomial processes, General random walks, Geometric random walks, Binomial models, Trinomial models. Continuous time processes – Brownian motion, Geometric Brownian motion, Wiener process; Introduction to stochastic calculus: stochastic integration, stochastic differential equations and their solutions; Itô's lemma. Black-Scholes differential equation

UNIT III (15 hours)

Intrinsic of option markets: Black-Scholes formula for European options, Implied volatility, Binomial Model for European options, Hedging portfolios: Delta, Gamma and Theta hedging. Cox-Ross-Rubinstein approach to option pricing. Discrete dividends, Trinomial model for American options, pricing American options, put call parity for American options, relationship between American and European options.

PRACTICAL/LAB WORK – (30 hours)**List of Practical:**

1. Relationship between various interest rates
2. Present value and future value
3. Relationship between interest rates and discount rates
4. To compute NPV and to obtain IRR of the investments.
5. To compute bond price and yields
6. Determination of spot rate curve
7. To verify "no arbitrage" principle.
8. To price future / forward contracts
9. Simulation of continuous time stochastic processes
10. To price options using Black – Scholes formula.
11. Pricing of options using discrete time models.
12. Impact of dividend on option prices.
13. Call-put parity for European options.
14. Application of Greeks to hedge investment portfolios.
15. Pricing of American options
16. Put call parity for American options.

ESSENTIAL READINGS:

- David, G.L. (2015). Investment Science, Oxford University Press (South Asian edition)
- Franke, J., Hardle, W.K. and Hafner, C.M. (2011). Statistics of Financial Markets: An Introduction, 3rd Ed., Springer Publications
- John C. Hull and Sankarshan Basu (2022) Options, Future and other derivatives, 11th edition, Pearson Indian edition.

SUGGESTIVE READINGS:

- Ovidiu Calin (2022): An informal introduction to stochastic calculus and its applications, second edition World Scientific
- Baxter, M., Rennie, A., & Rennie, A.J. (1996). Financial calculus: An introduction to derivative pricing. Cambridge university press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5B: ADVANCED DESIGN OF EXPERIMENTS
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Design of Experiments	4	3	0	1	Class XII pass with Mathematics	Basic Knowledge of Design of Experiments

Learning Objectives

The learning objectives include:

- To design and conduct experiments.
- To analyse and interpret data.
- To construct designs.
- To apply experimental design techniques in real world problems.

Learning Outcomes:

After completing this course, students should be able to:

- Apply of ANOVA technique for two – way classification, fixed effect models with unequal number of observations per cell, Random effect models with one observation per cell and the concept of Mixed effects models.
- Design and analysis of incomplete block designs, understand the concepts of orthogonality, connectedness and balancing.
- Understand the concepts of finite fields and finite geometries and apply them in constructing MOLS, balanced incomplete block designs.
- Apply techniques of Response surface methodology and appreciate the concepts of orthogonality, rotatability and blocking.

- Understand the concept of mixture experiments that are useful in our daily life, food industry, chemical industry, pharmaceutical companies.
- Understand and apply Crossover designs in practical situations.

SYLLABUS OF DSE - 5b

Theory

UNIT I (6 hours)

Analysis of Variance

Fixed effect models (2-way classification with unequal number of observations per cell), Random effect models (2-way classification with one observation per cell) and the concept of Mixed effect models.

UNIT II (12 hours)

Incomplete Block Designs

Concepts of Connectedness, Orthogonality and Balance. Intra block analysis of General Incomplete Block design. B.I.B designs with and without recovery of inter block information.

UNIT III (13 hours)

Finite fields

Finite Geometries- Projective geometry and Euclidean geometry. Construction of complete set of mutually orthogonal Latin squares. Construction of B.I.B.D. using finite Abelian groups, MOLs, finite geometry and method of differences.

UNIT IV (14 hours)

Some Useful Designs

Response surface designs for first and second order models, concepts of orthogonality, rotatability and blocking. Mixture Experiments—models and designs, Cross-over designs

PRACTICAL/LAB. WORK (30 HOURS)

List of Practical:

1. Based on ANOVA for 2-way classification with unequal number of observations per cell under fixed effects model
2. Based on ANOVA 2-way classification with one observation per cell under random effects model
3. Based on ANOVA 2-way classification with one observation per cell under mixed effects model
4. Based on Intra block analysis of an IBD
5. Based on analysis of a BIBD with and without inter block analysis.
6. Based on response designs for first and second-order models.
7. Based on mixture designs,
8. Based on Cross-over designs.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). An Outline of Statistical Theory, Vol 2, The world Press Private Limited.
- Das, M.N. and Giri, N.C. (2024). Design and Analysis of Experiments, Wiley Eastern Limited.
- Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
- Hinkel mann, K. and Kempthorne, O. (2022). Design and Analysis of Experiments, Vol. 2: Advanced Experimental Design, 9th edition, John Wiley & Sons.
- Bose, M. and Dey, A. (2009). Optimal Crossover Designs, World Scientific.

- Cornell, John A. (2002). Experiments with Mixtures, John Wiley & Sons.
- Myers, R. H. and Montgomery, D. C. (2016). Response Surface Methodology: Process and Product Optimization using Designed Experiments, 4th edition John Wiley & Sons.

SUGGESTED READINGS

- Chakrabarti, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
- Dean, A. and Voss, D. (2017). Design and Analysis of Experiments, Springer 2nd edition. First Indian Reprint 2006.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan Co., New York.
- Kshirsagar, A.M. (1983). A Course in Linear Models, Marcel Dekker, Inc., N.Y.
- Montgomery, D. C. (2005). Design and Analysis of Experiments, 6th ed., John Wiley & Sons.
- Raghavarao, D. and Padgett, L. V. (2005). Block Designs: Analysis, Combinatorics, and Applications, World Scientific.
- Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.
- Wu, C. F. J. and Hamada, M. (2011). Experiments: Planning, Analysis and Parameter Design Optimization, John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE –5C : ADVANCED THEORY OF BIOSTATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced theory of Biostatistics	4	3	0	1	Studied Biostatistics	Basic knowledge of survival analysis and survival models

Learning objectives:

The learning objectives include:

- Comparison of Survival in two groups
- Epidemiological Study and epidemic models.
- Independent and dependent risks in Competing risk theory.
- Concept of Relative Risk, Odds Ratio and Attributable Risk.
- Concept of Clinical trials.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Different methods for comparing survival rates of two groups of patients.
- Concept of Prospective, Retrospective and cross-sectional studies. Different epidemic models.
- Distinction between Relative Risk, Odds Ratio and Attributable Risk and their confidence interval.

SYLLABUS OF DSE-5c

Theory

UNIT I

(11 hours)

Comparison of Survival in two groups:

Log-rank test, Gehan's generalized Wilcoxon test, Cox-Mantel test, Mantel-Haenszel Test, Comparison of two exponential survival distributions: Likelihood ratio test, Cox's F-test, Concept of covariates and proportional hazard, Cox's proportional hazard model.

UNIT II

(12 hours)

Epidemiological Study:

Prospective study, Retrospective study, cross-sectional study and their comparison. Sensitivity, specificity and predictivity of medical tests. Likelihood ratio of a positive and negative test result. Epidemic Model: Concept of epidemic and epidemic models, Simple Stochastic Epidemic model (including derivations), Duration of an epidemic. General epidemic model & Carrier-borne epidemic model (concept and definition only)

UNIT III

(16 hours)

Competing Risk Theory:

Concept of Competing risk theory with independent and dependent risks. Bivariate Normal dependent risk model and its derivations. Concept of risk, hazard and odds, definition of relative risk (RR), relative risks in independent sample, attributable risk in independent samples, definition of odds ratio (OR), odds ratio in two independent samples, confidence interval and test of hypothesis for relative risk and odds ratio (independent samples)

UNIT IV

(6 hours)

Clinical Trials:

Planning and designing clinical trials, Phase-I, Phase-II and Phase-III clinical trials. Single, double and triple blinding.

PRACTICAL/LAB WORK (30 HOURS)

List of Practicals:

1. Comparison of survival of two groups using Log-rank test.
2. Comparison of survival of two groups using Gehan's generalized Wilcoxon test.
3. Comparison of survival of two groups using Cox-Mantel test.
4. Comparison of survival of two groups using Mantel-Haenszel test.
5. Comparison of survival of two groups using Likelihood ratio test.
6. Comparison of survival of two groups using Cox's F-test.
7. Computation of Sensitivity and specificity of a medical test.
8. Computation of likelihood ratio of a medical test.
9. Computation of positive and negative predictivities and hence predictive validity of a medical test.
10. Calculation of relative risk and its confidence interval.
11. Calculation of odds ratio and its confidence interval.
12. Calculation of attributable risk and its confidence interval.
13. Calculation of probability of r susceptible getting infected by time t.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2nd Ed., New Central Book Agency.
- Lee, E.T. and Wang, J.W. (2013): Statistical Methods for Survival data Analysis, 4th Ed., John Wiley & Sons.
- Indrayan, A. (2017): Medical Biostatistics, 4th Ed., Chapman and Hall/CRC.

SUGGESTED READINGS:

- Miller, R.G. (2011): Survival Analysis. John Wiley & Sons.
- Elandt-Johnson R.C (1971): Probability model and Statistical Methods in Medical Biostatistics, 2nd Ed., Chapman and Hall/CRC. Genetics, John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should be able to understand:

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d**Theory****UNIT I (15 hours)****Introduction to Research:**

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II (15 hours)**Methods & Techniques of Data Collection:**

Survey methodology and Data collection, Source of data collection- Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III (15 hours)**Data Processing & Analysis:**

Data processing, Exploratory data analysis, Various techniques - Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques for data analysis covered in core statistics papers, Techniques of interpretation, Precautions in interpretation.

Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

Computer Application: Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing.

PRACTICAL/LAB WORK – (30 hours)

PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2021): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2019): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Poole, M. (2001): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2021): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2013): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics

SUGGESTIVE READINGS

- Pannerselvan, R. (2018): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2011): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2013): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2010): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (2016): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (2003): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, time to time.

Category II

B.A.(Prog) with Statistics as Non-Major/Major Semester-VII

DISCIPLINE SPECIFIC CORE COURSE-7: STOCHASTIC PROCESSES AND QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Processes and Queueing Theory	4	3	0	1		Basic knowledge of Probability theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To understand the concept of stochastic process and markov chain.
- To analyze the queueing models with applications;
- To identify the real life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Stability of Markov chains.
- Poisson process and its variations.
- Queuing systems.
- Random walk and ruin theory.

SYLLABUS OF DSC-7

Theory

UNIT I

Probability Generating Function (12 Hours)

Probability Distributions: Generating functions, Bivariate probability generating functions.

Stochastic Process: Introduction, Stationary Process.

UNIT II

Markov Chain

(18 Hours)

Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Classification of states and chains, stability of Markov system. Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

UNIT III

Poisson Process and Queuing theory

(15 Hours)

Postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process. Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

PRACTICAL/ LAB WORK – (30 hours)

List of Practical:

1. Problems based on probability generating function to compute exact and approximate probabilities using partial fraction theorem.
2. Problems based on (covariance) stationary processes.
3. Markov Chains:
 - a) Simulation of Markov chains and Calculation of transition probability matrices.
 - b) Stability of Markov chains.
 - c) To check whether the given chain is irreducible or not.
4. Simulation and applications of Poisson processes.
5. Calculation of probabilities for given birth and death processes.
6. Calculation of probabilities for ruin problems.
7. Problems based on (M/M/1) queuing models.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Reading:

- Medhi, J. (2022). Stochastic Processes, 6th edition, New Age International Publishers.
- Gross, Donald and Harris, Carl M (2017) Fundamentals of Queueing Theory, 5th Edition, Wiley International.
- Feller, W. (2008). Introduction to probability Theory and Its Applications, Vol. 3rd Ed., Wiley International.

Suggested Readings:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat, B.R.(2021). Stochastic Models: Analysis and Applications, 2nd edition New Age International Publishers.
- Taha, H. (2019). Operations Research: An Introduction, 10th edition Prentice-Hall India.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course**Discipline Specific Elective Course for B.A.(Prog) Semester-VII****DISCIPLINE SPECIFIC ELECTIVE COURSE – 5A: LINEAR PROGRAMMING TECHNIQUES****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming Techniques	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include:

- Concept of mathematical formulation to a real-life problem through Linear Programming.
- This course develops the ideas underlying the Simplex Method for Linear Programming Problem.
- The course covers Linear Programming with applications to Transportation and Assignment problem. Such problems arise in manufacturing, resource planning and financial sectors.

Learning Outcomes:

After completing this course, students should be able to:

- Learn about the graphical solution of linear programming problem with two variables.
- Learn about the relation between basic feasible solutions and extreme points.
- Understand the theory of the simplex method used to solve linear programming problems.
- Learn about two-phase and Big-M methods to deal with problems involving artificial variables
- Solve transportation and assignment problems.

SYLLABUS OF DSE – 5a**Theory****Unit I:****(14 Hours)****Introduction to Linear Programming:**

Linear programming problem: Standard, Canonical and matrix forms, Formulation of Linear Programming Problem, Graphical solution; Basic solutions, Basic feasible solutions.

Unit II:**(16 Hours)****Methods of Solving Linear Programming Problem:**

Simplex method: Optimal solution, Termination criteria for optimal solution of the linear programming problem, Unique and alternate optimal solutions, Unboundedness; Artificial variables, Two-phase method, Big-M method.

Unit III:**(15 Hours)****Transportation and Assignment Problems:**

Transportation Problem: Definition and formulation; Methods of finding initial basic feasible solutions; Northwest-corner rule. Least-cost method; Vogel's approximation method; Algorithm for solving transportation problem. Assignment Problem: Mathematical formulation and Hungarian method of solving Assignment problem.

PRACTICAL/LAB WORK – (30 hours)**List of Practical:**

1. Graphical representation of Linear Programming Problem and its solution.
2. Graphical identification of basic solutions, basic feasible solution and optimal solution.
3. Solution of Linear Programming Problem by Simplex method.
4. Solution of Linear Programming Problem by Big-M method.
5. Solution of Transportation Problem as a Linear Programming Problem.
6. Solution of Assignment Problem as a Linear Programming Problem.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Reading:

- Hadley, G. (2002). Linear Programming. Narosa Publishing House. New Delhi.
- Taha, H.A. (2014). Operations Research. An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.

Suggested Readings:

- Hillier, Frederick S. & Lieberman, Gerald J. (2017). Introduction to Operations Research (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**DISCIPLINE SPECIFIC CORE COURSE-5B: INTRODUCTION TO
STATISTICAL LINEAR MODELS**

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	practical		
Introduction to Statistical Linear Models	4	3	0	1		Basic knowledge of Matrix theory and Probability distributions

Learning Objectives:

Learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allows the students to work effectively with them.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics.

SYLLABUS OF DSC-14

Theory

UNIT I

(12 Hours)

Introduction

Statistical Linear Models and their classification, Estimability of linear parametric functions, Gauss-Markov setup, Normal equations and Gauss-Markov theorem, full rank case and non-full rank case (without proof)

UNIT II

(8 Hours)

Distribution of quadratic forms

Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

UNIT III

(13 Hours)

Simple and Multiple linear regression: Estimation of parameters and testing of hypotheses, Confidence intervals, Bias in regression estimates Lack of fit and pure error, Residuals and their plot. Techniques for variable selection. Polynomial Regression models: Orthogonal Polynomials.

UNIT IV

(12 Hours)

Analysis of Variance:

Technique of analysis of variance (ANOVA) in one-way and two-way classifications with an equal number of observations per cell under fixed effect model.

PRACTICAL/LABWORK -30 Hours

List of Practical:

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Linear Regression
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Orthogonal Polynomials.
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

Suggestive Readings:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed, John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(2012): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**DISCIPLINE SPECIFIC ELECTIVE COURSE –5C: STATISTICAL METHODS IN
PSYCHOLOGY AND EDUCATION**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Methods in Psychology and Education	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics and probability distributions

Learning Objectives:

The learning objectives include:

- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

Learning Outcomes:

After successful completion of this course, students should be able to:

- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

SYLLABUS OF DSC-5c

Theory

Unit 1:

(15 Hours)

Importance of statistics in psychology and education.

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements. Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring. Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

Unit 2:

(15 Hours)

Reliability and Validity:

Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.

Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

Unit 3: (15 Hours)

Test Scores:

Meaning and differences between norm referencing and criterion referencing.

Raw score transformations- percentile scores, standard score, normalised standard scores, T-scores and Stanine scores.

Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

PRACTICAL LAB WORK (30 hours)

List of Practical:

1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anastasia, A. and Urbina, S. (2016) Psychological testing , Prentice Hall
- Garrett H.E.(2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ(2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2019) Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K.(2016) Statistics in Psychology and Education. PHI learning Pvt Ltd.

SUGGESTED READINGS:

- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2016) Fundamental of Statistics, Volume 2, World Press Pvt Ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should be able to understand:

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d**Theory****UNIT I****(15 hours)****Introduction to Research:**

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II**(15 hours)****Methods & Techniques of Data Collection:**

Survey methodology and Data collection, Source of data collection- Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III**(15 hours)****Data Processing & Analysis:**

Data processing, Exploratory data analysis, Various techniques- Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques for data analysis covered in core statistics papers, Techniques of interpretation, Precautions in interpretation.

Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

Computer Application: Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing.

PRACTICAL/LAB WORK– (30 hours)

PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2021): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2019): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Poole, M. (2001): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2021): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2013): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics

SUGGESTIVE READINGS

- Pannerselvan, R. (2018): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2011): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2013): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2010): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (2016): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (2003): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Category III

B.Sc. (Prog) Mathematical Sciences with Statistics Semester-VII

DISCIPLINE SPECIFIC CORE COURSE-7: STOCHASTIC PROCESSES AND QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Processes and Queueing Theory	4	3	0	1		Basic knowledge of Probability theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To understand the concept of stochastic process and markov chain.
- To analyze the queueing models with applications;
- To identify the real life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Stability of Markov chains.
- Poisson process and its variations.
- Queuing systems.
- Random walk and ruin theory.

SYLLABUS OF DSC-7

Theory

UNIT I

Probability Generating Function

(12 Hours)

Probability Distributions: Generating functions, Bivariate probability generating functions. Stochastic Process: Introduction, Stationary Process.

UNIT II

Markov Chain

(18 Hours)

Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Classification of states and chains, stability of Markov system. Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

UNIT III

Poisson Process and Queuing theory

(15 Hours)

Postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process. Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

PRACTICAL/ LAB WORK – (30 hours)

List of Practical:

1. Problems based on probability generating function to compute exact and approximate probabilities using partial fraction theorem.
2. Problems based on (covariance) stationary processes.
3. Markov Chains:
 - d) Simulation of Markov chains and Calculation of transition probability matrices.
 - e) Stability of Markov chains.
 - f) To check whether the given chain is irreducible or not.
4. Simulation and applications of Poisson processes.
5. Calculation of probabilities for given birth and death processes.
6. Calculation of probabilities for ruin problems.
7. Problems based on (M/M/1) queuing models.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Medhi, J. (2022). Stochastic Processes, 6th edition New Age International Publishers.
- Gross, Donald and Harris, Carl M (2017) Fundamentals of Queueing Theory, 5th Edition, Wiley International.
- Feller, W. (2008). Introduction to probability Theory and Its Applications, Vol,3rd Ed., Wiley International.

SUGGESTED READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat, B.R.(2021).Stochastic Models: Analysis and Applications, 2th Edition New Age International Publishers.
- Taha, H. (2019). Operations Research: An Introduction, 10th Edition Prentice-Hall India.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course**Discipline Specific Elective Course for B.Sc. (Prog) Mathematical Sciences**
Semester-VII**DISCIPLINE SPECIFIC ELECTIVE COURSE – 5A: LINEAR PROGRAMMING
TECHNIQUES****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming Techniques	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include:

- Concept of mathematical formulation to a real-life problem through Linear Programming.
- This course develops the ideas underlying the Simplex Method for Linear Programming Problem.
- The course covers Linear Programming with applications to Transportation and Assignment problem. Such problems arise in manufacturing, resource planning and financial sectors.

Learning Outcomes:

After completing this course, students will possess skills concerning:

- Learn about the graphical solution of linear programming problem with two variables.
- Learn about the relation between basic feasible solutions and extreme points.
- Understand the theory of the simplex method used to solve linear programming problems.
- Learn about two-phase and Big-M methods to deal with problems involving artificial variables
- Solve transportation and assignment problems.

SYLLABUS OF DSE – 5a**Theory****Unit I:****(14 Hours)****Introduction to Linear Programming:**

Linear programming problem: Standard, Canonical and matrix forms, Formulation of Linea

Programming Problem, Graphical solution; Basic solutions, Basic feasible solutions.

Unit II: (16 Hours)

Methods of Solving Linear Programming Problem:

Simplex method: Optimal solution, Termination criteria for optimal solution of the linear programming problem, Unique and alternate optimal solutions, Unboundedness; Artificial variables, Two-phase method, Big-M method.

Unit III: (15 Hours)

Transportation and Assignment Problems:

Transportation Problem: Definition and formulation; Methods of finding initial basic feasible solutions; Northwest-corner rule. Least- cost method; Vogel's approximation method; Algorithm for solving transportation problem.

Assignment Problem: Mathematical formulation and Hungarian method of solving Assignment problem.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Graphical representation of Linear Programming Problem and its solution.
2. Graphical identification of basic solutions, basic feasible solution and optimal solution.
3. Solution of Linear Programming Problem by Simplex method.
4. Solution of Linear Programming Problem by Big-M method.
5. Solution of Transportation Problem as a Linear Programming Problem.
6. Solution of Assignment Problem as a Linear Programming Problem.
- 7.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Reading:

- Hadley, G. (2002). Linear Programming. Narosa Publishing House, New Delhi.
- Taha, H.A. (2014). Operations Research, An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.

Suggested Readings:

- Hillier, Frederick S. & Lieberman, Gerald J. (2017). Introduction to Operations Research (10th ed.). Mc Graw-Hill Education (India) Pvt. Ltd.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**DISCIPLINE SPECIFIC CORE COURSE-5B: INTRODUCTION TO
STATISTICAL LINEAR MODELS**

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	practical		
Introduction to Statistical Linear Models	4	3	0	1		Basic knowledge of Matrix theory and Probability distributions

Learning Objectives:

Learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics.

**SYLLABUS OF DSC-14
THEORY**

UNIT I

(12 Hours)

Introduction

Statistical Linear Models and their classification, Estimability of linear parametric functions, Gauss-Markov setup, Normal equations and Gauss-Markov theorem, full rank case and non-full rank case (without proof)

UNIT II

(8 Hours)

Distribution of quadratic forms

Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

UNIT III

(13 Hours)

Regression analysis:

Simple and Multiple linear regression: Estimation of parameters and testing of hypotheses, Confidence intervals, Bias in regression estimates Lack of fit and pure error, Residuals and their plot. Techniques for variable selection. Polynomial Regression models: Orthogonal Polynomials.

UNIT IV

(12 Hours)

Analysis of Variance:

Technique of analysis of variance (ANOVA) in one-way and two-way classifications with an equal number of observations per cell under fixed effect model.

PRACTICAL/LABWORK -30 Hours

List of Practical:

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Linear Regression
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Orthogonal Polynomials.
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

Suggestive Readings:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(2012): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**DISCIPLINE SPECIFIC ELECTIVE COURSE –5C: STATISTICAL METHODS IN
PSYCHOLOGY AND EDUCATION**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Methods in Psychology and Education	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics and probability distributions

Learning Objectives:

The learning objectives include:

- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

Learning Outcomes:

After successful completion of this course, students should be able to:

- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of Psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

SYLLABUS OF DSC-5c

Theory

Unit 1:

(15 Hours)

Importance of statistics in psychology and education.

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements.

Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring.

Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

Unit 2:

(15 Hours)

Reliability and Validity:

Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.

Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

Unit 3:

(15 Hours)

Test Scores:

Meaning and differences between norm referencing and criterion referencing.

Raw score transformations- percentile scores, standard score, normalised standard scores, T-scores and Stanine scores.

Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

PRACTICAL LAB WORK (30 hours)

List of Practical:

1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anastasia, A. and Urbina, S. (2016) Psychological testing , Prentice Hall.
- Garrett H.E. (2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ (2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2019) Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K. (2016) Statistics in Psychology and Education. PHI learning Pvt ltd.

SUGGESTED READINGS:

- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2016) Fundamental of Statistics, Volume 2, World Press Pvt ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d**Theory****UNIT I****(15 hours)****Introduction to Research:**

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II**(15 hours)****Methods & Techniques of Data Collection:**

Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III.

(15 hours)

Data Processing & Analysis: Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.

Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

Computer Application: Data Communication and networks, Website. Webpage, Search Engines, Scientific search engines Scientific Word Processing.

PRACTICAL/LAB WORK – (30 hours)

PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2021): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2019): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Poole, M. (2001): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2021): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2013): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics

SUGGESTIVE READINGS

- Pannerselvan, R. (2018): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2011): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2013): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2010): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (2016): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (2003): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Category VI
**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF STATISTICS (Semester-VII)**
GENERAL ELECTIVE COURSE – 7A: NONPARAMETRIC METHODS
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nonparametric Methods	4	3	0	1	Class XII pass with Mathematics	Knowledge of hypothesis testing

Learning Objectives

The learning objectives include:

- Utility of Nonparametric/distribution free tests and its role for different type of data
- Quantile and Empirical distributions and their utility
- Test for randomness, location and scales under nonparametric setup
- Test association of bivariate samples

Learning Outcomes:

After completing this course, students should be able to:

- Distinguish between parametric and nonparametric test and appreciate different measurement scales.
- Understand quantile and empirical distribution function and its utility.
- Use nonparametric test for both one/two samples problem, Test for randomness, Kolmogorov- Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Mann Whitney U test, Kruskal-Wallis one-way analysis of variance by ranks.
- Test association of bivariate samples using Kendall Tau and Spearman's rank correlation.

SYLLABUS OF GE-7A
Theory
UNIT I
(15 hours)
Nonparametric Tests:

Introduction and Concept, Non-parametric tests-their advantages and disadvantages, comparison with parametric tests. Measurement scale-nominal, ordinal, interval and ratio. The quantile function, the empirical distribution function, Test for randomness based on total number of runs.

UNIT II

(15 hours)

One-Sample, two-sample problem, and Paired-Sample Procedures: the sign test, treatment of ties in rank tests, Wilcoxon signed-rank test, Wald-Wolfowitz runs test, Kolmogorov-Smirnov one and two-sample test, median test, and the Mann-Whitney U test.

UNIT III

(15 hours)

Linear Rank Tests for the Location and Scale Problem:

Definition of linear rank statistics, Wilcoxon rank-sum test; Tests of the Equality of k Independent Samples: The Kruskal-Wallis one-way ANOVA test; Measures of Association for Bivariate Samples: definition of measures of association in a bivariate population, Kendall's Tau coefficient, Spearman's coefficient of rank correlation.

PRACTICAL/LAB WORK(30 hours):

List of Practical

1. Obtaining quantile and Empirical Distribution
2. Test for randomness
3. Sign test
4. Wilcoxon Signed rank test
5. Wald-Wolfowitz runs test,
6. Kolmogorov-Smirnov one sample test,
7. median test and the Mann-Whitney U test.
8. Wilcoxon rank-sum test
9. The Kruskal-Wallis one-way ANOVA test
10. Test based on Kendall's Tau coefficient.
11. Spearman's coefficient of rank correlation

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gibbons, J. D., and Chakraborti, S. (2021): Nonparametric statistical inference. CRC press.
- Siegel, S. (2014). Nonparametric statistics for the behavioural sciences. McGraw-Hill.

SUGGESTIVE READINGS:

- Kloeke, J., and McKean, J. W. (2024) : Nonparametric statistical methods using R. CRC Press.
- Hollander, M., Wolfe, D.A., and Chicken, E.(2013):Nonparametric statistical methods (Vol. 751). John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERAL ELECTIVE COURSE – 7B: INTRODUCTION TO BAYESIAN INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction To Bayesian Inference	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives:

The learning objectives of this course is

- To introduce students to the Bayesian approach to statistics
- To make students understand the basic difference between the commonly taught Frequentist approach and the Bayesian Paradigm.
- To demonstrate the benefits of using a Bayesian approach and obtaining results that are more interpretable

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Bayes theorem for random variables
- Prior and posterior distributions
- Conjugate prior
- Non-informative priors
- Bayesian point estimation
- Bayesian Credible intervals
- Bayes factor

SYLLABUS OF GE-7b

Theory

UNIT I: (5 Hours)

Bayes Theorem for Random Variables

Revision of some basic distributions; Bayes theorem for events; Bayes theorem for random variables; Concept of likelihood function, prior distribution and posterior distribution.

UNIT II: (12 Hours)

Conjugate Prior and Non-Informative Priors

Thumb rule for constructing a conjugate prior; Conjugate families for samples from various standard distributions: Uniform prior; Jeffreys' non-informative priors.

UNIT III:

(15 Hours)

Bayes Estimation and Credible Interval

Elements of Bayes Decision Theory; Loss Functions; Squared error loss function; Bayes risk; Normal and Extensive form of analysis; Bayesian credible intervals.

UNIT IV:

(13 hours)

Hypothesis Testing

Prior and posterior odds; Bayes factor for simple versus simple hypothesis; Lindley's procedure for test of significance.

PRACTICAL/LAB WORK: (30 HOURS)

List of Practical

1. Plotting of Prior and posterior distributions for Binomial distribution case.
2. Plotting of Prior and posterior distributions for Poisson distribution case.
3. Bayes Estimation using Normal distribution and Squared error loss function.
4. Bayes Estimation using Binomial distribution and Absolute error loss function.
5. Construction of credible intervals and their comparison with corresponding classical confidence interval for Normal distribution case.
6. Construction of credible intervals and their comparison with corresponding classical confidence interval for Binomial distribution case.
7. Normal Approximation to Posterior Distribution.
8. Construction of HPD credible interval for Normal distribution case.

**Practical work to be conducted using electronic spreadsheet / EXCEL/
Statistical Software Package/ SPSS/ calculators.**

ESSENTIAL READINGS:

- Barnett, V. (1999). Comparative Statistical Inference, J. Wiley, New York.
- Bansal, A.K. (2007). Bayesian Parametric Inference, Narosa Publishing House.
- Berger, J.O. (1985). Statistical Decision Theory and Bayesian analysis, Second Edition, Springer-Verlag, New York.

SUGGESTED READINGS:

- Box, G.E.P. and Tiao, G.C. (1992). Bayesian Inference in Statistical Analysis, Addison-Wesley.
- Lee, P. M. (2012). Bayesian Statistics: An Introduction, Arnold Press.
- O'Hagan, A. and Forster, J. (2010). Kendall's Advanced theory of Statistics, Volume 2B, Bayesian Inference, Oxford University Press, New York.
- Robert, C.P. (2007). The Bayesian Choice: A Decision Theoretic Foundations to Computational Implementation, Second Edition, Springer-Verlag, New York.

**Note: Examination scheme and mode shall be as prescribed by the
Examination Branch University of Delhi, from time to time.**

GENERAL ELECTIVE COURSE – 7C: ELEMENTS OF STOCHASTIC PROCESS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Stochastic Process	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Statistics, Probability theory, and discrete Probability distributions

Learning Objectives:

The learning objectives include:

- Introduce the concept of probability generating function
- To understand transitions through Markov chains
- To identify real-life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- The basic concepts of probability generating functions and its applications.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Basic applications of Markov chains.
- Poisson processes and its properties.

SYLLABUS OF GE-7c

Theory

UNIT I

(15 hours)

Generating functions, probability generating functions and their applications in discrete distributions. Stochastic Process: Parametric space and State space with examples. Covariance Stationary processes.

UNIT II

(15 hours)

Markov Chains: Definition of Markov Chain, States of Markov chain, transition probability matrix, order of Markov chain, higher transition probabilities of Markov chain. Classification of States as Transient, Persistent, Null, Non-null, and Ergodic. Reducible and irreducible Markov chains, Stability of Markov system (numerical only).

UNIT III

(15 hours)

Poisson Process: postulates of Poisson process, properties and applications of Poisson process.

PRACTICAL/LAB WORK – (30 hours)

List of Practicals:

1. Generating probability distributions- Binomial, Poisson and geometric and obtaining their pgfs.
2. Generating sequence of numbers using the given generating function.
3. Computing probability generating function using the given sequence of probabilities and obtaining the mean & variance of the r.v. from the pgf.
4. Extracting probability distributions from the probability generating functions.
5. Examining covariance stationarity of a stochastic process.
6. Constructing the transition probability matrix from the given problem and calculating various probabilities.
7. Computing higher order probabilities from a given t.p.m.
8. Classifying the states of a Markov chain
9. Determining irreducibility of a Markov chain
10. Obtaining stable solution of a Markov chain.
11. Verifying additive property of a Poisson process.
12. Decomposition of a Poisson process.
13. Obtaining the autocorrelation function of a Poisson process.

**Practical work to be conducted using electronic spreadsheet / EXCEL/
Statistical Software Package/ SPSS/ calculators.**

ESSENTIAL READINGS:

- Medhi, J. (2009). Stochastic Processes, New Age International Publishers.
- Gupta and Kapoor (2020). Fundamentals of Statistics, 12th edition, Sultan Chand and sons.

SUGGESTIVE READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat, B.R. (2021). Stochastic Models: Analysis and Applications, New Age International Publishers

**Note: Examination scheme and mode shall be as prescribed by the Examination
Branch University of Delhi, from time to time.**

INDEX DEPARTMENT OF STATISTICS
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B.Sc.(H)Statistics Semester-VIII

Category I

DISCIPLINE SPECIFIC CORE COURSE - 20: BAYESIAN INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title and code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorial	Practical		
Bayesian Inference	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives:

The learning objectives of this course is

- To introduce students to the Bayesian approach to statistics.
- To make students understand the basic difference between the commonly-taught Frequentist approach and the Bayesian Paradigm.
- To demonstrate the benefits of using a Bayesian approach and obtaining results that are more interpretable.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Bayes theorem for random variables
- Prior and posterior distributions
- Conjugate prior
- Non-informative priors
- Bayesian point estimation
- Bayesian Credible intervals
- Bayes factor

SYLLABUS OFDSC-20

Theory

UNIT I

(5 Hours)

Bayes Theorem for Random Variables

Concept of inverse probability; Bayes theorem for random variables; Concept of likelihood function, prior distribution and posterior distribution.

SUGGESTED READINGS:

- Box, G.E.P. and Tiao, G.C. (2011). Bayesian Inference in Statistical Analysis, John Wiley & Sons (reprint).
- Lee, P. M. (2012). Bayesian Statistics: An Introduction 4th edition, Wiley.
- O'Hagan, A. and Forster, J. (2010). Kendall's Advanced theory of Statistics, Volume 2B, Bayesian Inference, published by Wiley.
- Robert, C.P. (2007). The Bayesian Choice: A Decision Theoretic Foundations to Computational Implementation, Second Edition, Springer-Verlag, New York (reprint).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective for B.Sc.(H) Statistics Semester-VIII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6 A: NON PARAMETRIC TESTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nonparametric Testing	4	3	0	1	Class XII pass with Mathematics	Knowledge of Hypothesis testing

Learning Objectives

The learning objectives include:

- Usefulness of Nonparametric distribution free tests their strength and weaknesses
- Quantile and Empirical distributions and their utility
- Test for randomness, location and scales under nonparametric setup
- Test association of bivariate samples

Learning Outcomes

After completing this course, students should be able to:

- Make distinction between Parametric and Nonparametric test and measurement scales.
- Appreciate the role of quantile and empirical distribution function and associated tests.
- Identify suitable nonparametric test for both location and scale and able to apply one/two tests including Kolmogorov-Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Kruskal-Wallis one-way analysis of variance by ranks, Friedman two-way analysis of variance by ranks.
- Test association of bivariate samples using Kendall tau and Spearman's rank correlation.

UNIT II**(12 Hours)****Conjugate Prior and Non-Informative Priors**

Thumb rule for constructing a conjugate prior; Conjugate families for samples from various standard distributions; Uniform prior; Jeffreys' non-informative priors; Normal approximations to posterior distribution.

UNIT III**(15 Hours)****Bayes Estimation and Credible Interval**

Elements of Bayes Decision Theory; Loss Functions such as Squared error loss function, Bilinear loss function; Bayes risk; Normal and Extensive form of analysis; Duality between loss and prior; Generalized maximum likelihood estimate; Bayesian credible intervals; Difference between Bayesian credible intervals and classical confidence intervals; Application in linear regression model.

UNIT IV**(13 hours)****Hypothesis Testing**

Prior and posterior odds; Bayes factor for simple versus simple hypothesis; Bayes factor for composite versus composite hypothesis; Lindley's procedure for test of significance.

PRACTICAL/LAB WORK–30 Hours**List of Practical:**

1. Plotting of Prior and posterior distributions for Binomial distribution case.
2. Plotting of Prior and posterior distributions for Poisson distribution case.
3. Bayes Estimation using Normal distribution and Squared error loss function.
4. Bayes Estimation using Binomial distribution and Absolute error loss function.
5. Construction of credible intervals and their comparison with corresponding classical confidence interval for Normal distribution case.
6. Construction of credible intervals and their comparison with corresponding classical confidence interval for Binomial distribution case.
7. Normal Approximation to Posterior Distribution.
8. Construction of HPD credible interval for Normal case.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Bansal, A.K. (2007). Bayesian Parametric Inference, Narosa Publishing House.
- Barnett, V. (2008). Comparative Statistical Inference, J. Wiley, New York.
- Berger, J.O. (2010-softcover published and 2013- eBook published). Statistical Decision Theory and Bayesian analysis, Second Edition, Springer-Verlag, New York.

SYLLABUS OF DSE-6A**Theory****UNIT I****(15 hours)****Introduction**

Nonparametric Tests: Non-parametric tests-their advantages and disadvantages, comparison with parametric tests. Measurement scale-nominal, ordinal, interval and ratio. The quantile function, the empirical distribution function, Glivenko Cantelli Theorem (without proof), Kolmogorov Goodness of fit test, confidence interval for a population quantile, hypothesis testing for a population quantile.

UNIT II**(15 hours)****One sample and two sample tests**

One-Sample, two-sample problem and Paired-Sample Procedures: the sign test and confidence interval for the median, rank-order statistics, treatment of ties in rank tests, Wilcoxon signed-rank test, confidence interval, Wald-Wolfowitz runs test, Kolmogorov- Smirnov one and two-sample test, median test and the Mann-Whitney U test.

UNIT III**(15 hours)****K sample tests**

Linear Rank Tests for the Location and Scale Problem: Definition of linear rank statistics, Wilcoxon rank-sum test; Tests of the Equality of k Independent Samples: The Kruskal- Wallis one-way ANOVA test and multiple comparisons.; Measures of Association for Bivariate Samples: definition of measures of association in a bivariate population, Kendall's Tau coefficient, Spearman's coefficient of rank correlation.

PRACTICAL/ LABWORK (30hours):**List of Practical:**

1. Obtaining quantile and Empirical Distribution
2. Test for randomness
3. Sign test
4. Wilcoxon Signed rank test
5. Wald-Wolfowitz runs test,
6. Kolmogorov-Smirnov one and two-sample test,
7. Median test and the Mann-Whitney U test.
8. Wilcoxon rank-sum test
9. The Kruskal-Wallis one-way ANOVA test
10. Test based on Kendall's Tau coefficient.
11. Spearman's coefficient to rank correlation

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gibbons, J.D., and Chakraborti, S. (2020): Nonparametric statistical inference. CRC press.
- Siegel, S. (1988). Nonparametric statistics for the behavioral sciences, 2nd ed. McGraw-Hill.

SUGGESTIVE READINGS:

- Kloeke, J., and McKean, J. W. (2024): Nonparametric statistical methods using R, 2nd Edition. CRC Press.
- Hollander, M., Wolfe, D. A., and Chicken, E. (2013): Nonparametric statistical methods (Vol. 751). John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**DISCIPLINE SPECIFIC ELECTIVE COURSE–6B: RELIABILITY
THEORY AND LIFE TESTING**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory And Life Testing	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives

The learning objectives include:

- To understand the reliability and their application area.
- To develop the thinking of students so that they can use the concepts of reliability in real life scenario.
- To determine if the performance of components, equipment, and systems, either under closely controlled and known stress conditions in a testing laboratory or under field use conditions.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability and life testing.
- Various estimation procedures of reliability function(s).
- Comparison of various estimates of reliability through simulation study using different software.
- Real data fitting in reliability modelling

SYLLABUS OF DSE-6B**THEORY****UNIT I****(12 hours)****Reliability and reliability measures**

Definition of components and systems, coherent systems, Reliability, Maintainability and Availability; Lifetime distributions, failure rates, MTTF, Bathtub failure rate, reliability of coherent systems in terms of paths and cuts, modular decomposition, reliability importance of components; Parametric families of some common lifetime distributions and their properties (Exponential, Weibull and Gamma).

UNIT II**(10 hours)****Reliability estimation**

Various methods of reliability estimation (Classical and Bayesian); Exponential, Weibull and Gamma lifetime distributions, Reliability estimation under complete, truncated and censored samples, estimates based on components of ordered statistics.

UNIT III**(10 hours)****Stress-Strength and multicomponent reliability**

Stress-Strength reliability: concepts and its estimation for exponential, Weibull and gamma distributions, k-out-of-n (exponential and gamma). Mixture distribution, convolutions and competing risks: introduction, mixture of exponentials, mixture of Weibull, competing risk. Bayesian's Approximation and Reliability: Lindley's expansion, reliability estimation (Normal and Weibull)

UNIT IV**(13 hours)****Reliability systems and life testing**

Reliability of series/parallel systems: introduction, series systems with identical components. Reliability bounds (classical and Bayesian approaches), parallel systems. Different types of redundancy and use of redundancy in reliability improvement. Problems of life testing. Notions of Ageing: IFR, IFRA, NBU, DMRL, NBUE and HNBUE classes, their duals and relationship between them.

PRACTICAL/LABWORK--(30hours)**List of Practical:**

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate, MTBF for various systems.
3. Calculation of stress-strength reliability and its estimates.
4. Various reliability and hazard rate plots.
5. Validation of reliability estimates through simulation study.
6. Behavior of reliability estimates corresponding to sample size.
7. Behavior of hazard rates corresponding to different values of parameter(s).
8. Effect of different sample sizes on reliability estimates.
9. Comparison of various methods of estimation of reliability through simulation study.
10. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Balagurusamy (2017): Reliability Engineering; Wiley
- Sinha, S.K(1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1981): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston. (Reprint)
- Lawless, J.F. (2011): Statistical Models and Methods for Life Time Data, 2nd edition; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.
- Nelson, W (2003): Applied Life Data Analysis; John Wiley.
- Rand M and Hoyland A (2020): System reliability theory, Models, Statistical methods and its applications 3rd edition; Wiley.
- Zacks, S (2011 softcover published and 2012 eBook published): Introduction to Reliability Analysis, Springer Verlag

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6C: GENERALIZED LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	tutorials	practical		
Generalized Linear Models	4	3	0	1	Class XII Pass with Mathematics	Knowledge of general linear models

Learning Objectives:

Learning objectives include:

- Provide the ability to learn and use linear and non-linear models for normal data
- Developing ability to learn generalized linear models for normal and non-normal responses.

Learning Outcomes:

After completion of this course, students should be able to:

- Use linear and Non-linear models, apply data transformations, and appreciate the need and uses of generalized linear models.
- Use logistic and Poisson regression models.
- Understand deviance, analysis of deviance, Lack-of-Fit tests in Logistic and Poisson regression, and the concept of overdispersion.
- Use Log linear models for contingency tables, and likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, and partial association.
- Understand graphical and non-graphical models.
- Use the concepts of Generalized Linear Models in real life problems.

SYLLABUS OF DSE - 6C**UNIT I****(11 Hours)****Nonlinear Regression Models**

Review of linear regression models, Nonlinear regression models, Origins of Nonlinear Models, Transforming to a Linear Model, Estimation of parameters and Statistical Inferences in nonlinear regression.

UNIT II**(12 Hours)****Logistic regression models**

Logistic regression models, Estimation of parameters, Statistical Inferences on model parameters, Confidence Intervals, Lack-of-Fit tests, and Diagnostic checking in Logistic regression.

UNIT III**(12 Hours)****Poisson Regression Models**

Poisson regression models, Estimation of parameters in Poisson regression, Applications in Poisson regressions. Overdispersion in Logistic and Poisson regression models. Link function.

UNIT IV**(10 Hours)****Log-Linear Models**

Log-linear models for contingency tables: interpretation of parameters, Estimation of parameters, likelihood ratio tests for various hypotheses, Graphical and decomposable models.

PRACTICAL/LABWORK-30Hours**List of Practical**

1. Fitting of non-linear regression model.
2. Fitting of logistic regression model.
3. Tests of hypotheses about parameters.
4. Analysis of deviance.
5. Lack-of-Fit tests in Logistic regression.

6. Fitting of Poisson regression model.
7. Log-linear models for contingency tables.
8. Tests for independence,
9. Tests for marginal and conditional independence,
10. Tests for partial association.

Practical work to be conducted using electronic spreadsheet /EXCEL/Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Dobson, A.J. and Barnett, A.G. (2018): Introduction to Generalized Linear Models, 4th ed., Chapman and Hall/CRC. London.
- Myers, R.H., Montgomery, D.C., Vining, G.G. and Robinson, T.J. (2010): Generalized Linear Models with Applications in Engineering and the Sciences, 2nd ed., John Wiley & Sons.

SUGGESTED READINGS:

- McCullagh, P. and Nelder, J.A. (1989): Generalized Linear Models, 2nd ed., Chapman and Hall.
- Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). Introduction to Linear Regression Analysis (6th ed.). John Wiley and Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6D: ADVANCED STOCHASTIC PROCESSES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Stochastic Processes	4	3	0	1	Class XII Pass with Mathematics.	Advanced Knowledge of Probability Theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To define, design and build stochastic models
- To model and analyze transitions through Markov chains

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Tools needed to analyze stochastic processes.
- Markov chain applications.
- Concept of population growth and extinction of population with Branching Process.
- Recurrence of events based on renewal theory.
- Poisson processes and their applications in Birth and Death models.
- Queuing models and their applications

SYLLABUS OF DSE-6d**Theory****UNIT I (13 hours)**

Determination Of Higher Transition Probabilities, A periodic Chain: Limiting Behavior, Graph Theoretic Approach, Finite Reducible Chains with a Single non- trivial Closed Class

UNIT II (15 hours)

Concept of Characteristic functions, Laplace, and Inverse Laplace Transformations.
Branching Process, properties of generating functions of branching processes, probability of ultimate extinction, and its application.
Renewal Processes in Discrete Time, Relation Between $F(s)$ and $P(s)$ and Renewal Interval.

UNIT III (12 hours)

Pure Birth Process, Pure Death Process, Birth And Death Process, Linear Growth Models, Queuing Processes, Steady State Distribution, Little's Formula, Poisson Queuing Models $M/M/1: GD/\infty/\infty$ and its characteristics, waiting time distribution under this model, $M/M/1: GD/N/\infty$ and characteristics, Average system length, Average queue length, $M/M/C: GD/\infty/\infty$ and its characteristics average queue length, average system length, average waiting time, and problems based on all three models.

PRACTICAL/LABWORK–(30hours)**List of Practical:**

1. Simulation of Markov chains.
2. Calculation of higher transition probability matrices.
3. To check whether the given chain is irreducible or not using the concept of stationarity
4. Classification of states.
5. Extinction of population under GW branching Process.
6. Problems based on Renewal theory.
7. Simulation and applications of Poisson processes.
8. Generate the Yule-Furry process and verify that the process follows a geometric distribution.
9. Mean size of population and probability of extinction under linear growth process.
10. Computation of expected customers in the system and expected queue length under $(M/M/1);(GD/\infty/\infty)$ queuing system.
11. Computation of the Average length of a non-empty queue and the fluctuation (variance) of the number of customers in the system under $(M/M/1);(GD/\infty/\infty)$ queuing system.
12. Computation of expected number of customers in the system and expected queue length under $(M/M/1);(GD/N/\infty)$ queuing system.
13. Computation of expected number of customers in the system and expected queue length under $(M/M/C);(GD/N/\infty)$ queuing system .

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol, 3rd Ed., Wiley International.
- Medhi, J. (2022) Stochastic Processes, Sixth edition New Age International Publishers.
- Sheldon M. Ross (2007): Introduction to Probability Models, 9th edition, Academic Press publications
- Karlin & Taylor (1975): A first course in stochastic processes, 2nd edition, Academic Press publications

SUGGESTIVEREADINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- P.G. Hoel, S.C. Port and C.J. Stone (1986): Introduction to Stochastic Processes. Waveland Press
- J.G. Kemeny, J.L. Snell and A.W. Knapp (1960): Finite Markov Chains.
- Geoffrey R, Grimmett & David R. Stirzaker (2004), Reprint: Probability and Random Processes
- Bhat, B.R. (2021). Stochastic Models: Analysis and Applications, New Age International Publishers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.A (Prog) with Statistics as Non-Major/Major Semester-VIII**Category-II****DISCIPLINE SPECIFIC CORE COURSE-8: FUNDAMENTALS OF ECONOMETRICS****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Econometrics	4	3	0	1	Class XII pass with Mathematics	Knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- To judge the validity of the economic theories
- To carry out evaluation of economic theories in numerical terms
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of econometrics.
- Specification of the model.
- Simple Linear Regression.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.

SYLLABUS OF DSC-8**Theory****UNIT I****(15 hours)****Introduction**

Nature and Scope of Econometrics: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, interpretation of regression, nature and sources of data for econometric analysis, different measurement scales of variables

UNIT II (15 hours)

Regression Models

Simple and Multiple Linear Regression Model: Estimation of model by method of ordinary least squares (OLS), properties of estimators, goodness of fit, tests of hypotheses, confidence intervals, coefficient of determination, Gauss-Markov theorem and forecasting.

UNIT III (5 hours)

Autocorrelation

Auto correlation: Concept, consequences of auto correlated disturbances, detection and solution of autocorrelation.

UNIT IV (10 hours)

Multicollinearity and Heteroscedasticity

Violations of Classical Assumptions: Multicollinearity- Concept, Consequences, Detection and Remedies. Heteroscedasticity and serial correlation- Concept and Consequences.

PRACTICAL/LAB WORK- (30hours)

List of Practical:

1. Problems based on estimation of simple linear model.
2. Testing of parameters of simple linear model.
3. Multiple Regression.
4. Problems concerning specification errors.
5. Problems related to consequences of Multicollinearity.
6. Diagnostics of Multicollinearity.
7. Problems related to consequences Heteroscedasticity.
8. Diagnostics of Heteroscedasticity.
9. Estimation of problems of General linear model under Heteroscedastic distance terms.
10. Problems related to selection of best regression model.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gujarati, D. Porter, D. and Pal M. (2020). Basic Econometrics, 6th Ed., McGraw Hill Companies.
- Johnston, J., Dinardo, J. (1997). Econometric Methods, 4th Ed., McGraw-Hill Education (ISE Editions).

SUGGESTIVE READINGS:

- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.
- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2018) Econometric Analysis. 8th Edition, Pearson.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective for B.A. (Prog) with Statistics as Non-Major/Major
Semester-VIII

**DISCIPLINE SPECIFIC ELECTIVE COURSE-6A: INTRODUCTION TO
NON-PARAMETRIC METHODS**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Non-Parametric Methods	4	3	0	1	Class XII Pass with Mathematics	Knowledge of elementary Statistical Inference

Learning Objectives

Learning objectives include:

- To understand the basic principles and concepts of non-parametric statistics.
- To learn the different types of non-parametric statistical tests and their applications.

Learning Outcomes:

After completion of this course, students should be able to:

- Develop an understanding of the differences between parametric and non-parametric statistical tests and their advantages and disadvantages.
- Apply and interpret the results of various non-parametric tests for hypothesis testing, goodness-of-fit testing, testing for randomness, and measuring the association between variables.

SYLLABUS OF DSE-6A

Theory

UNIT I

(11 hours)

Introduction: Definition of non-parametric statistics, Various scales of measurements – the Nominal or categorical scale, the Ordinal or ranking scale, the interval scale and the ratio scale. The differences between parametric and non-parametric statistical tests. Advantages and disadvantages of non-parametric statistical tests.

UNIT II

(15 hours)

One Sample Tests

One-Sample Tests: Chi-Square Goodness of Fit Test for testing whether a sample comes from a specific distribution; Kolmogorov-Smirnov Test for goodness of fit, One Sample Runs Test for Randomness to test for independence of the order of observations in the sequence. Testing the difference between the median of a sample and a hypothesized value: Sign Test, Wilcoxon Signed-Rank Test.

UNIT III**(19 hours)****K Sample Tests**

Two-Sample Tests: Whether two samples come from the same continuous distribution-Wald-Wolfowitz Runs test, Kolmogorov-Smirnov test. Test for the difference between the medians of two independent samples - Median Test, Mann-Whitney U Test. Comparison of medians of k independent samples - Kruskal-Wallis one-way analysis of variance by ranks. Measure of association between two variables - Spearman Rank-Order correlation coefficient and significance.

PRACTICAL/LABWORK-(30hours)**List of Practical:**

1. Chi-Square Goodness of Fit Test
2. Kolmogorov-Smirnov One Sample Test
3. One Sample Runs Test for Randomness
4. Sign Test
5. Wilcoxon Signed-Rank Test.
6. Wald-Wolfowitz Runs Test
7. Kolmogorov-Smirnov Two-Sample Test
8. Median Test
9. Wilcoxon-Mann-Whitney U Test
10. Kruskal-Wallis one-way analysis of variance by ranks
11. Spearman Rank-Order correlation coefficient

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gun, A. M., Gupta, M. K., & Dasgupta, B. (2022). An outline of statistical theory. World Press Pvt Limited.
- Siegal Sidney, and N. John Castellan 1988. Nonparametric Statistics for the Behavioral Sciences. New York (6).
- Gibbons, J. D., & Chakraborti, S. (2020). Nonparametric statistical inference 6th edition. CRC press.

SUGGESTIVE READINGS:

- Sprent, P., & Smeeton, N. C. (2025). Applied nonparametric statistical methods, 5th edition. CRC press.
- Sheskin, D. J. (2020). Handbook of parametric and nonparametric statistical procedures, 5th edition. CRC Press. Boca Raton, FL.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE–6B: RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course Title Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory	4	3	0	1	Class XII pass with Mathematics	Knowledge of probability distributions

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability, Maintainability and Availability.
- Various estimation procedures of reliability function(s).
- Calculation of Reliability of series and parallel systems.

SYLLABUS OF DSE-6B

Theory

UNIT I (10 hours)

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual life time function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II (08 hours)

Common life time distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III (12 hours)

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV (15 hours)

Reliability systems and ageing

Reliability of series/parallel systems: introduction, series systems with identical components.

Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LABWORK–(30hours)

List of Practical:

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practical on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1981): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2011): Statistical Models and Methods for Life Time Data, 2nd edition; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE–6C: MULTIVARIATE DATA ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis	4	3	0	1	Class XII pass with Mathematics	Knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- To study the concept of Bivariate Normal Distribution along with their properties.
- To study the concept of Multivariate Normal Distribution along with their properties and analysis of multivariate data.
- Concepts of regression plane, multiple and partial correlation coefficients.
- Applications of discriminant analysis, principal component analysis and factor analysis.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- The understanding of regression plane, multiple and partial correlation coefficients.
- Analysing multivariate data using data reduction techniques like principal component analysis, factor analysis.
- Classification method namely discriminant analysis.

SYLLABUS OF DSE-6C**Theory****UNIT1****(16 hours)****Bivariate Normal Distribution:**

Probability density function of Bivariate Normal Distribution. Moment generating function, marginal, conditional pdf of BVN and properties of BVN. Introduction of random vector, probability mass/ density functions, distribution function, mean vector and dispersion matrix. Marginal and conditional distributions of random vector.

UNIT2**(16 hours)****Multivariate Normal distribution:**

Probability density function and properties of Multivariate Normal distribution. Moment generating function, marginal and conditional pdf of MVN. Sampling distribution for mean vector and variance-covariance matrix. Regression plane, multiple and partial correlation coefficient and their properties.

UNIT3**(13 hours)****Data Analysis**

Data Reduction Techniques: Principal component analysis and its applications, Factor analysis and its applications, Discriminant analysis and its applications.

PRACTICAL/LABWORK–(30hours)**List of Practical:**

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression space.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant analysis.
10. Factor Analysis.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, 3rdEd., John Wiley & Sons.
- Johnson, R.A. and Wichern, D.W. (2012). Applied Multivariate Analysis, 6th Ed., Prentice Hall India Learning Private Limited
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). An Outline of Statistical Theory, Volume II, World Press
- Brian S. Everett and Graham Dunn. (2001). Applied multivariate data analysis, second edition, Oxford University Press.

SUGGESTED READINGS

- S.C. Gupta and V.K. Kapoor (2020). Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- Kshirsagar, A.M. (1972). Multivariate Analysis, 1stEd., Marcel Dekker.
- Muirhead, R.J. (2005). Aspects of Multivariate Statistical Theory, John Wiley.
- Arora, S. and Bansal, L. (1989 - Reprint 2002). New Mathematical Statistics, 1st Ed., Vanita Printers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6D: STATISTICAL SIMULATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Simulation	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics

Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of pseudo-random number generators as well as from standard statistical distributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real-world systems by utilizing mathematical models with an emphasis on simulation.

- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

SYLLABUS OF DSE-6D

Theory

Unit I

(12 Hours)

Introduction to simulation:

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

Unit II

(18 Hours)

Random numbers generation:

Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transfo

Unit III

(15 Hours)

Applications of simulation:

Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

Practical/Lab Work–(30hours)

List of Practical:

1. Pseudo-random number generators;
2. Generation of U (0,1).
3. Generation using the inverse transform method applied to:
4. Discrete distribution and
5. Continuous distribution.
6. Monte Carlo simulation method and applications.
7. Problems based on Queueing systems.
8. Problems based on Inventory Controls, etc.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Sheldon M. Ross (2022) Simulation, Sixth Edition, Elsevier Academic press publication.
- Taha, H. A. (2014). Operations Research. An Introduction, 9th Ed, Pearson Education.
- Swarup, K. Gupta, P.K. and Mohan, M. (2022). Operations Research, 20th Revised Edition, Sultan Chand & Sons.

SUGGESTED READINGS:

- Voss, J. (2013). An introduction to statistical computing: A simulation-based approach, 1st Ed., Wiley series in computational statistics.
- Sharma, J.K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.
- Payer T. A. (1982). Introduction to simulation, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (Prog) Mathematical Sciences with Statistics Semester-VIII**Category II****DISCIPLINE SPECIFIC CORE COURSE-8: FUNDAMENTALS OF ECONOMETRICS****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Econometrics	4	3	0	1	Class XII pass with Mathematics	Knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- To judge the validity of the economic theories
- To carry out evaluation of economic theories in numerical terms
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of econometrics.
- Specification of the model.
- Simple Linear Regression.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.

SYLLABUS OF DSC-8**Theory****UNIT I****(15 hours)****Introduction**

Nature and Scope of Econometrics: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, interpretation of regression, nature and sources of data for econometric analysis, different measurement scales of variables

UNIT II (15 hours)**Regression Models**

Simple and Multiple Linear Regression Model: Estimation of model by method of ordinary least squares (OLS), properties of estimators, goodness of fit, tests of hypotheses, confidence intervals, coefficient of determination, Gauss-Markov theorem and forecasting.

UNIT III (5 hours)**Autocorrelation**

Autocorrelation: Concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

UNIT IV (10 hours)**Multicollinearity and Heteroscedasticity**

Violations of Classical Assumptions: Multicollinearity- Concept, Consequences, Detection and Remedies. Heteroscedasticity and serial correlation– Concept and Consequences.

PRACTICAL/LAB WORK–(30hours)**List of Practical:**

1. Problems based on estimation of simple linear model.
2. Testing of parameters of simple linear model.
3. Multiple Regression.
4. Problems concerning specification errors.
5. Problems related to consequences of Multicollinearity.
6. Diagnostics of Multicollinearity.
7. Problems related to consequences Heteroscedasticity.
8. Diagnostics of Heteroscedasticity.
9. Estimation of problems of General linear model under Heteroscedastic distance terms.
10. Problems related to selection of best regression model.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gujarati, D. Porter, D. and Pal M. (2020). Basic Econometrics, 6th Ed., McGraw Hill Companies.
- Johnston, J., Dinardo, J. (1997). Econometric Methods, 4th Ed., McGraw-Hill Education (ISE Editions).

SUGGESTIVE READINGS:

- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.
- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2018) Econometric Analysis. 8th Edition, Pearson.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**Discipline Specific Elective for B.Sc.(Prog) Mathematical Sciences with
Statistics Semester-VIII**

**DISCIPLINESPECIFIC ELECTIVE COURSE-6A: INTRODUCTION TO
NON-PARAMETRIC METHODS**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Non- Parametric Methods	4	3	0	1	Class XII Pass with Mathematics	Knowledge of elementary Statistical Inference

Learning Objectives

Learning objectives include:

- To understand the basic principles and concepts of non-parametric statistics.
- To learn the different types of non-parametric statistical tests and their applications.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Develop an understanding of the differences between parametric and non-parametric statistical tests and their advantages and disadvantages.
- Be able to apply and interpret the results of various non-parametric tests for hypothesis testing, goodness-of-fit testing, testing for randomness, and measuring the association between variables.

SYLLABUS OF DSE-6A

Theory

UNIT I

(11 hours)

Introduction

Introduction: Definition of non-parametric statistics, Various scales of measurements – the Nominal or categorical scale, the Ordinal or ranking scale, the interval scale and the ratio scale. The differences between parametric and non-parametric statistical tests. Advantages and disadvantages of non-parametric statistical tests.

UNIT II

(15 hours)

One Sample Tests

One-Sample Tests: Chi-Square Goodness of Fit Test for testing whether a sample comes from a specific distribution; Kolmogorov-Smirnov Test for goodness of fit, One Sample Runs Test for Randomness to test for independence of the order of observations in the sequence. Testing the difference between the median of a sample and a hypothesized value: Sign Test, Wilcoxon Signed-Rank Test.

UNIT III (19 hours)**K Sample Tests**

Two-Sample Tests: Whether two samples come from the same continuous distribution-Wald-Wolfowitz Runs test, Kolmogorov-Smirnov test. Test for the difference between the medians of two independent samples - Median Test, Mann-Whitney U Test. Comparison of medians of k independent samples - Kruskal-Wallis one-way analysis of variance by ranks. Measure of association between two variables - Spearman Rank-Order correlation coefficient and significance.

PRACTICAL/LAB WORK-(30hours)**List of Practical:**

1. Chi-Square Goodness of Fit Test
2. Kolmogorov-Smirnov One Sample Test
3. One Sample Runs Test for Randomness
4. Sign Test
5. Wilcoxon Signed-Rank Test.
6. Wald-Wolfowitz Runs Test
7. Kolmogorov-Smirnov Two-Sample Test
8. Median Test
9. Wilcoxon-Mann-Whitney U Test
10. Kruskal-Wallis one-way analysis of variance by ranks
11. Spearman Rank-Order correlation coefficient

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Gun, A.M., Gupta, M.K., & Dasgupta, B. (2022). An outline of statistical theory. World Press Pvt Limited.
- Siegel, Sidney, and N. John Jr." Castellan. 1988. Nonparametric Statistics for the Behavioral Sciences." New York (6).
- Gibbons, J. D., & Chakraborti, S. (2020). Nonparametric statistical inference 6th edition. CRC press

SUGGESTIVEREADINGS:

- Sprent, P., & Smeeton, N. C. (2025). Applied nonparametric statistical methods, 5th edition. CRC press.
- Sheskin, D. J. (2020). Handbook of parametric and nonparametric statistical procedures, 5th edition. CRC Press. Boca Raton, FL.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE–6B: RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course Title Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory	4	3	0	1	Class XII pass with Mathematics	Knowledge of probability distributions

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should be able to:

- Understand the concepts of Reliability, Maintainability and Availability.
- Various estimation procedures of reliability function(s).
- Calculate reliability of series and parallel systems.

SYLLABUS OF DSE-6B

Theory

UNIT I

(10 hours)

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual lifetime function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II

(08 hours)

Common life time distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III

(12 hours)

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV**(15 hours)****Reliability systems and ageing**

Reliability of series/parallel systems: introduction, series systems with identical components. Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LAB WORK–(30hours)**List of Practical:**

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practical on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1981): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2011): Statistical Models and Methods for Life Time Data, 2nd edition; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE–6C: MULTIVARIATE DATA ANALYSIS
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis	4	3	0	1	Class XII pass with Mathematics	Knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- To study the concept of Bivariate Normal Distribution along with their properties.
- To study the concept of Multivariate Normal Distribution along with their properties and multivariate data analysis.
- Concepts of regression plane, multiple and partial correlation coefficients.
- Applications of discriminant analysis, principal component analysis and factor analysis.

Learning Outcomes:

After completing this course, students should be able to:

- Understand the basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- Understand the regression plane, multiple and partial correlation coefficients.
- Analyze the multivariate data using data reduction techniques like principal component analysis, factor analysis.
- Classify method namely discriminant analysis.

SYLLABUS OF DSE-6C

Theory

UNIT I

(16 hours)

Bivariate Normal Distribution:

Probability density function of Bivariate Normal Distribution. Moment generating function, marginal, conditional pdf of BVN and properties of BVN. Introduction of random vector, Probability mass/ density functions, distribution function, mean vector and dispersion matrix. Marginal and conditional distributions of random vector.

UNIT II

(16 hours)

Multivariate Normal distribution:

Probability density function and properties of Multivariate Normal distribution. Moment generating function, marginal and conditional pdf of MVN. Sampling distribution for mean vector and variance-covariance matrix. Regression plane, multiple and partial correlation coefficient and their properties.

UNIT III

(13 hours)

Data Analysis

Data Reduction Techniques: Principal component analysis and its applications, Factor analysis and its applications, Discriminant analysis and its applications.

PRACTICAL/LAB WORK–(30hours)

List of Practical:

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression space.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant analysis.
10. Factor Analysis.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3rd Ed., John Wiley & Sons.
- Johnson, R.A. and Wichern, D.W. (2012). *Applied Multivariate Analysis*, 6th Ed., Prentice Hall India Learning Private Limited.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). *An Outline of Statistical Theory*, Volume II, World Press.
- Brian S. Everett and Graham Dunn. (2001). *Applied multivariate data analysis*, second edition, Oxford University Press.

SUGGESTED READINGS

- S.C. Gupta and V.K. Kapoor (2020). *Fundamentals of Mathematical Statistics*, 12th Ed., Sultan Chand and Sons.
- Kshirsagar, A.M. (1972). *Multivariate Analysis*, 1st Ed., Marcel Dekker.
- Muirhead, R.J. (2005). *Aspects of Multivariate Statistical Theory*, John Wiley
- Arora, S. and Bansil, L. (1989 - Reprint 2002). *New Mathematical Statistics*, 1st Ed., Vanita Printers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE–6D: STATISTICAL SIMULATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite Of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Simulation	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics

Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of Pseudo random number generators as well as from standard statistical distributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real world systems by

- utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

SYLLABUS OF DSE- 6D

Theory

Unit I

(12 Hours)

Introduction to simulation:

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

Unit II

(18 Hours)

Random numbers generation:

Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transform method; Generating the Discrete and Continuous random variables.

Unit III

(15 Hours)

Applications of simulation:

Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

Practical/Lab Work–(30hours)

List of Practical:

1. Pseudo random number generators;
2. Generation of U (0,1).
3. Generation using the inverse transform method applied to:
4. Discrete distribution and
5. Continuous distribution.
6. Monte Carlo simulation method and applications.
7. Problems based on Queueing systems.
8. Problems based on Inventory Controls, etc.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Sheldon M. Ross (2022) *Simulation, Sixth Edition*, Elsevier Academic press publication.
- Taha, H. A. (2014). *Operations Research. An Introduction*, 9th Ed, Pearson Education India.
- Swarup, K. Gupta, P.K. and Mohan, M. (2022). *Operations Research*, 20th Revised Edition, Sultan Chand & Sons.

SUGGESTED READINGS:

- Voss, J. (2013). *An introduction to statistical computing: A simulation-based approach*, 1st Ed., Wiley series in computational statistics.
- Sharma, J.K. (2017). *Operations Research: Theory and applications*, 6th Edition,

Trinity Press.

- Payer T.A. (1982). *Introduction to simulation*, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF STATISTICS (SEMESTER-VIII)
CATEGORY-VI**

GENERIC ELECTIVE COURSE-8A: ORDER STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Order Statistics	4	3	0	1	Class XII Pass with Mathematics	Knowledge of statistical distributions and stochastic processes

Learning Objectives

The learning objective of this course is:

- To make the students aware of the properties and applications of order statistics.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Find joint, marginal, and conditional distributions of order statistics in the continuous and discrete cases.
- Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and, in particular, from some specific continuous distributions such as uniform and exponential.
- Understand the Markov Chain property of order statistics in the continuous case.
- Understand the distribution-free bounds for moments of order statistics and of the range.
- Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
- Learn how to obtain distribution-free confidence intervals for population quantile and

distribution-free tolerance intervals for population distributions based on order statistics

SYLLABUS OF GE-8a

Theory

UNIT I

(15 hours)

Introduction

Introduction to order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the range, median and other systematic statistics, Examples based on some specific continuous distributions.

UNIT II

(10 hours)

Conditional distribution of order statistics

Conditional distributions. Order statistics as a Markov Chain. Order statistics for a discrete parent. Examples based on some specific discrete distributions.

UNIT III

(10 hours)

Moments of order statistics

Moments of order statistics. Need of Recurrence relations and identities for moments of order statistics. Recurrence's relations and identities for single and product moments of order statistics from an arbitrary distribution. Recurrence relations for single and product moments of order statistics from some specific distributions.

UNIT IV

(10 hours)

Distribution-free intervals of order statistics

Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range.

PRACTICAL/LABWORK-(30hours)

List of Practical:

1. Problem solving using joint, marginal and conditional distributions of order statistics for some specific continuous distributions.
2. Distribution-free confidence intervals for population quantiles for various distributions.
3. Calculating Means, variances, and covariances by using exact expressions for the moment of order statistics for some specific continuous distribution.
4. Problems based on Markov Chain property of order statistics in the continuous case.
5. Distribution of sample range and other systematic statistics in sampling from different distributions.
6. Conditional distribution of order statistics in sampling from different distributions.
7. Calculating exact moments of order statistics by using recurrence relations for arbitrary continuous distributions.
8. Calculating exact moments of order statistics by using recurrence relations for some specific distributions.
9. Distribution-free confidence intervals for population quantiles for various distributions.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- David, H. A. and Nagaraja, H. N. (2003). *Order Statistics*, 3rd ed., John Wiley & Sons.

SUGGESTIVE READINGS:

- Arnold, B.C., Balakrishnan, N. and Nagaraja H.N. (2008). *A First Course in Order Statistics*, SIAM Publishers.
- Arnold, B.C. and Balakrishnan, N. (1989). *Relations, Bounds and Approximations for Order Statistics*, Vol. 53, Springer-Verlag.
- Ahsanullah, M., Nevzorav, V.B. and Shakil, M. (2013). *An Introduction to Order Statistics*, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
- Shahbaz, M.Q., Ahsanullah, M., Shahbaz, S.H. and Al-Zahrani, B.M. (2016). *Ordered Random variables: Theory and Applications*. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE COURSE-8B: STATISTICS INFINANCE
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistics in Finance	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Calculus, Probability theory and Financial markets

Learning Objectives

The learning objectives include:

- To study the Financial Statistics which deals primary and secondary financial markets and the mathematical models used by these markets?
- To study to deal with the risks in financial markets

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:\

- Primary financial markets and their products such as equity, bonds and cash deposits
- Secondary financial markets and their products such as futures, forwards and options (American and European)
- Applications of stochastic models to price various secondary financial markets products.
- Hedging techniques

SYLLABUS OF GE-8B

Theory

UNIT I

(12 hours)

Theory of interest rates

Theory of interest rates- Simple and compound interest, Nominal and effective rates of interest, interest rates of varying frequencies, continuous rates, accumulation and discount factors, relationship between interest rates and discount rates, present value, future value.

Unit II

(14 hours)

Project appraisal and investment performance

Project appraisal and investment performance- Net present value, IRR, effect of taxation, Valuation of securities-fixed asset securities, related assets, perpetuities, bonds, coupon rates, bond-pricing formula.

Unit III

(14 hours)

Introduction to derivative pricing

An introduction to derivative pricing- arbitrage, futures and forwards, European options- Call and put, put call parity, volatility, Black-Scholes option pricing formula, binomial model of option pricing. Hedging- delta, gamma and theta.

PRACTICAL/LABWORK–(30hours)

List of Practical:

1. Relationship between various interest and discount rates
2. Calculation of present values and future values of cashflows
3. To compute NPV and to obtain IRR of the investments.
4. To compute bond price and yields
5. To verify “no arbitrage” principle.
6. To price future/ forward contracts
7. To price options using Black–Scholes formula.
8. Pricing of options using discrete time models.
9. Call-put parity for options.
10. Application of Greeks to hedge investment portfolios.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- David, G.L. (2015). Investment Science, Oxford University Press (South Asian edition).
- John C. Hull and Sankarshan Basu (2018) (10th edition) Options, Future and other derivatives, Pearson Indian edition

SUGGESTIVE READINGS:

- Franke, J., Hardle, W.K. and Hafner, C.M. (2019- softcover published and eBook published). *Statistic of Financial Markets: An Introduction*, 3rd Ed., Springer Publications.
- Garrett S.J. (2013) An introduction to the mathematics of Finance: A deterministic approach, 2nd edition, Elsevier
- Ambrose Lo (2018): Derivative Pricing: A problem-based primer, Chapman & Hall

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE COURSE-8C: INTRODUCTION TO RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Reliability Theory	4	3	0	1	Class XII Pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should be able to:

- Understand the Concept of Reliability, Maintainability and Availability.
- Understand the various estimation procedures of reliability function(s).
- Calculate Reliability of series and parallel systems.

SYLLABUS OF GE-8c

Theory

UNIT I

(10 hours)

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual lifetime function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II

(08 hours)

Common life time distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III

(12 hours)

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV

(15hours)

Reliability systems and ageing

Reliability of series/parallel systems: introduction, series systems with identical components. Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LABWORK–(30hours)

List of Practical:

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practical on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1981): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2011): Statistical Models and Methods for Life Time Data, 2nd edition; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

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Syllabi of Semester-VII and VIII based on UGCF - 2022**DEPARTMENT OF MATHEMATICS****Category-I****B.Sc. (Hons.) Mathematics, Semester-VII****DISCIPLINE SPECIFIC CORE COURSE – 19: LINEAR ANALYSIS****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Analysis	4	3	1	0	Class XII pass with Mathematics	Metric Spaces, Advanced Linear Algebra

Learning Objectives: The objective of the course is to introduce:

- Norm and normed spaces, Banach spaces and Hilbert spaces as complete normed spaces and their properties.
- Various forms of matrix norms with examples.
- Classes of bounded linear operators on normed spaces and Hilbert spaces, respectively.
- Four important theorems: Hahn-Banach, Uniform boundedness, Open mapping, and Closed graph as the cornerstones of the theory of Banach spaces.

Learning Outcomes: This course will enable the students to:

- Analyze and demonstrate examples of normed linear spaces with their properties.
- Characterize the bounded linear operators on normed spaces as continuous functions.
- Understand and apply Schwarz and Bessel's inequality, Parseval's identity.
- Illustrate linear operators, self-adjoint, unitary and normal operators on Hilbert spaces.
- Prove and apply fundamental theorems from the theory of normed and Banach spaces.

SYLLABUS OF DSC-19**UNIT – I: Normed Spaces and Banach Spaces****(15 hours)**

Normed spaces, Banach spaces, Properties of normed spaces, Finite dimensional normed spaces and subspaces, Compactness and finite dimension; Matrix norms; Linear operators, Bounded linear operators; Linear functionals, Linear operators and functionals on finite dimensional spaces; Normed spaces of operators, Dual space.

UNIT – II: Hilbert Spaces**(15 hours)**

Overview of inner product spaces and its properties, Hilbert spaces, Orthogonal complements and direct sums, Orthonormal sets and sequences, Bessel inequality; Total orthonormal sets and sequences; Riesz representations theorem, Hilbert-adjoint operator, Self-adjoint, Unitary and normal operators.

UNIT – III: Fundamental Theorems for Normed and Banach Spaces**(15 hours)**

Hahn Banach theorems for real and complex vector spaces, Hahn Banach theorem for normed spaces; Reflexive spaces; Uniform boundedness theorem, Open mapping theorem, Closed graph theorem.

Essential Readings

1. Kreyszig, Erwin (1989). Introductory Functional Analysis with Applications (1st ed.). John Wiley & Sons. Wiley-India Student Edition. Indian Reprint 2007.
2. Horn, Roger A. and Johnson, Charles R. (2013). Matrix Analysis (2nd ed.). Cambridge University Press.

Suggestive Readings

- Bollobás Béla (1999). Linear Analysis: An Introductory Course (2nd ed.). Cambridge University Press.
- Rynne, Bryan P. and Youngson, Martin A. (2008). Linear Functional Analysis (2nd ed.). Springer-Verlag London Limited.

DSE Courses of B.Sc. (Hons) Mathematics, Semester-VII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(i): ADVANCED DIFFERENTIAL EQUATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Differential Equations	4	3	1	0	Class XII pass with Mathematics	Multivariate Calculus, Ordinary and Partial Differential Equations

Learning Objectives: The main objective of this course is to:

- Study the existence, uniqueness, and stability of solutions of IVPs, to explore the solution of system of linear equations.
- Study Green's function and its applications in boundary value problems, Eigenvalues and Eigenfunctions of Sturm Liouville systems.
- Investigate the solutions and applications of Laplace, wave, and diffusion equations.

Learning Outcomes: This course will enable the students to find the:

- Existence, uniqueness, and continuity of solutions of IVPs.
- Properties of zeros of solutions of linear second order ODE's.
- Green's function of a BVP and its applications.
- Eigenvalues and eigenfunctions of Sturm-Liouville systems.
- Solutions of Laplace, wave, and diffusion equations with their applications.

SYLLABUS OF DSE-5(i)

UNIT – I: Existence and Uniqueness for Initial-Value Problems (15 hours)

Well posed problems, Picard's existence theorem, uniqueness and continuity theorems for initial value problems of first order; Existence and uniqueness theorems for systems and higher order IVPs; Sturm separation and comparison theorems; Homogeneous linear systems, Nonhomogeneous linear systems, Linear systems with constant coefficients.

UNIT – II: Stability Theory and Boundary-Value Problems (10 hours)

Stability of autonomous system of differential equations, Critical point of an autonomous system and their classification, Stability of linear systems with constant coefficients, Linear plane autonomous systems, Perturbed systems; Two-point boundary-value problem, Green's functions and their construction; Sturm-Liouville systems, Eigenvalues and Eigenfunctions.

UNIT – III: Laplace, Wave and Diffusion Equations with Applications (20 hours)

Laplace's equation, Boundary value problems, Maximum and minimum principles, Uniqueness of solution and their continuous dependence on boundary data, Solution of the Dirichlet and Neumann problem for a half plane by Fourier transform method, Theory of Green's function for Laplace's equation in three dimension and application in solution of Dirichlet and Neumann problem for semi-infinite spaces; Wave equation, Helmholtz's first and second theorems, Theory of Green's function for wave equation and its applications; Diffusion equation, Solution of initial boundary value problems for diffusion equation, Green's function for diffusion equation and its applications.

Essential Readings

1. Myint-U, Tyn (1978). Ordinary Differential Equations. Elsevier, North-Holland, Inc.
2. Ross S. L. (2007). Differential Equations (2nd ed.) John Wiley & Sons. India.
3. Sneddon Ian N. (2006). Elements of Partial Differential Equations. Dover Publications.

Suggestive Readings

- Coddington, E. A. (2012). An Introduction to Ordinary Differential Equations. Dover Publications.
- Amaranath T. (2023). An Elementary Course in Partial Differential Equations (3rd ed.). Narosa Publishing House.
- McOwen, Robert C. (2003). Partial Differential Equations, Pearson Education.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(ii): DYNAMICAL SYSTEMS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Dynamical Systems	4	3	1	0	Class XII pass with Mathematics	Calculus, Differential Equations, Linear Algebra, Metric spaces

Learning Objectives: Primary objective of this course is to introduce:

- The fundamental concepts of dynamical systems and emphasize on its study through several applications.
- The concepts of the periodic points, hyperbolicity and chaos explained through examples.
- Symbolic dynamics which help to represent and understand various dynamical systems.

Learning Outcomes: This course will enable the students to:

- Understand and demonstrate the basic concepts of dynamical systems and properties.
- Obtain fixed points and discuss the stability of the dynamical system.
- Understand Sharkovsky's theorem, Schwarzian derivative and Devaney chaos.
- Gain command in understanding subshifts of finite type and Markov chain which eventually leads to various areas of dynamical systems.

SYLLABUS OF DSE-5(ii)

UNIT – I: Orbits under Discrete Dynamical Systems (12 hours)

Dynamical systems: Discrete and continuous, Population Models, Newton's Method; Discrete dynamical system: Definition, examples and orbits, Periodic and eventually periodic points, Stable and unstable sets, Phase portrait, Graphical analysis of one-dimensional maps; Hyperbolicity, A glimpse of bifurcations, Analysis of families of logistic maps.

UNIT – II: Introduction to Chaos (15 hours)

Symbolic dynamics, Sequence space, Shift map, Itinerary map, Subshifts of finite type, Conjugacy and chaos, Sensitive dependence on initial conditions, Topological transitivity, Devaney chaos, Expansive homeomorphisms, Expansivity of interval and circle maps; Structural stability, Sharkovsky's theorem and examples, Schwarzian derivative; Period 3 case.

UNIT – III: More on Symbolic Dynamics (18 hours)

Full shifts, Shift spaces, Languages, Higher block shifts and higher power shifts, Sliding block codes; Finite type constraints, Graphs and their shifts, Graph representations of shifts of finite type, Markov chain; Shadowing property and subshifts of finite type.

Essential Readings

1. Aoki, N. and Hiraide, K. (1994). Topological Theory of Dynamical Systems: Recent Advances. Elsevier Science, North-Holland.
2. Devaney, Robert L. (2022). An Introduction to Chaotic Dynamical Systems (3rd ed.). CRC Press, Taylor & Francis Group.
3. Lind, Douglas and Marcus, Brian (2021). An Introduction to Symbolic Dynamics and Coding (2nd ed.). Cambridge University Press.

Suggestive Readings

- Bruin, Henk (2022). Topological and Ergodic Theory of Symbolic Dynamics. Graduate Studies in Mathematics (228), American Mathematical Society.
- Martelli, Mario (1999). Introduction to Discrete Dynamical Systems and Chaos. John Wiley & Sons, Inc., New York.
- Robinson, Clark (1998). Dynamical Systems: Stability, Symbolic Dynamics, and Chaos (2nd ed.). CRC press.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(iii): FUNDAMENTALS OF TOPOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Topology	4	3	1	0	Class XII pass with Mathematics	Metric Spaces

Learning Objectives: The main objective of this course is to:

- Having in depth understanding of metric spaces and realizing strength of notions like path connectedness, countability axioms and theorems due to Tietze and Baire.
- Create Topological spaces fundamentals, naturally abstracting out from metric spaces.
- Study powerful notions like connectedness, compactness, product topology leading to major results like Tychonoff Theorem.

Learning Outcomes: This course will enable the students to:

- Realize beautiful transitions of some of the major notions and results from metric spaces to topological spaces wherein we do not have facility of distance.
- Appreciate possibility of continuous deformation of several spaces into known spaces through notions developed during the course work.
- Enhance ability to create examples and counter examples classifying various notions.
- Have better understanding of Euclidean spaces and its subspaces, infinite dimensional spaces, and several non-Euclidean spaces.
- Acquire a detailed elucidation of connectedness and compactness of topological spaces.

SYLLABUS OF DSE-5(iii)

UNIT-I: Countability Axioms, Separability and Lindelöf Spaces (12 hours)

Review of the properties of metric spaces; Spaces of sequences of numbers, their convergence and completeness, Completion of a metric space; Local base and base, First and second axiom of countability, Separable and Lindelöf spaces.

UNIT-II: Baire Category Theorem and Localized Versions of Connectedness (12 hours)

Nowhere dense subsets, Category I and category II sets, Baire category theorem; Extension theorems; Tietze's Extension Theorem; Local connectedness, Arcwise connectedness; Totally bounded sets and its connection with completeness and compactness.

UNIT-III: Introduction to Topological Spaces (21 hours)

Topology; Basis and subbasis for a topology; Product and subspace topology; Closed sets, Closure, Interior and limit points of a set, Hausdorff spaces; Continuous functions, Homeomorphism; Product topology for an indexed family of spaces; Connectedness and Compactness.

Essential Readings

1. Munkres James R. (2002). Topology (2nd ed.). Prentice Hall of India Pvt. Ltd.
2. Shirali Satish and Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Suggestive Readings

- Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. Delhi.
- Searcóid, Mícheál Ó (2007). Metric Spaces. Springer-Verlag.
- Simmons, G. F. (2017). Introduction to Topology and Modern Analysis. McGraw Hill Education. Delhi.

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(iv):
INFORMATION THEORY AND CODING**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Information Theory and Coding	4	3	1	0	Class XII pass with Mathematics	Probability and Statistics, Linear Algebra

Learning Objectives: The main objective of this course is to:

- Define and comprehend the concepts of information and its relationship with uncertainty and entropy.
- Apply basic principles of probability theory to measure information content.
- Learn basic information inequalities and their applications.
- Introduce error-detecting and error-correcting codes.
- Learn various decoding techniques.
- Get exposure to linear codes and bounds on linear codes.

Learning Outcomes: This course will enable the students to:

- Understand information and entropy, and calculate various entropies.
- Apply mutual information, conditional entropy, and information-theoretic measures.
- Know about the detection and correction of errors while transmission.
- Understand and demonstrate encoding and decoding of linear codes, and gain knowledge about some bounds on linear codes.

SYLLABUS OF DSE-5(iv)**UNIT – I: Concepts of Information Theory****(15 hours)**

A measure of uncertainty, H function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes. Entropy,

Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, A measure of mutual information.

UNIT – II: Information Inequality and Coding Theory (15 hours)

Interpretation of Shannon's fundamental inequalities, Redundancy, Efficiency and channel capacity, Jensen's inequality and its characterizations, The log sum inequality and its applications. Introduction to error detecting and correcting codes, Maximum likelihood decoding, Hamming distance, Nearest neighbour/minimum distance decoding, Distance of a code, Main coding theory problems, Equivalence of codes, Sphere-packing bound, Perfect codes, Balanced block designs, Finite fields, The ISBN code.

UNIT – III: Linear Codes (15 hours)

Introduction to vector space over finite fields, Linear codes, Bases for linear codes, Encoding and decoding with a linear code, Dual code, Generator and parity check matrices, Nearest neighbour decoding for linear codes, Syndrome decoding. Binary Hamming codes, q -ary Hamming codes.

Essential Readings

1. Cover, Thomas M. and Thomas, Joy A. (2006). Elements of Information Theory (2nd ed.). Wiley India. Indian Reprint 2017.
2. Hill, Raymond. (1996). A First Course in Coding Theory. Oxford University Press.
3. Reza, Fazlollah M. (1961). An Introduction to Information Theory. Dover Publications Inc, New York. Reprint July 2022.

Suggestive Readings

- Bose, R. (2016). Information Theory, Coding and Cryptography (3rd ed.). McGraw-Hill.
- Hamming, R. W. (1980). Coding and Information Theory, Prentice Hall, Englewood.
- Ling, S. and Xing, C. (2004). Coding Theory: A First Course. Cambridge University Press.
- Pless, V. (1998). Introduction to the Theory of Error-Correcting Codes. John-Wiley.
- Sloane, N. J. A. and MacWilliams, F. J. (2007). Theory of Error Correcting Codes. North-Holland Mathematical Library 16, North-Holland.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(v): OPTIMIZATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization	4	3	1	0	Class XII pass with Mathematics	Multivariate Calculus

Learning Objectives: The main objective of this course is to introduce:

- Nonlinear optimization problems.
- Convex and generalized convex functions and their properties.
- Optimality and duality in nonlinear optimization.
- Methods to solve unconstrained optimization problems, quadratic and fractional programming problems with linear constraints.

Learning Outcomes: This course will enable the students to:

- Learn about the optimal solutions of nonlinear optimization problems.
- Understand and apply Karush-Kuhn-Tucker (KKT) necessary and sufficient optimality conditions for nonlinear optimization problems.
- Demonstrate and apply Lagrangian duality results, and techniques to solve certain classes of nonlinear optimization problems.

SYLLABUS OF DSE-5(v)

UNIT – I: Nonlinear Optimization and Convex Functions (15 hours)

Problem statement of a nonlinear optimization problem, Example of production inventory, Location facilities, Stochastic resource allocation, Convex sets, Convex functions, Epigraph and hypograph of a function, Differentiable convex function, Twice differentiable convex function, Minima of convex function, Quasiconvex functions, Psuedoconvex functions.

UNIT – II: Optimality and Duality Theory in Nonlinear Optimization (15 hours)

Unconstrained problems: Necessary optimality conditions, Sufficient optimality conditions; Problems having inequality constraints: Fritz John optimality conditions, Karush-Kuhn-Tucker (KKT) necessary optimality conditions; Fritz John conditions, KKT necessary and sufficient optimality conditions for problems with inequality and equality constraints; Lagrangian dual problem, Weak duality theorem, Duality gap, Strong duality theorem.

UNIT – III: Numerical Methods to Solve Nonlinear Optimization Problems (15 hours)

Descent property, Order of convergence, Global convergence, Steepest descent method, Newton's method, Wolfe's method for quadratic programming problem; Linear fractional programming problem and simplex algorithm.

Essential Readings

1. Bazaraa, Mokhtar S., Sherali, Hanif D. & Shetty, C. M. (2006). Nonlinear Programming: Theory and Algorithms (3rd ed.). John Wiley & Sons. Wiley India (2017).
2. Chandra, Suresh, Jayadeva and Mehra, Aparna (2009). Numerical Optimization with Applications. Narosa Publishing House Pvt. Ltd. Delhi. Second Reprint 2016.

Suggestive Readings

- Durea, Marius and Strugariu, Radu. (2014). An Introduction to Nonlinear Optimization Theory. de Gruyter Open.
- Eiselt, H. A. and Sandblom, Carl-Louis. (2019). Nonlinear Optimization: Methods and Applications. Springer Nature Switzerland.
- Luenberger, David, G. and Ye, Yinyu. (2021). Linear and Nonlinear Programming (5th ed.). Springer Nature Switzerland.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(vi): RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The main objective of this course is to:

- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:

- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE - 5(vi)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics;

Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (<https://publicationethics.org/>)
3. Declaration on Research Assessment.
https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics;
(<https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874>)
5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (<https://www.d.umn.edu/~jgallian/goodPPtalk.pdf>). MATH HORIZONS.
6. Lampion, Leslie (2008). LaTeX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.
10. Tantau, Till, Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group.
(<https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf>)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

B.A. (Prog.) Semester-VII with Mathematics as Major
Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-7): NUMERICAL METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Numerical Methods	4	3	0	1	Class XII pass with Mathematics	Calculus, Real Analysis

Learning Objectives: The primary objective of this course is to introduce:

- Solutions of nonlinear equations in one variable by various methods.
- Interpolation and approximation, numerical differentiation, and integration.
- Direct methods for solving linear systems, numerical solution of ODE's.

Learning Outcomes: This course will enable the students to:

- Find the consequences of finite precision and the inherent limits of numerical methods.
- Appropriate numerical methods to solve algebraic and transcendental equations.
- Solve first order initial value problems of ODE's numerically using Euler methods.

SYLLABUS OF DSC-7

UNIT-I: Errors and Roots of Transcendental and Polynomial Equations (12 hours)

Errors: Roundoff error, Local truncation error, Global truncation error; Order of a method, Convergence, and terminal conditions; Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method.

UNIT-II: Algebraic Linear Systems and Interpolation (18 hours)

Gaussian elimination method (with row pivoting); Iterative methods: Jacobi method, Gauss-Seidel method; Interpolation: Lagrange form, Newton form, Finite difference operators.

UNIT-III: Numerical Differentiation, Integration and ODE (15 hours)

Numerical differentiation: First and second order derivatives; Numerical integration: Trapezoidal rule, Simpson's rule; Ordinary differential equation: Euler's method.

Essential Readings

1. Chapra, Steven C. (2018). Applied Numerical Methods with MATLAB for Engineers and Scientists (4th ed.). McGraw-Hill Education.
2. Fausett, Laurene V. (2009). Applied Numerical Analysis Using MATLAB. Pearson. India.
3. Jain, M. K., Iyengar, S. R. K., & Jain R. K. (2012). Numerical Methods for Scientific and Engineering Computation (6th ed.). New Age International Publishers. Delhi.

Suggestive Reading

- Bradie, Brian (2006). A Friendly Introduction to Numerical Analysis. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third Impression, 2011.

Note: Non programmable scientific calculator may be allowed in the University examination.

Practical / Lab work to be performed in Computer Lab: Use of computer algebra software (CAS), for example Mathematica/MATLAB/Maple/ Maxima/Scilab etc., for developing the following numerical programs:

1. Bisection method
2. Secant method and Regula-Falsi method
3. Newton-Raphson method
4. Gauss-Jacobi method and Gauss-Seidel method
5. Lagrange interpolation and Newton interpolation
6. Trapezoidal rule and Simpson's rule
7. Euler's method for solving first order initial value problems of ODE's.

DSE Courses of B.A. (Prog.) Semester-VII
Category-II

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3(i): ADVANCED LINEAR ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Linear Algebra	4	3	1	0	Class XII pass with Mathematics	Linear Algebra

Learning Objectives: The objective of the course is to introduce:

- Linear functionals, dual basis and the dual (or transpose) of a linear transformation.
- Diagonalization problem and Jordan canonical form for linear operators or matrices using eigenvalues.
- Inner product, norm, Cauchy-Schwarz inequality, and orthogonality on real or complex vector spaces.
- The adjoint of a linear operator with application to least squares approximation and minimal solutions to linear system.
- Characterization of self-adjoint (or normal) operators on real (or complex) spaces in terms of orthonormal bases of eigenvectors and their corresponding eigenvalues.

Learning Outcomes: This course will enable the students to:

- Understand the notion of an inner product space in a general setting and how the notion of inner products can be used to define orthogonal vectors, including to the Gram-Schmidt process to generate an orthonormal set of vectors.
- Use eigenvectors and eigenspaces to determine the diagonalizability of a linear operator.
- Find the Jordan canonical form of matrices when they are not diagonalizable.
- Learn about normal, self-adjoint, and unitary operators and their properties, including the spectral decomposition of a linear operator.
- Find the singular value decomposition of a matrix.

SYLLABUS OF DSE-3(i)

UNIT-I: Dual Spaces, Diagonalizable Operators and Canonical Forms (18 hours)

The change of coordinate matrix; Dual spaces, Double dual, Dual basis, Transpose of a linear transformation and its matrix in the dual basis, Annihilators; Eigenvalues, eigenvectors, eigenspaces and the characteristic polynomial of a linear operator; Diagonalizability, Direct sum of subspaces, Invariant subspaces and the Cayley-Hamilton theorem; The Jordan canonical form and the minimal polynomial of a linear operator.

UNIT-II: Inner Product Spaces and the Adjoint of a Linear Operator (12 hours)

Inner products and norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel's inequality; Adjoint of a linear operator with applications to least squares approximation and minimal solutions to systems of linear equations.

UNIT-III: Class of Operators and Their Properties (15 hours)

Normal, self-adjoint, unitary and orthogonal operators and their properties; Orthogonal projections and the spectral theorem; Singular value decomposition for matrices.

Essential Reading

1. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2019). Linear Algebra (5th ed.). Pearson Education India Reprint.

Suggestive Readings

- Hoffman, Kenneth, & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.
- Lang, Serge (1987). Linear Algebra (3rd ed.). Springer.

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(ii): ELEMENTS OF METRIC SPACES**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Metric Spaces	4	3	1	0	Class XII pass with Mathematics	Calculus, Real Analysis

Learning Objectives: The objective of the course is to introduce:

- The usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- The two important topological properties, namely connectedness, and compactness of metric spaces with their characterizations.

Learning Outcomes: This course will enable the students to:

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities.
- Analyze how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting.

SYLLABUS OF DSE-3(ii)**UNIT-I: Topology of Metric Spaces****(18 hours)**

Inequalities, Definition and examples, Sequences and Cauchy sequences, Complete metric space; Open and closed balls, Neighborhood, Open set, Interior of a set, Limit point of a set, Closed set, Closure of a set; Subspaces.

UNIT-II: Continuity and Uniform Continuity in Metric Spaces**(15 hours)**

Continuous mappings, Sequential criterion, and other characterizations of continuity; Uniform continuity; Homeomorphism, isometry, and equivalent metrics.

UNIT-III: Connected and Compact Spaces**(12 hours)**

Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings; Compactness and boundedness, Characterizations of compactness, Continuous functions on compact spaces.

Essential Reading

1. Shirali, Satish & Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Suggestive Reading

- Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(iii): MATHEMATICAL DATA SCIENCE**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Data Science	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of R/Python, Probability and Statistics

Learning Objectives: The main objective of this course is to:

- Introduce various types of data and their sources, along with steps involved in data science case-study, including problems with data and their rectification and creation methods.
- Cover dimensionality reduction techniques, clustering algorithms and classification methods.

Learning Outcomes: The course will enable the students to:

- Gain a comprehensive understanding of data science, its mathematical foundations including practical applications of regression, principal component analysis, singular value decomposition, clustering, support vector machines, and k -NN classifiers.
- Demonstrate data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation and regularization using R/Python.
- Use real-world datasets to practice dimensionality reduction techniques such as PCA, SVD, and multidimensional scaling using R/Python.

SYLLABUS OF DSE-3(iii)

UNIT-I: Principles of Data Science

(12 hours)

Types of Data: nominal, ordinal, interval, and ratio; Steps involved in data science case-study: question, procurement, exploration, modeling, and presentation; Structured and unstructured data: streams, frames, series, survey results, scale and source of data – fixed, variable, high velocity, exact and implied/inferred; Overview of problems with data – dirty and missing data in tabular formats – CSV, data frames in R/Pandas, anomaly detection, assessing data quality, rectification and creation methods, data hygiene, meta-data for inline data-description-markups such as XML and JSON; Overview of other data-source formats – SQL, pdf, Yaml, HDF5, and Vaex.

Unit-II: Mathematical Foundations

(15 hours)

Model driven data in R^n , Log-likelihoods and MLE, Chebyshev, and Chernoff-Hoeffding inequalities with examples, Importance sampling; Norms in Vector Spaces– Euclidean, and metric choices; Types of distances: Manhattan, Hamming, Mahalanobis, Cosine and angular distances, KL divergence; Distances applied to sets– Jaccard, and edit distances; Modeling text with distances; Linear Regression: Simple, multiple explanatory variables, polynomial, cross-validation, regularized, Lasso, and matching pursuit; Gradient descent.

Unit-III: Dimensionality Reduction, Clustering and Classification

(18 hours)

Problem of dimensionality, Principal component analysis, Singular value decomposition (SVD), Best k -rank approximation of a matrix, Eigenvector and eigenvalues relation to SVD, Multidimensional scaling, Linear discriminant analysis; Clustering: Voronoi diagrams, Delaunay triangulation, Gonzalez's algorithm for k -center clustering, Lloyd's algorithm for k -means clustering, Mixture of Gaussians, Hierarchical clustering, Density-based clustering and outliers, Mean shift clustering; Classification: Linear classifiers, Perceptron algorithm, Kernels, Support vector machines, and k -nearest neighbors (k -NN) classifiers.

Essential Readings

1. Mertz, David. (2021). Cleaning Data for Effective Data Science, Packt Publishing.
2. Ozdemir, Sinan. (2016). Principles of Data Science, Packt Publishing.
3. Phillips, Jeff M. (2021). Mathematical Foundations for Data Analysis, Springer. (<https://mathfordata.github.io/>).

Suggestive Readings

- Frank Emmert-Streib, et al. (2022). Mathematical Foundations of Data Science Using R. (2nd ed.). De Gruyter Oldenbourg.
- Wes McKinney. (2022). Python for Data Analysis (3rd ed.). O'Reilly.
- Wickham, Hadley, et al. (2023). R for Data Science (2nd ed.). O'Reilly.

Practical (30 hours)- Practical work to be performed in Computer Lab using R/Python:

1. To explore different types data (nominal, ordinal, interval, ratio) and identify their properties.
2. To deal with dirty and missing data, such as imputation, deletion, and data normalization.
3. Use the real-world datasets (<https://data.gov.in/>) to demonstrate the following:
 - a) Data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation, and regularization.
 - b) Dimensionality reduction techniques such as principal component analysis, singular value decomposition (SVD), and multidimensional scaling.
 - c) Clustering algorithms such as k -means, hierarchical, and density-based clustering and evaluate the quality of the clustering results.
 - d) Classification methods such as linear classifiers, support vector machines (SVM), and k -nearest neighbors (k -NN).

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(iv): INTEGRAL TRANSFORMS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Integral Transforms	4	3	1	0	Class XII pass with Mathematics	Differential Equations, Elementary Mathematical Analysis

Learning Objectives: Primary objective of this course is to introduce:

- The basic idea of integral transforms of functions and their applications through an introduction to Fourier series expansion of a periodic function.
- Fourier transform and Laplace transform of functions of a real variable with applications to solve ODE's and PDE's.

Learning Outcomes: The course will enable the students to:

- Understand the Fourier series associated with a periodic function, its convergence, and the Gibbs phenomenon.
- Compute Fourier and Laplace transforms of classes of functions.
- Apply techniques of Fourier and Laplace transforms to solve ordinary and partial differential equations and initial and boundary value problems.

SYLLABUS OF DSE-3(iv)**UNIT-I: Fourier Series and Integrals (18 hours)**

Piecewise continuous functions and periodic functions, Systems of orthogonal functions, Fourier series: Convergence, examples and applications of Fourier series, Fourier cosine series and Fourier sine series, The Gibbs phenomenon, Complex Fourier series, Fourier series on an arbitrary interval, The Riemann-Lebesgue lemma, Pointwise convergence, uniform convergence, differentiation, and integration of Fourier series; Fourier integrals.

UNIT-II: Integral Transform Methods (15 hours)

Fourier transforms, Properties of Fourier transforms, Convolution theorem of the Fourier transform, Fourier transforms of step and impulse functions, Fourier sine and cosine transforms, Convolution properties of Fourier transform; Laplace transforms, Properties of Laplace transforms, Convolution theorem and properties of the Laplace transform, Laplace transforms of the heaviside and Dirac delta functions.

UNIT-III: Applications of Integral Transforms (12 hours)

Finite Fourier transforms and applications, Applications of Fourier transform to ordinary and partial differential equations; Applications of Laplace transform to ordinary differential equations, partial differential equations, initial and boundary value problems.

Essential Readings

1. Tyn Myint-U & Lokenath Debnath (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhauser. Indian Reprint.
2. Lokenath Debnath & Dambaru Bhatta (2015). Integral Transforms and Their Applications (3rd ed.). CRC Press Taylor & Francis Group.

Suggestive Readings

- Baidyanath Patra (2018). An Introduction to Integral Transforms. CRC Press.
- Joel L. Schiff (1999). The Laplace Transform-Theory and Applications. Springer.
- Rajendra Bhatia (2003). Fourier Series (2nd ed.). Texts and Readings in Mathematics, Hindustan Book Agency, Delhi.
- Yitzhak Katznelson (2004). An Introduction to Harmonic Analysis (3rd ed.). Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(v): RESEARCH METHODOLOGY**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The main objective of this course is to:

- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:

- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE-3(v)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics; Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (<https://publicationethics.org/>)
3. Declaration on Research Assessment.
https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics;
(<https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874>)

5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (<https://www.d.umn.edu/~jgallian/goodPPtalk.pdf>). MATH HORIZONS.
6. L^aT_EX, Leslie (2008). L^aT_EX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.
10. Tantau, Till, Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group.
(<https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf>)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting L^aT_EX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running L^aT_EX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

B.Sc. (Physical Sciences/Mathematical Sciences) Semester-VII
Category-III

DISCIPLINE SPECIFIC CORE COURSE (DSC-7): NUMERICAL METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Numerical Methods	4	3	0	1	Class XII pass with Mathematics	Calculus, Real Analysis

Learning Objectives: The primary objective of this course is to introduce:

- Solutions of nonlinear equations in one variable by various methods.
- Interpolation and approximation, numerical differentiation, and integration.
- Direct methods for solving linear systems, numerical solution of ODE's.

Learning Outcomes: This course will enable the students to:

- Find the consequences of finite precision and the inherent limits of numerical methods.
- Appropriate numerical methods to solve algebraic and transcendental equations.
- Solve first order initial value problems of ODE's numerically using Euler methods.

SYLLABUS OF DSC-7

UNIT-I: Errors and Roots of Transcendental and Polynomial Equations (12 hours)

Errors: Roundoff error, Local truncation error, Global truncation error; Order of a method, Convergence, and terminal conditions; Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method.

UNIT-II: Algebraic Linear Systems and Interpolation (18 hours)

Gaussian elimination method (with row pivoting); Iterative methods: Jacobi method, Gauss-Seidel method; Interpolation: Lagrange form, Newton form, Finite difference operators.

UNIT-III: Numerical Differentiation, Integration and ODE (15 hours)

Numerical differentiation: First and second order derivatives; Numerical integration: Trapezoidal rule, Simpson's rule; Ordinary differential equation: Euler's method.

Essential Readings

1. Chapra, Steven C. (2018). Applied Numerical Methods with MATLAB for Engineers and Scientists (4th ed.). McGraw-Hill Education.
2. Fausett, Laurene V. (2009). Applied Numerical Analysis Using MATLAB. Pearson. India.
3. Jain, M. K., Iyengar, S. R. K., & Jain R. K. (2012). Numerical Methods for Scientific and Engineering Computation (6th ed.). New Age International Publishers. Delhi.

Suggestive Reading

- Bradie, Brian (2006). A Friendly Introduction to Numerical Analysis. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third Impression, 2011.

Note: Non programmable scientific calculator may be allowed in the University examination.

Practical / Lab work to be performed in Computer Lab: Use of computer algebra software (CAS), for example Mathematica/MATLAB/Maple/ Maxima/Scilab etc., for developing the following numerical programs:

1. Bisection method
2. Secant method and Regula-Falsi method
3. Newton-Raphson method
4. Gauss-Jacobi method and Gauss-Seidel method
5. Lagrange interpolation and Newton interpolation
6. Trapezoidal rule and Simpson's rule
7. Euler's method for solving first order initial value problems of ODE's.

DSE Courses of B.Sc. (Physical Sciences/Mathematical Sciences) Sem-VII**Category-III****DISCIPLINE SPECIFIC ELECTIVE COURSE – 5(i): ADVANCED LINEAR ALGEBRA****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Linear Algebra	4	3	1	0	Class XII pass with Mathematics	Linear Algebra

Learning Objectives: The objective of the course is to introduce:

- Linear functionals, dual basis and the dual (or transpose) of a linear transformation.
- Diagonalization problem and Jordan canonical form for linear operators or matrices using eigenvalues.
- Inner product, norm, Cauchy-Schwarz inequality, and orthogonality on real or complex vector spaces.
- The adjoint of a linear operator with application to least squares approximation and minimal solutions to linear system.
- Characterization of self-adjoint (or normal) operators on real (or complex) spaces in terms of orthonormal bases of eigenvectors and their corresponding eigenvalues.

Learning Outcomes: This course will enable the students to:

- Understand the notion of an inner product space in a general setting and how the notion of inner products can be used to define orthogonal vectors, including to the Gram-Schmidt process to generate an orthonormal set of vectors.
- Use eigenvectors and eigenspaces to determine the diagonalizability of a linear operator.
- Find the Jordan canonical form of matrices when they are not diagonalizable.
- Learn about normal, self-adjoint, and unitary operators and their properties, including the spectral decomposition of a linear operator.
- Find the singular value decomposition of a matrix.

SYLLABUS OF DSE-5(i)**UNIT-I: Dual Spaces, Diagonalizable Operators and Canonical Forms (18 hours)**

The change of coordinate matrix; Dual spaces, Double dual, Dual basis, Transpose of a linear transformation and its matrix in the dual basis, Annihilators; Eigenvalues, eigenvectors, eigenspaces and the characteristic polynomial of a linear operator; Diagonalizability, Direct sum of subspaces, Invariant subspaces, and the Cayley-Hamilton theorem; The Jordan canonical form and the minimal polynomial of a linear operator.

UNIT-II: Inner Product Spaces and the Adjoint of a Linear Operator (12 hours)

Inner products and norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel's inequality; Adjoint of a linear operator with applications to least squares approximation and minimal solutions to systems of linear equations.

UNIT-III: Class of Operators and Their Properties (15 hours)

Normal, self-adjoint, unitary and orthogonal operators and their properties; Orthogonal projections and the spectral theorem; Singular value decomposition for matrices.

Essential Reading

1. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2019). Linear Algebra (5th ed.). Pearson Education India Reprint.

Suggestive Readings

- Hoffman, Kenneth, & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.
- Lang, Serge (1987). Linear Algebra (3rd ed.). Springer.

DISCIPLINE SPECIFIC ELECTIVE COURSE-5(ii): ELEMENTS OF METRIC SPACES**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Metric Spaces	4	3	1	0	Class XII pass with Mathematics	Calculus, Real Analysis

Learning Objectives: The objective of the course is to introduce:

- The usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- The two important topological properties, namely connectedness, and compactness of metric spaces with their characterizations.

Learning Outcomes: This course will enable the students to:

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities.
- Analyse how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting.

SYLLABUS OF DSE-5(ii)**UNIT-I: Topology of Metric Spaces****(18 hours)**

Inequalities, Definition and examples, Sequences and Cauchy sequences, Complete metric space; Open and closed balls, Neighborhood, Open set, Interior of a set, Limit point of a set, Closed set, Closure of a set; Subspaces.

UNIT-II: Continuity and Uniform Continuity in Metric Spaces**(15 hours)**

Continuous mappings, Sequential criterion, and other characterizations of continuity; Uniform continuity; Homeomorphism, isometry, and equivalent metrics.

UNIT-III: Connected and Compact Spaces**(12 hours)**

Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings; Compactness and boundedness, Characterizations of compactness, Continuous functions on compact spaces.

Essential Reading

1. Shirali, Satish & Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Suggestive Reading

- Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.

DISCIPLINE SPECIFIC ELECTIVE COURSE-5(iii): MATHEMATICAL DATA SCIENCE**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Data Science	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of R/Python, Probability and Statistics

Learning Objectives: The main objective of this course is to:

- Introduce various types of data and their sources, along with steps involved in data science case-study, including problems with data and their rectification and creation methods.
- Cover dimensionality reduction techniques, clustering algorithms and classification methods.

Learning Outcomes: The course will enable the students to:

- Gain a comprehensive understanding of data science, its mathematical foundations including practical applications of regression, principal component analysis, singular value decomposition, clustering, support vector machines, and k -NN classifiers.
- Demonstrate data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation and regularization using R/Python.
- Use real-world datasets to practice dimensionality reduction techniques such as PCA, SVD, and multidimensional scaling using R/Python.

SYLLABUS OF DSE-5(iii)

UNIT-I: Principles of Data Science

(12 hours)

Types of Data: nominal, ordinal, interval, and ratio; Steps involved in data science case-study: question, procurement, exploration, modeling, and presentation; Structured and unstructured data: streams, frames, series, survey results, scale and source of data – fixed, variable, high velocity, exact and implied/inferred; Overview of problems with data – dirty and missing data in tabular formats – CSV, data frames in R/Pandas, anomaly detection, assessing data quality, rectification and creation methods, data hygiene, meta-data for inline data-description-markups such as XML and JSON; Overview of other data-source formats – SQL, pdf, Yaml, HDF5, and Vaex.

Unit-II: Mathematical Foundations

(15 hours)

Model driven data in R^n , Log-likelihoods and MLE, Chebyshev, and Chernoff-Hoeffding inequalities with examples, Importance sampling; Norms in Vector Spaces– Euclidean, and metric choices; Types of distances: Manhattan, Hamming, Mahalanobis, Cosine and angular distances, KL divergence; Distances applied to sets– Jaccard, and edit distances; Modeling text with distances; Linear Regression: Simple, multiple explanatory variables, polynomial, cross-validation, regularized, Lasso, and matching pursuit; Gradient descent.

Unit-III: Dimensionality Reduction, Clustering and Classification

(18 hours)

Problem of dimensionality, Principal component analysis, Singular value decomposition (SVD), Best k -rank approximation of a matrix, Eigenvector and eigenvalues relation to SVD, Multidimensional scaling, Linear discriminant analysis; Clustering: Voronoi diagrams, Delaunay triangulation, Gonzalez's algorithm for k -center clustering, Lloyd's algorithm for k -means clustering, Mixture of Gaussians, Hierarchical clustering, Density-based clustering and outliers, Mean shift clustering; Classification: Linear classifiers, Perceptron algorithm, Kernels, Support vector machines, and k -nearest neighbors (k -NN) classifiers.

Essential Readings

1. Mertz, David. (2021). Cleaning Data for Effective Data Science, Packt Publishing.
2. Ozdemir, Sinan. (2016). Principles of Data Science, Packt Publishing.
3. Phillips, Jeff M. (2021). Mathematical Foundations for Data Analysis, Springer.
(<https://mathfordata.github.io/>).

Suggestive Readings

- Frank Emmert-Streib, et al. (2022). Mathematical Foundations of Data Science Using R. (2nd ed.). De Gruyter Oldenbourg.
- Wes McKinney. (2022). Python for Data Analysis (3rd ed.). O'Reilly.
- Wickham, Hadley, et al. (2023). R for Data Science (2nd ed.). O'Reilly.

Practical (30 hours)- Practical work to be performed in Computer Lab using R/Python:

1. To explore different types data (nominal, ordinal, interval, ratio) and identify their properties.
2. To deal with dirty and missing data, such as imputation, deletion, and data normalization.
3. Use the real-world datasets (<https://data.gov.in/>) to demonstrate the following:
 - e) Data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation, and regularization.
 - f) Dimensionality reduction techniques such as principal component analysis, singular value decomposition (SVD), and multidimensional scaling.
 - g) Clustering algorithms such as k -means, hierarchical, and density-based clustering and evaluate the quality of the clustering results.
 - h) Classification methods such as linear classifiers, support vector machines (SVM), and k -nearest neighbors (k -NN).

DISCIPLINE SPECIFIC ELECTIVE COURSE-5(iv): INTEGRAL TRANSFORMS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Integral Transforms	4	3	1	0	Class XII pass with Mathematics	Differential Equations, Elementary Mathematical Analysis

Learning Objectives: Primary objective of this course is to introduce:

- The basic idea of integral transforms of functions and their applications through an introduction to Fourier series expansion of a periodic function.
- Fourier transform and Laplace transform of functions of a real variable with applications to solve ODE's and PDE's.

Learning Outcomes: The course will enable the students to:

- Understand the Fourier series associated with a periodic function, its convergence, and the Gibbs phenomenon.
- Compute Fourier and Laplace transforms of classes of functions.
- Apply techniques of Fourier and Laplace transforms to solve ordinary and partial differential equations and initial and boundary value problems.

SYLLABUS OF DSE-5(iv)

UNIT-I: Fourier Series and Integrals

(18 hours)

Piecewise continuous functions and periodic functions, Systems of orthogonal functions, Fourier series: Convergence, examples and applications of Fourier series, Fourier cosine series and Fourier sine series, The Gibbs phenomenon, Complex Fourier series, Fourier series on an arbitrary interval, The Riemann-Lebesgue lemma, Pointwise convergence, uniform convergence, differentiation, and integration of Fourier series; Fourier integrals.

UNIT-II: Integral Transform Methods

(15 hours)

Fourier transforms, Properties of Fourier transforms, Convolution theorem of the Fourier transform, Fourier transforms of step and impulse functions, Fourier sine and cosine transforms, Convolution properties of Fourier transform; Laplace transforms, Properties of Laplace transforms, Convolution theorem and properties of the Laplace transform, Laplace transforms of the heaviside and Dirac delta functions.

UNIT-III: Applications of Integral Transforms

(12 hours)

Finite Fourier transforms and applications, Applications of Fourier transform to ordinary and partial differential equations; Applications of Laplace transform to ordinary differential equations, partial differential equations, initial and boundary value problems.

Essential Readings

1. Tyn Myint-U & Lokenath Debnath (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhauser. Indian Reprint.
2. Lokenath Debnath & Dambaru Bhatta (2015). Integral Transforms and Their Applications (3rd ed.). CRC Press Taylor & Francis Group.

Suggestive Readings

- Baidyanath Patra (2018). An Introduction to Integral Transforms. CRC Press.
- Joel L. Schiff (1999). The Laplace Transform-Theory and Applications. Springer.
- Rajendra Bhatia (2003). Fourier Series (2nd ed.). Texts and Readings in Mathematics, Hindustan Book Agency, Delhi.
- Yitzhak Katznelson (2004). An Introduction to Harmonic Analysis (3rd ed.). Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE-5(v): RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The main objective of this course is to:

- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:

- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE-5(v)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics;

Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (<https://publicationethics.org/>)
3. Declaration on Research Assessment.
https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics;
(<https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874>)
5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (<https://www.d.umn.edu/~jgallian/goodPPTalk.pdf>). MATH HORIZONS.
6. Lamport, Leslie (2008). LaTeX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.
10. Tantau, Till, Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group.
(<https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf>)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

**COMMON POOL OF GENERIC ELECTIVES (GE) Semester-VII COURSES OFFERED
BY DEPARTMENT OF MATHEMATICS**

Category-IV

GENERIC ELECTIVES (GE-7(i)): APPLIED ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Applied Algebra	4	3	1	0	Class XII pass with Mathematics	Linear Algebra, Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Introduce the applications of linear algebra in the field of science and arts.
- Develop the analytical and numerical skills to apply the algebraic concepts in real-life situations.
- Understand the identification numbers and different check digit schemes that can be used to reduce the errors during their transmission.

Learning Outcomes: This course will enable the students to:

- Understand the system of linear equations, matrices, and transformations in the fields of economics, science, engineering, and computer science.
- Apply the combinatorics and graph theory in scheduling and reliability theory.
- Learn about identification numbers and using check digits to check for errors after the identification number has been transmitted.

SYLLABUS OF GE-7(i)

UNIT-I: Applications of Linear Algebra (15 hours)

Applications of linear systems: Leontief input-output model in economics, Traffic flow, and diet problem; Applications to computer graphics, difference equations and Markov chains; Applications to linear models: Least-squares problems, and least-squares lines.

UNIT-II: Latin Squares and Graph Models (12 hours)

Latin squares, Table for a finite group as a Latin square, Latin squares as in design of experiments; Mathematical models for matching jobs, Spelling checker, Network reliability, Street surveillance, Scheduling meetings, Interval graph modeling and Influence model, Pitcher pouring puzzle.

UNIT-III: Various Check Digit Schemes**(18 hours)**

Developing identification numbers, Types of identification numbers, Transmission errors, Check digits, Integer division, Modular arithmetic, US postal money orders, Airline ticket identification numbers, The Universal Product Code check digit scheme, ISBN check digit scheme, Creating Identification numbers, IBM scheme, Symmetry, Symmetry and Rigid motions, Verhoeff check digit scheme.

Essential Readings

1. David C. Lay, Steven R. Lay and Judi J. McDonald (2016). Linear Algebra and Its Applications (5th ed.). Pearson.
2. Tucker, Alan (2012). Applied Combinatorics (6th ed.). John Wiley & Sons, Inc.
3. Kirtland, Joseph (2001). Identification Numbers and Check Digit Schemes. Mathematical Association of America.

Suggestive Readings

- Andirilli, Stephen and Hecker, David (2016). Elementary Linear Algebra (5th ed.). Academic Press, Elsevier.
- Lidl, Rudolf and Pilz, Günter (1998). Applied Abstract Algebra (2nd ed.). Springer. Indian Reprint 2014.
- Strang, Gilbert (2016). Introduction to Linear Algebra (5th ed.). Wellesley-Cambridge.

GENERIC ELECTIVES (GE-7(ii)): ELEMENTS OF METRIC SPACES**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Metric Spaces	4	3	1	0	Class XII pass with Mathematics	Calculus, Real Analysis

Learning Objectives: The objective of the course is to introduce:

- The usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- The two important topological properties, namely connectedness, and compactness of metric spaces with their characterizations.

Learning Outcomes: This course will enable the students to:

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities.
- Analyse how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting.

SYLLABUS OF GE-7(ii)**UNIT-I: Topology of Metric Spaces****(18 hours)**

Inequalities, Definition and examples, Sequences and Cauchy sequences, Complete metric space; Open and closed balls, Neighborhood, Open set, Interior of a set, Limit point of a set, Closed set, Closure of a set; Subspaces.

UNIT-II: Continuity and Uniform Continuity in Metric Spaces**(15 hours)**

Continuous mappings, Sequential criterion, and other characterizations of continuity; Uniform continuity; Homeomorphism, isometry, and equivalent metrics.

UNIT-III: Connected and Compact Spaces**(12 hours)**

Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings; Compactness and boundedness, Characterizations of compactness, Continuous functions on compact spaces.

Essential Reading

1. Shirali, Satish & Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Suggestive Reading

- Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House.

GENERIC ELECTIVES (GE-7(iii)): INTRODUCTION TO GRAPH THEORY**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Graph Theory	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- Problem-solving techniques using various concepts of graph theory.
- Various properties like planarity and chromaticity of graphs.
- Several applications of these concepts in solving practical problems.

Learning Outcomes: This course will enable the students to:

- Good familiarity with all initial notions of graph theory and related results and seeing them used for some real-life problems.
- Learning notion of trees and their enormous usefulness in various problems.
- Learning various algorithms and their applicability.
- Studying planar graphs, Euler theorem associated to such graphs and some useful applications like coloring of graphs.

SYLLABUS OF GE-7(iii)**UNIT-I: Graphs, Types of Graphs and Basic Properties****(12 hours)**

Graphs and their representation, Pseudographs, Subgraphs, Degree sequence, Euler's theorem, Isomorphism of graphs, Paths and circuits, Connected graphs, Euler trails and circuits, Hamiltonian paths and cycles, Adjacency matrix, Weighted graphs, Travelling salesman problem, Dijkstra's algorithm.

UNIT-II: Directed Graphs and Applications, Trees**(18 hours)**

The Chinese postman problem; Digraphs, Bellman-Ford algorithm, Tournaments, Directed network, Scheduling problem; Trees and their properties, Spanning trees, Kruskal's algorithm, Prim's algorithm, Acyclic digraphs and Bellman's algorithm.

UNIT-III: Planar Graphs, Graph Coloring and Network Flows**(15 hours)**

Planar graphs, Euler's formula, Kuratowski theorem, Graph coloring, Applications of graph coloring, Circuit testing and facilities design, Flows and cuts, Max flow-min cut theorem, Matchings, Hall's theorem.

Essential Reading

1. Goodaire, Edgar G., & Parmenter, Michael M. (2011). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint.

Suggestive Readings

- Bondy, J. A. & Murty, U.S.R. (2008), Graph Theory with Applications. Springer.
- Chartrand, Gary, & Zhang, P. (2012). A First Course in Graph Theory. Dover Publications.
- Diestel, R. (1997). Graph Theory (Graduate Texts in Mathematics). Springer Verlag.
- West, Douglas B. (2001). Introduction to graph theory (2nd ed.). Pearson India.

GENERIC ELECTIVES (GE-7(iv)): TOPICS IN MULTIVARIATE CALCULUS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Topics in Multivariate Calculus	4	3	1	0	Class XII pass with Mathematics	Calculus

Learning Objectives: The primary objective of this course is to introduce the:

- Extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Applications of multivariable calculus tools to physics, economics, and optimization.

- Geometry and visualisation of curves and surfaces in two dimensions (plane) and three dimensions (space).
- Techniques of integration to functions of two and three independent variables.

Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems.

SYLLABUS OF GE-7(iv)

UNIT-I: Calculus of Functions of Several Variables (18 hours)

Basic Concepts, Limits and Continuity, Tangent Planes, Partial Derivatives, Total Differential, Differentiability, Chain Rules, Directional Derivatives and the Gradient, Extrema of Functions of Two Variables, Method of Lagrange multipliers with one constraint.

UNIT-II: Double and Triple Integrals (15 hours)

Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

UNIT-III: Green's, Stokes' and Gauss Divergence Theorem (12 hours)

Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, Gauss divergence theorem.

Essential Reading

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.

Suggestive Reading

- Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.

Syllabi of Semester - VIII based on UGCF - 2022**DEPARTMENT OF MATHEMATICS****Category-I****B.Sc. (Hons.) Mathematics, Semester-VIII****DISCIPLINE SPECIFIC CORE COURSE (DSC)– 20: FIELD THEORY AND GALOIS EXTENSION****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Field Theory and Galois Extension	4	3	1	0	Class XII pass with Mathematics	Group Theory, Ring Theory

Learning Objectives: The objective of the course is to introduce:

- Tools of field theory such as field extensions, splitting fields, normal extensions, separability, and separable extensions.
- Galois extensions and the Fundamental theorem of Galois theory.
- Link between group theory and the roots of polynomials, developed by Galois, to solve the problem of solvability of polynomial equations by radicals.
- Some applications, such as cyclotomic polynomials, finite fields, and simple extensions.

Learning Outcomes: This course will enable the students to:

- Identify and construct examples of fields, distinguish between algebraic and transcendental extensions, and characterize normal extensions in terms of splitting fields.
- Identify and characterize separable extensions, define Galois extensions, construct examples of automorphism groups of a field as well as prove the fundamental theorem of Galois theory.
- Use the Galois theory of equations to prove that a polynomial equation over a field is solvable by radicals if and only if its Galois group is solvable and hence deduce that a general quintic equation is not solvable by radicals.
- Define cyclotomic polynomials and find its Galois group using roots of unity, classify finite fields and prove that every finite separable extension is simple.

SYLLABUS OF DSC-20**UNIT – I: Field Extensions****(15 hours)**

Fields and prime subfields, Field extensions, Degree of field extensions, Tower theorem, Algebraic and transcendental elements, Algebraic and transcendental extensions, Monomorphism of field extensions, Ruler and compass constructions, Splitting fields, Extensions of monomorphisms, Uniqueness of splitting field.

UNIT – II: Galois Extensions and the Fundamental Theorem (15 hours)

Normal extensions, Separability and separable extensions, Monomorphisms and automorphisms of field extension, Galois extensions, Automorphism/Galois groups and fixed fields, Galois theory of polynomials, The fundamental theorem of Galois theory.

UNIT – III: Some Applications and Solvability by Radicals (15 hours)

The Discriminant, Cyclotomic polynomials, extensions and its Galois group, Solution by radicals, Existence and Uniqueness of finite fields, Simple extensions, and the primitive element theorem.

Essential Readings

1. Garling, D. J. H. (2021). Galois Theory and Its Algebraic Background (2nd ed.). Cambridge University Press.
2. Dummit, David S., and Foote, Richard M. (2011). Abstract Algebra (3rd ed.). Wiley.

Suggestive Readings

- Stewart, Ian (2022). Galois Theory (5th ed.). CRC Press. Chapman and Hall.
- Cox, David A. (2012). Galois Theory (2nd ed.). John Wiley & Sons.
- Cohn, P. M. (2003). Basic Algebra, Springer International Edition.

DSE Courses of B.Sc. (Hons) Mathematics, Semester -VIII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(i): ADVANCED MECHANICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Mechanics	4	3	1	0	Class XII pass with Mathematics	Calculus, Differential Equations, Mechanics

Learning Objectives: The main objective of this course is to:

- Provide the students an enriching experience of the basic concepts of mechanics in space and its related concepts.
- Impart quality understanding to the students about Newtonian, Lagrangian and Hamiltonian mechanics along with practical applications of these concepts in real life.
- Understand the concept of fluid, their classifications, model, and approaches to study the fluid flow.

Learning Outcomes: This course will equip the students with the:

- Fundamental concepts of force systems, generalized coordinates, kinematics of a particle and a rigid body.
- Thorough and in depth understanding of the classification of dynamical systems, Lagrangian and Hamiltonian's equations.
- Formulation of mass and momentum conservation principle; solution for non-viscous flow, the motion of sphere, cylinder, and two-dimensional flow.
- Understanding of the concepts of stress and strain in viscous flow; derivation of Navier-Stokes equation of motion and related problems.

SYLLABUS OF DSE-6(i)

UNIT – I: Newtonian Mechanics

(15 hours)

General force systems, Equilibrium of a system of particles, Reduction of a force systems, Equilibrium of a rigid body, Generalized coordinates and constraints, Work and potential energy, Kinematics of a particle and a rigid body. Moments and product of inertia. Kinetic energy and angular momentum, Motion of a particle and a system, Moving frame of reference, Motion of a rigid body.

UNIT – II: Lagrangian and Hamiltonian Mechanics

(12 hours)

Lagrange's equations for a particle in plane, Classification of dynamical systems, Lagrange's equations for any simple dynamical system, general dynamical system and for impulsive motion; Applications of Lagrange's equations, Hamiltonian and the Canonical equations of motion, The passage from the Hamiltonian to the Lagrangian, Conservative systems.

UNIT – III: Fluid Mechanics**(18 hours)**

Classification of fluids, Continuum model, Eulerian and Lagrangian approach of description, Differentiation following the fluid motion, Velocity of a fluid particle, Irrotational flow, Velocity potential, Equipotential surfaces, Streamlines and Pathlines, Mass flux density, Conservation of mass leading to equation of continuity, Boundary surface; Forces in fluid flows, Conservation of linear momentum and its mathematical formulation (Euler's equation of motion), Bernoulli's equation, Axi-symmetric flows and motion of sphere; Two-dimensional flows, Motion of cylinder, Stream function, Complex potential, Line sources and line sinks, Line doublet, Milne-Thomson circle theorem; Viscous flow, Stress components in a real fluid, Stress and strain analysis, Navier-Stokes equations of motion and its applications.

Essential Readings

1. Chorlton, F. (2005). Textbook of Fluid Dynamics. CBS Publishers, Delhi. Reprint 2018.
2. Synge, J. L. and Griffith, B. A. (2017). Principles of Mechanics (3rd ed.). McGraw-Hill Education. Indian Reprint.

Suggestive Readings

- Gantmacher, F. (1975). Lectures in Analytic Mechanics. MIR publisher, Moscow.
- Goldstein, H., Poole, C.P. and Safco, J.L. (2002). Classical Mechanics. (3rd ed.). Addison Wesley.
- Kundu, Piyush K. and Cohen, Ira M., Dowling, David R. (2016). Fluid Mechanics (6th ed.). Academic Press.
- Mitchell, John W. (2020). Fox and McDonald's Introduction to Fluid Mechanics. (10th ed.). John Wiley & Sons.
- Taylor, John R. (2005). Classical Mechanics. University Science Books.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(ii): CRYPTOGRAPHY**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Cryptography	4	3	1	0	Class XII pass with Mathematics	Group Theory, Linear Algebra

Learning Objectives: Primary objective of this course is to:

- Learn challenges and types of attacks on the security of cryptographic protocols.
- Understand concept of confusion and diffusion, that is central to the security of symmetric key cryptography.
- Learn mathematical hard problems, which can be used to build various public key cryptosystems.
- Gain knowledge of post quantum cryptography that resist quantum attacks.

Learning Outcomes: This course will enable the students to:

- Learn classical cryptosystems Caesar cipher, Monoalphabetic cipher, Hill cipher, Vigenère cipher and their security analysis.
- Understand Feistel cipher structure to achieve confusion and diffusion in case of Data Encryption Standard (DES).
- Understand Advanced Encryption Standard (AES) structure and its operations along with key generation.
- Learn key sharing protocol – Diffie Hellman key exchange, Public-key cryptosystems – RSA, Elgamal, and Elliptic curve cryptography.
- Learn Lagrange interpolation secret sharing scheme.
- Learn hash functions and their applications, digital signatures scheme.
- Gain knowledge of code-based cryptography – McEliece cryptosystem.

SYLLABUS OF DSE-6(ii)

UNIT–I: Classical Cryptosystems and Review of Finite Fields (15 hours)

Overview of Cryptography, Symmetric key and Public-key cryptography, Security attacks, Relation between key length and security, Objectives and applications of cryptography primitives, Types of attacks from cryptanalyst view, Kerckhoff's principle; Substitution techniques - Caesar cipher, Monoalphabetic cipher, Hill cipher, Vigenère cipher, One-time pad; Euclidean Algorithm, Modular Arithmetic, Statement of Fermat's, Euler's and Chinese Remainder theorems, Discrete logarithm, Finite fields of the form $GF(p)$ and $GF(2^n)$, Binary and ASCII representation, Pseudo-random bit generation.

UNIT – II: Modern Block Ciphers (12 hours)

Introduction to stream and block ciphers, Diffusion and Confusion, The Feistel cipher Structure, Data Encryption Standard (DES); Advanced Encryption Standard (AES) Structure, AES transformation functions, Key expansion, AES Example.

UNIT – III: Public-key Cryptography, Hash Functions, Digital Signatures and Post Quantum Cryptography (18 hours)

Introduction to Public key cryptography, RSA cryptosystem, Diffie Hellman key exchange, Man in the middle attack, Elgamal cryptosystem, Elliptic curve arithmetic, Elliptic curve cryptography, Secret sharing; Hash functions, Applications of hash functions – MAC and digital signature, Simple Hash functions, Security requirements of Hash functions, Properties of SHA family of hash functions; Digital signatures, Elgamal and Schnorr digital signature scheme; Introduction to post quantum cryptography, Linear codes, Generating matrix, Parity check matrix, McEliece cryptosystem.

Essential Readings

1. Stallings, William (2023). Cryptography and Network Security, Principles and Practice (8th ed.). Pearson Education Limited. Global Edition.
2. Stinson, Douglas R. and Paterson, Maura, B. (2019). Cryptography: Theory and Practice (4th ed.). CRC Press.
3. Trappe, Wade and Washington, Lawrence C. (2020). Introduction to Cryptography with Coding Theory (3rd ed.). Pearson Education International.

Suggestive Readings

- Hoffstein, Jeffrey. Pipher, Jill & Silverman, Joseph H. (2014). An Introduction to Mathematical Cryptography (2nd ed.). Springer New York.
- Goldreich O. (2005). Foundations of Cryptography: Basic tools - Vol.1, Cambridge University Press.
- Goldreich O. (2009). Foundations of Cryptography: Vol.2, Basic applications, Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(iii): INDUSTRIAL MATHEMATICS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Industrial Mathematics	4	3	0	1	Class XII pass with Mathematics	Calculus, Real Analysis, Linear Algebra, Ordinary and Partial Differential Equations

Learning Objectives: The main objective of this course is to:

- Orient the learners to understand nature and working of industrial systems and their models.
- Familiarize the learners with control and maneuvering of industrial processes through sample case-studies and encourage design-thinking and understanding.

Learning Outcomes: This course will enable the students to:

- Determine the controllability, stability, and observability of a system from the model description.
- Comprehend the signal processing landscape and analyse signals using real and spatial domain representations.
- Model/analyse an industrial system from its description and use mathematical formulations to investigate and manipulate the system for specific objectives.

SYLLABUS OF DSE-6(iii)**UNIT – I: Understanding Systems from their Mathematical Description (15 hours)**

Continuous-time linear systems, Laplace transform, Transfer function and analogous systems, State-space models, Block-diagram algebra, Signal flow graph, Order of a system and reduced-order models; Discrete-time systems, Z-transform and its inverse, Feedback systems, Stability: Routh-Hurwitz criterion, Root locus method, Controllability and Observability.

UNIT – II: Mathematical Tools for Signals (15 hours)

Signal-to-noise ratio, Analog and digital messages, Channel bandwidth and rate of communication, Modulation, Randomness and redundancy; Signal energy and power, Period and aperiodic signals, Signal operations, Unit impulse function, Vector representation of signals, Orthogonality, Correlation of signals, Signal representation by orthogonal signal sets.

UNIT – III: Case Studies**(15 hours)**

Sample Cases: Continuous casting, Water filtration, Factory fires, Irrigation.

Essential Readings

1. Fulford, Glenn R., and Broadbridge, Philip (2002). Industrial Mathematics: Case Studies. Cambridge University Press.
2. Kheir, Naim A. (Ed.). (1996). Systems Modeling and Computer Simulation, CRC Press.
3. Lathi, B.P., and Ding, Zhi (2019). Modern Digital and Analog Communication Systems (5th ed.). Oxford University Press.

Suggestive Readings

- Friedman A., and Littman W. (1994). Industrial Mathematics: A Course in Solving Real-World Problems. SIAM (Society for Industrial and Applied Mathematics).
- Kreyszig, Erwin (2011). Advance Engineering Mathematics (10th ed.). John Wiley & Sons.
- MacClauer, Charles R. (2000). Industrial Mathematics: Modeling in Industry, Science, and Government. Prentice Hall, Inc.

Practical (30 hours)- Practical/Lab work using:

Mathematica/MATLAB/SciLab/C/C++/Python/R/FORTRAN or similar as per availability.

1. Use following methods to study, describe, and evaluate continuous/discrete systems:
 - (a) Root locus method.
 - (b) Routh-Horowitz criterion.
 - (c) Transfer function using Laplace transform.
 - (d) z-transform to convert continuous systems to equivalent discrete systems.
2. To apply controllability and observability analysis on a system description, using corresponding tools/libraries available.
3. To represent a signal/wave as vector data (sampling, choosing basis, and checking orthogonality).
4. To convolve and deconvolve signal/wave functions and represent the result as graphs.

Case Studies:

Besides reading the mentioned case-studies, ONE case may be chosen (in consultation with the instructor) as Semester Assignment for a brief similar study and analysis.

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(iv):
GEOMETRY OF CURVES AND SURFACES**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Geometry of Curves and Surfaces	4	3	1	0	Class XII pass with Mathematics	Calculus

Learning Objectives: The main objective of this course is to:

- Introduces the concept of curves and surfaces in Euclidean spaces $\mathbb{R}^n$.
- Study of the curves and surfaces via the tools of calculus and introduction of concepts like first and second fundamental forms, curvatures, and differential forms.
- Complete the celebrated Gauss-Bonnet theorem that establishes a connection between curvature of a geometric object with its topology.

Learning Outcomes: This course will enable the students to:

- Understand the concept of curves and surfaces embedded in the Euclidean spaces $\mathbb{R}^n$.
- Compute the curvature and torsion for a curve in the space.
- Understand the concept of differential forms and their integration.
- Make sense of the infinitesimal distance element via the study of the Riemannian metric.
- Get prepared to venture into further study of modern differential geometry of manifolds.

SYLLABUS OF DSE-6(iv)

UNIT – I: Geometry of Curves

(15 hours)

Concept of plane and space curves with examples, Parametrized plane and space-curves, Concepts of curvatures for curves, Frenet-Serret's formula for space curves, Global theorems for plane and space curves.

UNIT – II: Local Theory of Surfaces in the Space

(15 hours)

Concept of surfaces in the space with examples, Fundamental forms and curvatures with examples, Orthonormal frames, Exterior differential forms in two variables and their uses.

UNIT – III: Geometry of Surfaces

(15 hours)

Riemannian metric on a surface, Vector fields, Covariant derivatives, Concept of geodesic, Integration of exterior differential forms, Gauss-Bonnet theorem.

Essential Reading

1. Kobayashi, Shoshichi (2019). Differential Geometry of Curves and Surfaces. Springer Nature Singapore Pte Ltd. <https://doi.org/10.1007/978-981-15-1739-6>

Suggestive Readings

- Abbena Elsa, Salamon Simon, and Gray Alfred (2006). Modern Differential Geometry of Curves and Surfaces with Mathematica (3rd ed.). CRC Press.
- Carmo, Manfredo P. Do (2016). Differential Geometry of Curves and Surfaces (Revised and Updated Second Edition). Dover Publications.
- Pressley, Andrew (2010). Elementary Differential Geometry (2nd ed.). Springer-Verlag.
- Tapp, Kristopher (2016). Differential Geometry of Curves and Surfaces. Springer.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(v): INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Integral Equations and Calculus of Variations	4	3	1	0	Class XII pass with Mathematics	Ordinary, and Partial Differential Equations, Multivariate Calculus

Learning Objectives: The main objective of this course is to:

- Familiarize the learner with methods for solving Volterra and Fredholm integral equations.
- Know the determination of extremum of functional, necessary condition for an extremum, Euler's equation, and its generalization.

Learning Outcomes: This course will enable the students to:

- Compute the solutions to Volterra integral equations by method of resolvent kernel, method of successive approximations, method of Laplace transform, system of Volterra integral equations and integro-differential equation.
- Determine the solutions of Fredholm integral equations and derivation of Hilbert-Schmidt theorem.
- Understand the formulation of variational problems, the variation of a functional and its properties, extremum of functional, necessary condition for an extremum.

SYLLABUS OF DSE-6(v)

UNIT – I: Volterra Integral Equations

(12 hours)

Integral equations, Introduction and relation with linear differential equations; Volterra integral equations and its solutions, Method of resolvent kernel, Method of successive approximations, Convolution type of equation, Method of Laplace transform, System of Volterra integral equations, Integro-differential equation, Abel's integral equation and its generalizations.

UNIT – II: Fredholm Integral Equations

(18 hours)

Fredholm integral equations and its solutions, Method of resolvent kernels, Method of successive approximations, Integral equations with degenerate kernels, Eigenvalues and eigen functions and their properties, Hilbert-Schmidt theorem, Nonhomogeneous Fredholm integral equation with symmetric kernel, Fredholm alternative.

UNIT – III: Calculus of Variations**(15 hours)**

Variational problems, Variation of a functional and its properties, Extremum of functional, Necessary condition for an extremum, Euler's equation and its generalization, Variational derivative, General variation of a functional and variable end point problem, Sufficient conditions for the extremum of a functional.

Essential Readings

1. Gelfand, I. M. and Fomin, S.V. (2000). Calculus of Variations. Dover Publications, Inc.
2. Krasnov, M., Kiselev, A. and Makarenko, G. (1971). Problems and Exercises Integral Equations, Mir Publication Moscow.
3. Logan, J. David (1987). Applied Mathematics: A Contemporary Approach, John Wiley & Sons, Inc.

Suggestive Readings

- Hildebrand, F. B. (1992). Methods of Applied Mathematics (2nd ed.). Dover Publications.
- Zemyan, Stephen M. (2012). The Classical Theory of Integral Equations: A Concise Treatment. Birkhäuser.

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(vi):
MACHINE LEARNING: A MATHEMATICAL APPROACH**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Machine Learning: A Mathematical Approach	4	3	0	1	Class XII pass with Mathematics	Basic Knowledge of Python

Learning Objectives: The main objective of this course is to:

- Gain mathematical insights into the functioning of popular methods of Regression, Classification, Clustering and Dimension reduction.
- Understand the mathematical framework of learning and apply it to assess the performance of a number of regression, classification and density estimation algorithms
- Detect overfitting and employ regularization techniques to control it.

Learning Outcomes: This course will enable the students to:

- Learn how to build popular models of regression and classification including Linear regression, Polynomial regression, Logistic classifier, Support vector machine, Decision Tree, Random forests, Naïve Bayes classifier.
- Evaluate the performance of models on test data through analytical techniques (VC bounds and dimension) and Cross-validation to facilitate model selection and feature selection.
- Improve model performance by controlling overfitting through regularization techniques like Ridge and Lasso.

- Understand when to apply dimension reduction and combine it with other supervised learning methods.
- Understand and implement the key principles of Artificial Neural Networks in the context of regression and classification and employ them in function approximation.

SYLLABUS OF DSE-6(vi)

UNIT – I: Introduction to Machine Learning and its Applications (18 hours)

Overview of different tasks: Regression, Classification, and Clustering. Evaluation metrics– Mean Absolute error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE). Linear Regression, Cost function, Polynomial Regression, Gradient Descent Algorithm (GDA). Logistic Regression: Evaluation metrics - accuracy, precision, recall, confusion matrix, Receiver Operating Characteristic Curve (ROC curve) and Area Under ROC Curve (AUC), Vapnik-Chervonenkis (VC) dimension, VC bounds (only statement). k -fold validation, Concepts of training set, validation set and test set, Underfitting-Overfitting, Regularization techniques– Ridge, Lasso for Linear Regression and Logistic Regression, Bias-variance tradeoff.

UNIT – II: Popular Machine Learning Techniques (18 hours)

Cross-entropy and Gini Index, Decision Tree, Regression Tree, Random Forest and Bagging, Tree Pruning. Support Vector Machine (SVM), Kernel SVM (Gaussian) Similarity Criterion, k -Means clustering technique. Naive Bayes classifier- Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA). Dimensionality Reduction, Feature Selection, Principal Component Analysis (PCA).

UNIT – III: Introduction to Deep Learning (9 hours)

Artificial neural network (ANN), Activation functions – definition and examples (Sigmoid, ReLU, Tanh), neurons, layers, Cost function, Information passing, Back propagation algorithm, Optimizers, Learning rate, Statement of Universal Approximation Theorem for continuous functions, Regularization with ANN, Normalization.

Essential Readings

1. Abu-Mostafa, Y. S., Magdon-Ismael, M. & Lin, H.-T. (2012), Learning from Data, AML Book.
2. James, Gareth., Witten, D., Hastie, T., Tibshirani, R. and Taylor, J. (2023), An Introduction to Statistical Learning: with Applications in Python, Springer Nature Switzerland.
3. Ovidiu Calin, Springer. (2020). Deep Learning Architectures: A Mathematical Approach, Springer Nature Switzerland.

Suggestive Readings

- Deisenroth, M. P., Faisal, A. A., and Ong, C. S. (2020), Mathematics for Machine Learning, Cambridge University Press.
- Shalev-Shwartz, S., and Ben-David, S. (2014), Understanding Machine Learning - From Theory to Algorithms, Cambridge University Press.
- Phillips, Jeff. (2020), Mathematical Foundations for Data analysis, Springer.
- Goodfellow, I., Bengio, Y., and Courville, A. (2016), Deep Learning, MIT Press.
- Hastie, T.; Tibshirani, R., and Friedman, J. (2001), The Elements of Statistical Learning, Springer New York Inc.

Practical (30 hours)- Practical work to be performed in computer lab using Python.

Following lab exercises should be done for at least two classification problems or two regression problems or both, whenever applicable.

Following datasets can be used for classification problems

- https://scikit-learn.org/stable/datasets/toy_dataset.html
(Toy datasets, Iris plants dataset, handwritten digits dataset, Wine recognition dataset, Breast cancer diagnostic dataset)
- <https://pypi.org/project/ISLP/>
(Smarket dataset)

Following datasets can be used for regression problems

- <https://scikit-learn.org/0.15/modules/classes.html#module-sklearn.datasets>
(Diabetes dataset, Boston house dataset, California housing dataset, Advertising dataset)

Following tasks need to be performed for the below mentioned ML techniques in scikit learn (<https://scikit-learn.org/stable/>), whenever applicable:

- Split the dataset into two parts: training and test. Create and train model on training set and report model performance on test set.
- Test the model performance using k -fold cross validation (take $k = 5$ or 10) in terms of applicable metrics like – Accuracy, Precision, Recall, MAE, RMSE etc.
- Finding optimal parameters using Grid Search CV, whenever applicable; for example: in case of polynomial regression, employ Grid search CV to find the optimal value of the degree d for which the MSE is least.

Practicals List:

1. Create a Linear regression model. Use one variable at a time, all variable at a time, and statistically significant variables (using co-relation matrix) at a time, and observe the model performance. Preferably work with advertising dataset to predict sales in terms of the above features.
2. Fix a 10th order polynomial and sample 15 noisy data points (that is all 15 points do not lie on this polynomial). This is usually done by adding a white noise $\epsilon \sim N(0,1)$ to the polynomial $f(x)$. Using polynomial regression fit two models: one of order 10 and one of order 2. Compare the in-sample and out-sample errors for both models. Try to observe underfitting-overfitting, if any. In another scenario, take $f(x)$ to be a polynomial of order 50 and sample 15 noiseless data points (all lie on the graph of $f(x)$) and again fit a polynomial model of order 2 and 10. Compare the in-sample and out-sample errors. (refer to Exercise 4.2 and Problem 4.4 of [1]).
3. On the Smarket data, predict direction based on features Lag1 and Lag2. Split the Smarket dataset into training and testing parts in the ratio 80-20. Fit logistic regression on the training data and evaluate its accuracy on the test data via confusion matrix, ROC, and AUC. Plot decision boundary for the logistic regression in the 2D feature space spanned by Lag1 and Lag2 (you might need to rescale the variables).
4. Create decision tree models for classification and regression. Observe the effect of various parameters like - splitting criterion (Gini index, Cross entropy), max depth (for tree pruning). Examine overfitting-underfitting in the associated tree model. Display a decision tree.
5. Create Random Forest models for classification and regression. Observe the effect of number of estimators in the context of overfitting.

6. Create SVM models for classification and regression. Observe the effect of the parameter - kernel.
7. Create LDA and QDA models and assess them preferably on the digits dataset.
8. Create k -means cluster model for clustering. Observe the effect of parameter k (number of clusters). Plot k versus error to find out best k (Elbow criterion). Plot clusters in case of 2-dimensional data.
9. Demonstrate Principal Component Analysis (PCA) on a dataset with large number of features.
10. Create an ANN model for both classification and regression. Observe the effect of parameters- hidden layer sizes, activation functions (ReLU, Logistic/Sigmoid, Tanh), optimizers (Adam, Sgd), batch size, learning rate, early stopping, validation fraction, maximum number of iterations. Plot iteration number versus accuracy on training and validation dataset. The mnist dataset may be used to explore real strength of ANN. (<https://www.kaggle.com/datasets/oddratone/mnist-in-csv?resource=download> in csv format).

B.A. (Prog.) Semester-VIII with Mathematics as Major
Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-8): TOPICS IN MULTIVARIATE CALCULUS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Topics in Multivariate Calculus	4	3	0	1	Class XII pass with Mathematics	Calculus

Learning Objectives: The primary objective of this course is to introduce the:

- Extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Applications of multivariable calculus tools to physics, economics, and optimization.
- Geometry and visualisation of curves and surfaces in two dimensions (plane) and three dimensions (space).
- Techniques of integration to functions of two and three independent variables.

Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems.

SYLLABUS OF DSC-8

UNIT-I: Calculus of Functions of Several Variables

(18 hours)

Basic Concepts, Limits and Continuity, Tangent Planes, Partial Derivatives, Total Differential, Differentiability, Chain Rules, Directional Derivatives and the Gradient, Extrema of Functions of Two Variables, Method of Lagrange multipliers with one constraint.

UNIT-II: Double and Triple Integrals

(15 hours)

Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

UNIT-III: Green's, Stokes' and Gauss Divergence Theorem

(12 hours)

Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, Gauss divergence theorem.

Essential Reading

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.

Suggestive Reading

- Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.

DSE Courses of B.A. (Prog.) Semester-VIII
Category-II

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4(i): APPLIED ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Applied Algebra	4	3	1	0	Class XII pass with Mathematics	Linear Algebra, Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Introduce the applications of linear algebra in the field of science and arts.
- Develop the analytical and numerical skills to apply the algebraic concepts in real-life situations.
- Understand the identification numbers and different check digit schemes that can be used to reduce the errors during their transmission.

Learning Outcomes: This course will enable the students to:

- Understand the system of linear equations, matrices and transformations in the fields of economics, science, engineering and computer science.
- Apply the combinatorics and graph theory in scheduling and reliability theory.
- Learn about identification numbers and using check digits to check for errors after the identification number has been transmitted.

SYLLABUS OF DSE-4(i)

UNIT-I: Applications of Linear Algebra

(15 hours)

Applications of linear systems: Leontief input-output model in economics, Traffic flow, and diet problem; Applications to computer graphics, difference equations and Markov chains; Applications to linear models: Least-squares problems, and least-squares lines.

UNIT-II: Latin Squares and Graph Models

(12 hours)

Latin squares, Table for a finite group as a Latin square, Latin squares as in design of experiments; Mathematical models for matching jobs, Spelling checker, Network reliability, Street surveillance, Scheduling meetings, Interval graph modeling and Influence model, Pitcher pouring puzzle.

UNIT-III: Various Check Digit Schemes

(18 hours)

Developing identification numbers, Types of identification numbers, Transmission errors, Check digits, Integer division, Modular arithmetic, US postal money orders, Airline ticket identification numbers, The Universal Product Code check digit scheme, ISBN check digit

scheme, Creating Identification numbers, IBM scheme, Symmetry, Symmetry and Rigid motions, Verhoeff check digit scheme.

Essential Readings

1. David C. Lay, Steven R. Lay and Judi J. McDonald (2016). Linear Algebra and Its Applications (5th ed.). Pearson.
2. Tucker, Alan (2012). Applied Combinatorics (6th ed.). John Wiley & Sons, Inc.
3. Kirtland, Joseph (2001). Identification Numbers and Check Digit Schemes. Mathematical Association of America.

Suggestive Readings

- Andirilli, Stephen and Hecker, David (2016). Elementary Linear Algebra (5th ed.). Academic Press, Elsevier.
- Lidl, Rudolf and Pilz, Günter (1998). Applied Abstract Algebra (2nd ed.). Springer. Indian Reprint 2014.
- Strang, Gilbert (2016). Introduction to Linear Algebra (5th ed.). Wellesley-Cambridge.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(ii): ELEMENTS OF PARTIAL DIFFERENTIAL EQUATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Partial Differential Equations	4	3	1	0	Class XII pass with Mathematics	Differential Equations

Learning Objectives: The main objective of this course is to introduce:

- Basic concepts of first and second-order linear/nonlinear partial differential equations.
- Methods to solve first-order nonlinear PDEs and determine integral surfaces.
- Linear PDEs with constant coefficients, and finding their solutions using complimentary functions and particular integral.
- Modeling of wave equation, diffusion equation, traffic flow and their solutions.

Learning Outcomes: The course will enable the students to learn:

- Charpit's and Jacobi's methods to solve first-order nonlinear partial differential equations in two and three independent variables, respectively.
- Monge's method for integrating PDE of type $Rr + Ss + Tt = V$.
- The Cauchy problem and solutions of one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends.
- The macroscopic modeling of the traffic flow, where the focus will be on modeling the density of cars and their flow, rather than modeling individual cars and their velocity.

SYLLABUS OF DSE-4(ii)**UNIT-I: First-order Partial Differential Equations (18 hours)**

Review of basic concepts: Origins of first-order PDEs, Lagrange's method for solving linear equations of first order; Integral surfaces passing through a given curve, and surfaces orthogonal to a given system of surfaces; Nonlinear PDEs of the first order, and compatible systems of first-order PDEs; Charpit's method for solving nonlinear PDEs, special types of first-order PDEs, and solutions satisfying given conditions; Jacobi's method for solving nonlinear PDE with three independent variables.

UNIT – II: Second-order Partial Differential Equations (15 hours)

Origins of second-order PDEs, and solving linear PDEs with constant coefficients using methods of finding the complementary function and particular integral; Monge's method of integrating nonlinear second-order PDE of type $Rr + Ss + Tt = V$ with variable coefficients.

UNIT – III: Applications of Partial Differential Equations (12 hours)

Solution of one-dimensional diffusion equation and wave equation by method of separation of variables, d'Alembert's solution of the Cauchy problem for the one-dimensional wave equation; Solutions of homogeneous one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends; Traffic flow model.

Essential Readings

- 1 Myint-U, Tyn & Debnath, Lokenath. (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhäuser. Indian Reprint.
- 2 Piaggio, H.T.H. (2004). Differential Equations. CBS Publishers & Distributors, Delhi.
- 3 Sneddon, Ian N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.

Suggestive Readings

- Amaranath T. (2023). An Elementary Course in Partial Differential Equations (3rd ed.). Narosa Publishing House.
- Arrigo, Daniel (2023). An Introduction to Partial Differential Equations (2nd ed.). Springer.
- Kapoor, N. M. (2023). A Text Book of Differential Equations. Pitambar Publishing Company.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(iii): MATHEMATICAL STATISTICS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Statistics	4	3	1	0	Class XII pass with Mathematics	Probability and Statistics, Multivariate Calculus

Learning Objectives: The main objective of this course is to introduce the:

- Joint behavior of several random variables theoretically and through illustrative practical examples.
- Theory underlying modern statistics to give the student a solid grounding in (mathematical) statistics and the principles of statistical inference.
- Application of the theory to the statistical modeling of data from real applications, including model identification, estimation, and interpretation.
- Theory and analysis of multivariate data which covers two-factor analysis of variance, multiple linear regression including models for contingency tables.

Learning Outcomes: The course will enable the students to:

- Understand joint distributions of random variables including the multivariate normal distribution.
- Estimate model parameters from the statistical inference based on confidence intervals and hypothesis testing.
- Understand the theory of multiple regression models and contingency tables.
- Apply principles and theory to the statistical modeling and analysis of practical problems in a variety of application areas, and to interpret results and draw conclusions in context.

SYLLABUS OF DSE-4(iii)

UNIT-I: Joint Probability Distributions

(15 hours)

Joint probability mass function for two discrete random variables, Marginal probability mass function, Joint probability density function for two continuous random variables, Marginal probability density function, Independent random variables; Expected values, covariance, and correlation; Linear combination of random variables, Moment generating functions of linear combination of random variables; Conditional distributions and conditional expectation, The laws of total expectation and variance; Bivariate normal distribution.

UNIT-II: Sampling Distributions and Estimation

(12 hours)

Distribution of important statistics such as the sample totals, sample means, and sample proportions; Joint sampling distribution of sample mean and sample variance, t -statistic and F -statistic distributions based on normal random samples; Concepts and criteria for point estimation, The method of moments estimators and maximum likelihood estimation; Interval estimation and basic properties of confidence intervals, One-sample t confidence interval, Confidence intervals for a population proportion and population variance.

UNIT-III: Tests of Hypotheses, ANOVA and Multiple Regression Analysis

(18 hours)

Statistical hypotheses and test procedures, One-sample tests about: population mean, population proportion, and population variance; P -values for tests; Two-sample z -confidence interval and t -confidence interval tests; Single-factor ANOVA, Two-factor ANOVA without replication; Multiple linear regression model and estimating parameters; Chi-squared goodness-of-fit tests, Two-way Contingency tables.

Essential Reading

1. Devore, Jay L., Berk, Kenneth N. & Carlton Matthew A. (2021). Modern Mathematical Statistics with Applications. Third edition, Springer.

Suggestive Readings

- Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences. Ninth edition, Cengage Learning India Private Limited, Delhi. Fourth impression 2022.
- Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2019). Introduction to Mathematical Statistics. Eighth edition, Pearson. Indian Reprint 2020.
- Mood, A.M., Graybill, F.A., & Boes, D.C. (1974). Introduction the Theory of Statistics (3rd ed.). Tata McGraw Hill Pub. Co. Ltd. Reprinted 2017.
- Wackerly, Dennis D., Mendenhall III, William & Scheaffer, Richard L. (2008). Mathematical Statistics with Applications. 7th edition, Cengage Learning.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(iv): OPTIMIZATION TECHNIQUES**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques	4	3	1	0	Class XII pass with Mathematics	Multivariate Calculus

Learning Objectives: The primary objective of this course is to introduce:

- Nonlinear optimization problems
- Transshipment and dynamic programming problems
- Integer Programming, fractional programming problems
- Convex and generalized convex functions and their properties

Learning Outcomes: This course will enable the students to:

- Nonlinear programming problems and their applications
- Method to solve fractional programming problems with linear constraints
- Methods to solve dynamic programming problems using recursive computations

SYLLABUS OF DSE-4(iv)**UNIT-I: Transshipment and Dynamic Programming Problems (15 hours)**

Transshipment problem, Shortest-route problem; Dynamic programming, Recursive forward and backward computation, Knapsack/fly-away/cargo-loading problems solution through dynamic programming.

UNIT-II: Integer Programming Problems**(15 hours)**

Integer programming problem, Gomory's cutting plane method for integer problems, Mixed integer problems, Branch and bound method.

UNIT-III: Nonlinear Programming Problems**(15 hours)**

Convex functions, Convex programming problems; Generalized convex functions; Linear fractional programming problem, Charnes and Cooper transformation, Simplex algorithm to solve linear fractional programming problem.

Essential Readings

1. Chandra, Suresh, Jayadeva and Mehra, Aparna (2009). Numerical Optimization with Applications. Narosa Publishing House Pvt. Ltd. Delhi. Second Reprint 2016.
2. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Reading

- Swarup, K., Gupta, P.K., and Mohan, M. (1984). Operations Research. Sultan Chand.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(v): RINGS AND FIELDS
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Rings and Fields	4	3	1	0	Class XII pass with Mathematics	Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Understand the basic algebraic structures rings, Euclidean rings, polynomial rings and fields.
- Understand the form of ideals, maximal ideals in the quotient rings and their order preserving correspondence with the parent ring.
- Learn the concept of splitting fields of a polynomial over a field and its existence and uniqueness.
- Gain the knowledge of some geometric constructions using field extensions.

Learning Outcomes: This course will enable the students to:

- Have familiar with the algebraic structure rings, its maximal ideals, and quotient rings.
- Understand the polynomial rings in one variable over a field with the help of the concept of Euclidean rings.
- Learn the field extensions and the existence, uniqueness of splitting fields of any polynomial over a field.
- Gain the knowledge of structure of finite fields, constructability of numbers using straightedge and compass.

SYLLABUS OF DSE-4(v)**UNIT-I: Ideals in the quotient rings and Euclidean rings (15 hours)**

Ring homomorphism, First Fundamental theorem of ring homomorphism, Ideals in the quotient rings, Maximal ideals, Maximal ideals of rings of all real valued continuous functions on closed unit interval, Field of quotients of an integral domain, Euclidean rings, Units in Euclidean rings, Principal ideal rings, Unique factorization theorem, Prime elements and the ideal generated by them.

UNIT-II: Polynomial Rings and Field Extensions (15 hours)

Ring of Gaussian integers, Polynomial rings in one variable, Division algorithm, Irreducible polynomials and the ideal generated by them, Polynomial rings over the rational field, Gauss' lemma, Eisenstein criterion, Polynomial rings in n variables.

Extension of Fields: The Fundamental Theorem of Field Theory, Splitting Fields, Zeros of an irreducible polynomial.

UNIT-III: Algebraic Extensions (15 hours)

Characterization of field extensions, Finite extensions, Properties of algebraic extensions; Classification of Finite Fields, Structure of Finite Fields, Subfields of a Finite Field; Geometric Constructions: Constructible Numbers, Angle-Trisectors and Circle-Squares.

Essential Readings

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).
2. Herstein. I. N. (1975). Topics in Algebra (2nd ed.). Wiley India. Reprint 2022.

Suggestive Readings

- Dummit, David S., and Foote, Richard M. (2011). Abstract Algebra (3rd ed.), Wiley.
- Garling, D. J. H. (2021). Galois Theory and Its Algebraic Background (2nd ed.). Cambridge University Press.

B.Sc. (Physical Sciences/Mathematical Sciences) Semester-VIII
Category-III

DISCIPLINE SPECIFIC CORE COURSE – (DSC-8): TOPICS IN MULTIVARIATE CALCULUS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Topics in Multivariate Calculus	4	3	1	0	Class XII pass with Mathematics	Calculus

Learning Objectives: The primary objective of this course is to introduce the:

- Extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Applications of multivariable calculus tools to physics, economics, and optimization.
- Geometry and visualisation of curves and surfaces in two dimensions (plane) and three dimensions (space).
- Techniques of integration to functions of two and three independent variables.

Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems.

SYLLABUS OF DSC-8

UNIT-I: Calculus of Functions of Several Variables (18 hours)

Basic Concepts, Limits and Continuity, Tangent Planes, Partial Derivatives, Total Differential, Differentiability, Chain Rules, Directional Derivatives and the Gradient, Extrema of Functions of Two Variables, Method of Lagrange multipliers with one constraint.

UNIT-II: Double and Triple Integrals (15 hours)

Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integral over a parallelopiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

UNIT-III: Green's, Stokes' and Gauss Divergence Theorem (12 hours)

Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, Gauss divergence theorem.

Essential Reading

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.

Suggestive Reading

- Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.

DSE Courses of B.Sc. (Physical Sciences/Mathematical Sciences) Semester-VIII**Category-III****DISCIPLINE SPECIFIC ELECTIVE COURSE – 6(i): APPLIED ALGEBRA****CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Applied Algebra	4	3	1	0	Class XII pass with Mathematics	Linear Algebra, Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Introduce the applications of linear algebra in the field of science and arts.
- Develop the analytical and numerical skills to apply the algebraic concepts in real-life situations.
- Understand the identification numbers and different check digit schemes that can be used to reduce the errors during their transmission.

Learning Outcomes: This course will enable the students to:

- Understand the system of linear equations, matrices and transformations in the fields of economics, science, engineering and computer science.
- Apply the combinatorics and graph theory in scheduling and reliability theory.
- Learn about identification numbers and using check digits to check for errors after the identification number has been transmitted.

SYLLABUS OF DSE-6(i)**UNIT-I: Applications of Linear Algebra****(15 hours)**

Applications of linear systems: Leontief input-output model in economics, Traffic flow, and diet problem; Applications to computer graphics, difference equations and Markov chains; Applications to linear models: Least-squares problems, and least-squares lines.

UNIT-II: Latin Squares and Graph Models**(12 hours)**

Latin squares, Table for a finite group as a Latin square, Latin squares as in design of experiments; Mathematical models for matching jobs, Spelling checker, Network reliability, Street surveillance, Scheduling meetings, Interval graph modeling and Influence model, Pitcher pouring puzzle.

UNIT-III: Various Check Digit Schemes**(18 hours)**

Developing identification numbers, Types of identification numbers, Transmission errors, Check digits, Integer division, Modular arithmetic, US postal money orders, Airline ticket identification numbers, The Universal Product Code check digit scheme, ISBN check digit scheme, Creating Identification numbers, IBM scheme, Symmetry, Symmetry and Rigid motions, Verhoeff check digit scheme.

Essential Readings

1. David C. Lay, Steven R. Lay and Judi J. McDonald (2016). Linear Algebra and Its Applications (5th ed.). Pearson.
2. Tucker, Alan (2012). Applied Combinatorics (6th ed.). John Wiley & Sons, Inc.
3. Kirtland, Joseph (2001). Identification Numbers and Check Digit Schemes. Mathematical Association of America.

Suggestive Readings

- Andirilli, Stephen and Hecker, David (2016). Elementary Linear Algebra (5th ed.). Academic Press, Elsevier.
- Lidl, Rudolf and Pilz, Günter (1998). Applied Abstract Algebra (2nd ed.). Springer. Indian Reprint 2014.
- Strang, Gilbert (2016). Introduction to Linear Algebra (5th ed.). Wellesley-Cambridge.

**DISCIPLINE SPECIFIC ELECTIVE COURSE-6(ii): ELEMENTS OF
PARTIAL DIFFERENTIAL EQUATIONS**
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Partial Differential Equations	4	3	1	0	Class XII pass with Mathematics	Differential Equations

Learning Objectives: The main objective of this course is to introduce:

- Basic concepts of first and second-order linear/nonlinear partial differential equations.
- Methods to solve first-order nonlinear PDEs and determine integral surfaces.
- Linear PDEs with constant coefficients, and finding their solutions using complimentary functions and particular integral.
- Modeling of wave equation, diffusion equation, traffic flow and their solutions.

Learning Outcomes: The course will enable the students to learn:

- Charpit's and Jacobi's methods to solve first-order nonlinear partial differential equations in two and three independent variables, respectively.
- Monge's method for integrating PDE of type $Rr + Ss + Tt = V$.
- The Cauchy problem and solutions of one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends.
- The macroscopic modeling of the traffic flow, where the focus will be on modeling the density of cars and their flow, rather than modeling individual cars and their velocity.

SYLLABUS OF DSE-6(ii)**UNIT–I: First-order Partial Differential Equations (18 hours)**

Review of basic concepts: Origins of first-order PDEs, Lagrange's method for solving linear equations of first order; Integral surfaces passing through a given curve, and surfaces orthogonal to a given system of surfaces; Nonlinear PDEs of the first order, and compatible systems of first-order PDEs; Charpit's method for solving nonlinear PDEs, special types of first-order PDEs, and solutions satisfying given conditions; Jacobi's method for solving nonlinear PDE with three independent variables.

UNIT – II: Second-order Partial Differential Equations (15 hours)

Origins of second-order PDEs, and solving linear PDEs with constant coefficients using methods of finding the complementary function and particular integral; Monge's method of integrating nonlinear second-order PDE of type $Rr + Ss + Tt = V$ with variable coefficients.

UNIT – III: Applications of Partial Differential Equations (12 hours)

Solution of one-dimensional diffusion equation and wave equation by method of separation of variables, d'Alembert's solution of the Cauchy problem for the one-dimensional wave equation; Solutions of homogeneous one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends; Traffic flow model.

Essential Readings

- 1 Myint-U, Tyn & Debnath, Lokenath. (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhäuser. Indian Reprint.
- 2 Piaggio, H.T.H. (2004). Differential Equations. CBS Publishers & Distributors, Delhi.
- 3 Sneddon, Ian N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.

Suggestive Readings

- Amaranath T. (2023). An Elementary Course in Partial Differential Equations (3rd ed.). Narosa Publishing House.
- Arrigo, Daniel (2023). An Introduction to Partial Differential Equations (2nd ed.). Springer.
- Kapoor, N. M. (2023). A Text Book of Differential Equations. Pitambar Publishing Company.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6(iii): MATHEMATICAL STATISTICS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Statistics	4	3	1	0	Class XII pass with Mathematics	Probability and Statistics, Multivariate Calculus

Learning Objectives: The main objective of this course is to introduce the:

- Joint behavior of several random variables theoretically and through illustrative practical examples.
- Theory underlying modern statistics to give the student a solid grounding in (mathematical) statistics and the principles of statistical inference.
- Application of the theory to the statistical modeling of data from real applications, including model identification, estimation, and interpretation.
- Theory and analysis of multivariate data which covers two-factor analysis of variance, multiple linear regression including models for contingency tables.

Learning Outcomes: The course will enable the students to:

- Understand joint distributions of random variables including the multivariate normal distribution.
- Estimate model parameters from the statistical inference based on confidence intervals and hypothesis testing.
- Understand the theory of multiple regression models and contingency tables.
- Apply principles and theory to the statistical modeling and analysis of practical problems in a variety of application areas, and to interpret results and draw conclusions in context.

SYLLABUS OF DSE-6(iii)

UNIT-I: Joint Probability Distributions

(15 hours)

Joint probability mass function for two discrete random variables, Marginal probability mass function, Joint probability density function for two continuous random variables, Marginal probability density function, Independent random variables; Expected values, covariance, and correlation; Linear combination of random variables, Moment generating functions of linear combination of random variables; Conditional distributions and conditional expectation, The laws of total expectation and variance; Bivariate normal distribution.

UNIT-II: Sampling Distributions and Estimation

(12 hours)

Distribution of important statistics such as the sample totals, sample means, and sample proportions; Joint sampling distribution of sample mean and sample variance, t -statistic and F -statistic distributions based on normal random samples; Concepts and criteria for point estimation, The method of moments estimators and maximum likelihood estimation; Interval estimation and basic properties of confidence intervals, One-sample t confidence interval, Confidence intervals for a population proportion and population variance.

UNIT-III: Tests of Hypotheses, ANOVA and Multiple Regression Analysis

(18 hours)

Statistical hypotheses and test procedures, One-sample tests about: population mean, population proportion, and population variance; P -values for tests; Two-sample z -confidence interval and t -confidence interval tests; Single-factor ANOVA, Two-factor ANOVA without replication; Multiple linear regression model and estimating parameters; Chi-squared goodness-of-fit tests, Two-way Contingency tables.

Essential Reading

1. Devore, Jay L., Berk, Kenneth N. & Carlton Matthew A. (2021). Modern Mathematical Statistics with Applications. Third edition, Springer.

Suggestive Readings

- Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences. Ninth edition, Cengage Learning India Private Limited, Delhi. Fourth impression 2022.
- Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2019). Introduction to Mathematical Statistics. Eighth edition, Pearson. Indian Reprint 2020.
- Mood, A.M., Graybill, F.A., & Boes, D.C. (1974). Introduction the Theory of Statistics (3rd ed.). Tata McGraw Hill Pub. Co. Ltd. Reprinted 2017.
- Wackerly, Dennis D., Mendenhall III, William & Scheaffer, Richard L. (2008). Mathematical Statistics with Applications. 7th edition, Cengage Learning.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6(iv): OPTIMIZATION TECHNIQUES**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques	4	3	1	0	Class XII pass with Mathematics	Multivariate Calculus

Learning Objectives: The primary objective of this course is to introduce:

- Nonlinear optimization problems, Transshipment, and dynamic programming problems.
- Integer Programming, and fractional programming problems.
- Convex and generalized convex functions with their properties.

Learning Outcomes: This course will enable the students to:

- Nonlinear programming problems and their applications.
- Method to solve fractional programming problems with linear constraints.
- Methods to solve dynamic programming problems using recursive computations.

SYLLABUS OF DSE-6(iv)**UNIT-I: Transshipment and Dynamic Programming Problems (15 hours)**

Transshipment problem, Shortest-route problem; Dynamic programming, Recursive forward and backward computation, Knapsack/fly-away/cargo-loading problems solution through dynamic programming.

UNIT-II: Integer Programming Problems (15 hours)

Integer programming problem, Gomory's cutting plane method for integer problems, Mixed integer problems, Branch and bound method.

UNIT-III: Nonlinear Programming Problems (15 hours)

Convex functions, Convex programming problems; Generalized convex functions; Linear fractional programming problem, Charnes and Cooper transformation, Simplex algorithm to solve linear fractional programming problem.

Essential Readings

1. Chandra, Suresh, Jayadeva and Mehra, Aparna (2009). Numerical Optimization with Applications. Narosa Publishing House Pvt. Ltd. Second Reprint 2016.
2. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Reading

- Swarup, K., Gupta, P.K., and Mohan, M. (1984). Operations Research. Sultan Chand.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6(v): RINGS AND FIELDS
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Rings and Fields	4	3	1	0	Class XII pass with Mathematics	Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Understand the basic algebraic structures rings, Euclidean rings, polynomial rings and fields.
- Understand the form of ideals, maximal ideals in the quotient rings and their order preserving correspondence with the parent ring.
- Learn the concept of splitting fields of a polynomial over a field and its existence and uniqueness.
- Gain the knowledge of some geometric constructions using field extensions.

Learning Outcomes: This course will enable the students to:

- Have familiar with the algebraic structure rings, its maximal ideals, and quotient rings.
- Understand the polynomial rings in one variable over a field with the help of the concept of Euclidean rings.
- Learn the field extensions and the existence, uniqueness of splitting fields of any polynomial over a field.
- Gain the knowledge of structure of finite fields, constructability of numbers using straightedge and compass.

SYLLABUS OF DSE-6(v)

UNIT-I: Ideals in the quotient rings and Euclidean rings (15 hours)

Ring homomorphism, First Fundamental theorem of ring homomorphism, Ideals in the quotient rings, Maximal ideals, Maximal ideals of rings of all real valued continuous functions on closed unit interval, Field of quotients of an integral domain, Euclidean rings, Units in Euclidean rings, Principal ideal rings, Unique factorization theorem, Prime elements and the ideal generated by them.

UNIT-II: Polynomial Rings and Field Extensions (15 hours)

Ring of Gaussian integers, Polynomial rings in one variable, Division algorithm, Irreducible polynomials and the ideal generated by them, Polynomial rings over the rational field, Gauss' lemma, Eisenstein criterion, Polynomial rings in n variables.

Extension of Fields: The Fundamental Theorem of Field Theory, Splitting Fields, Zeros of an irreducible polynomial.

UNIT-III: Algebraic Extensions (15 hours)

Characterization of field extensions, Finite extensions, Properties of algebraic extensions; Classification of Finite Fields, Structure of Finite Fields, Subfields of a Finite Field; Geometric Constructions: Constructible Numbers, Angle-Trisectors and Circle-Squares.

Essential Readings

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).
2. Herstein. I. N. (1975). Topics in Algebra (2nd ed.). Wiley India. Reprint 2022.

Suggestive Readings

- Dummit, David S., and Foote, Richard M. (2011). Abstract Algebra (3rd ed.), Wiley.
- Garling, D. J. H. (2021). Galois Theory and Its Algebraic Background (2nd ed.). Cambridge University Press.

**COMMON POOL OF GENERIC ELECTIVES (GE) Semester-VIII COURSES OFFERED
BY DEPARTMENT OF MATHEMATICS**

Category-IV

GENERIC ELECTIVES (GE-8(i)): RINGS AND FIELDS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Rings and Fields	4	3	1	0	Class XII pass with Mathematics	Abstract Algebra

Learning Objectives: The primary objective of this course is to:

- Understand the basic algebraic structures rings, Euclidean rings, polynomial rings and fields.
- Understand the form of ideals, maximal ideals in the quotient rings and their order preserving correspondence with the parent ring.
- Learn the concept of splitting fields of a polynomial over a field and its existence and uniqueness.
- Gain the knowledge of some geometric constructions using field extensions.

Learning Outcomes: This course will enable the students to:

- Have familiar with the algebraic structure rings, its maximal ideals, and quotient rings.
- Understand the polynomial rings in one variable over a field with the help of the concept of Euclidean rings.
- Learn the field extensions and the existence, uniqueness of splitting fields of any polynomial over a field.
- Gain the knowledge of structure of finite fields, constructability of numbers using straightedge and compass.

SYLLABUS OF GE-8(i)

UNIT-I: Ideals in the quotient rings and Euclidean rings (15 hours)

Ring homomorphism, First Fundamental theorem of ring homomorphism, Ideals in the quotient rings, Maximal ideals, Maximal ideals of rings of all real valued continuous functions on closed unit interval, Field of quotients of an integral domain, Euclidean rings, Units in Euclidean rings, Principal ideal rings, Unique factorization theorem, Prime elements and the ideal generated by them.

UNIT-II: Polynomial Rings and Field Extensions (15 hours)

Ring of Gaussian integers, Polynomial rings in one variable, Division algorithm, Irreducible polynomials and the ideal generated by them, Polynomial rings over the rational field, Gauss' lemma, Eisenstein criterion, Polynomial rings in n variables.

Extension of Fields: The Fundamental Theorem of Field Theory, Splitting Fields, Zeros of an irreducible polynomial.

UNIT-III: Algebraic Extensions**(15 hours)**

Characterization of field extensions, Finite extensions, Properties of algebraic extensions;
 Classification of Finite Fields, Structure of Finite Fields, Subfields of a Finite Field;
 Geometric Constructions: Constructible Numbers, Angle-Trisectors and Circle-Squares.

Essential Readings

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).
2. Herstein. I. N. (1975). Topics in Algebra (2nd ed.). Wiley India. Reprint 2022.

Suggestive Readings

- Dummit, David S., and Foote, Richard M. (2011). Abstract Algebra (3rd ed.), Wiley.
- Garling, D. J. H. (2021). Galois Theory and Its Algebraic Background (2nd ed.). Cambridge University Press.

GENERIC ELECTIVES (GE-8(ii)): ELEMENTS OF PARTIAL DIFFERENTIAL EQUATIONS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Partial Differential Equations	4	3	1	0	Class XII pass with Mathematics	Differential Equations

Learning Objectives: The main objective of this course is to introduce:

- Basic concepts of first and second-order linear/nonlinear partial differential equations.
- Methods to solve first-order nonlinear PDEs and determine integral surfaces.
- Linear PDEs with constant coefficients, and finding their solutions using complimentary functions and particular integral.
- Modeling of wave equation, diffusion equation, traffic flow and their solutions.

Learning Outcomes: The course will enable the students to learn:

- Charpit's and Jacobi's methods to solve first-order nonlinear partial differential equations in two and three independent variables, respectively.
- Monge's method for integrating PDE of type $Rr + Ss + Tt = V$.
- The Cauchy problem and solutions of one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends.
- The macroscopic modeling of the traffic flow, where the focus will be on modeling the density of cars and their flow, rather than modeling individual cars and their velocity.

SYLLABUS OF GE-8(ii)**UNIT–I: First-order Partial Differential Equations****(18 hours)**

Review of basic concepts: Origins of first-order PDEs, Lagrange's method for solving linear equations of first order; Integral surfaces passing through a given curve, and surfaces orthogonal to a given system of surfaces; Nonlinear PDEs of the first order, and compatible systems of first-order PDEs; Charpit's method for solving nonlinear PDEs, special types of first-order PDEs, and solutions satisfying given conditions; Jacobi's method for solving nonlinear PDE with three independent variables.

UNIT – II: Second-order Partial Differential Equations**(15 hours)**

Origins of second-order PDEs, and solving linear PDEs with constant coefficients using methods of finding the complementary function and particular integral; Monge's method of integrating nonlinear second-order PDE of type $Rr + Ss + Tt = V$ with variable coefficients.

UNIT – III: Applications of Partial Differential Equations**(12 hours)**

Solution of one-dimensional diffusion equation and wave equation by method of separation of variables, d'Alembert's solution of the Cauchy problem for the one-dimensional wave equation; Solutions of homogeneous one-dimensional wave equations with initial boundary-value problems, and vibration of finite string with fixed ends; Traffic flow model.

Essential Readings

- 1 Myint-U, Tyn & Debnath, Lokenath. (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhäuser. Indian Reprint.
- 2 Piaggio, H.T.H. (2004). Differential Equations. CBS Publishers & Distributors, Delhi.
- 3 Sneddon, Ian N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.

Suggestive Readings

- Amaranath T. (2023). An Elementary Course in Partial Differential Equations (3rd ed.). Narosa Publishing House.
- Arrigo, Daniel (2023). An Introduction to Partial Differential Equations (2nd ed.). Springer.
- Kapoor, N. M. (2023). A Text Book of Differential Equations. Pitambar Publishing Company.

GENERIC ELECTIVES (GE-8(iii)): ELEMENTS OF COMPLEX ANALYSIS**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Complex Analysis	4	3	1	0	Class XII pass with Mathematics	Metric Spaces, Multivariate Calculus

Learning Objectives: The primary objective of this course is to:

- Acquaint with the basic ideas of complex analysis.
- Learn complex-valued functions with visualization through relevant examples.
- Emphasize on Cauchy's theorems, series expansions and calculation of residues.

Learning Outcomes: The accomplishment of the course will enable the students to:

- Grasp the significance of differentiability of complex-valued functions leading to the understanding of Cauchy-Riemann equations.
- Study some elementary functions and evaluate the contour integrals.
- Learn the role of Cauchy-Goursat theorem and the Cauchy integral formula.
- Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues, and apply Cauchy Residue theorem to evaluate integrals.

SYLLABUS OF GE-8(iii)

Unit-I: Analytic Functions

(15 hours)

Basic properties of complex numbers and their exponential form; Limits, continuity, and partial derivatives of functions of two variables. Limits, continuity, and partial derivatives of functions of a complex variable; Cauchy-Riemann Equations, Sufficient conditions for differentiability; Analytic functions and their examples; Exponential, logarithmic, and trigonometric functions.

Unit-II: Complex Integrals

(15 hours)

Derivatives of functions, Definite integrals of functions, Contours, Contour integrals and examples, Upper bounds for moduli of contour integrals, Antiderivatives; Statement of Cauchy-Goursat theorem; Cauchy integral formula and its extension, Cauchy's inequality, Liouville's theorem and the fundamental theorem of algebra.

Unit-III: Series and Residues

(15 hours)

Convergence of sequences and series of complex numbers; Taylor, and Laurent series with examples; Isolated singular points, Residues, Cauchy's residue theorem; Types of isolated singular points, Residues at poles and its examples.

Essential Reading

1. Brown, James Ward & Churchill, Ruel V. (2014). Complex Variables and Applications (9th ed.). McGraw-Hill Education. Indian Reprint.

Suggestive Readings

- Bak, Joseph & Newman, Donald J. (2010). Complex Analysis (3rd ed.). Undergraduate Texts in Mathematics, Springer.
- Mathews, John H., & Howell, Russell W. (2012). Complex Analysis for Mathematics and Engineering (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition.

GENERIC ELECTIVES (GE-8(iv)): OPTIMIZATION TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques	4	3	1	0	Class XII pass with Mathematics	Multivariate Calculus

Learning Objectives: The primary objective of this course is to introduce:

- Nonlinear optimization problems
- Transshipment and dynamic programming problems
- Integer Programming, fractional programming problems
- Convex and generalized convex functions and their properties

Learning Outcomes: This course will enable the students to:

- Nonlinear programming problems and their applications
- Method to solve fractional programming problems with linear constraints
- Methods to solve dynamic programming problems using recursive computations

SYLLABUS OF GE-8(iv)

UNIT-I: Transshipment and Dynamic Programming Problems (15 hours)

Transshipment problem, Shortest-route problem; Dynamic programming, Recursive forward and backward computation, Knapsack/fly-away/cargo-loading problems solution through dynamic programming.

UNIT-II: Integer Programming Problems (15 hours)

Integer programming problem, Gomory's cutting plane method for integer problems, Mixed integer problems, Branch and bound method.

UNIT-III: Nonlinear Programming Problems (15 hours)

Convex functions, Convex programming problems; Generalized convex functions; Linear fractional programming problem, Charnes and Cooper transformation, Simplex algorithm to solve linear fractional programming problem.

Essential Readings

1. Chandra, Suresh, Jayadeva, and Mehra, Aparna (2009). Numerical Optimization with Applications. Narosa Publishing House Pvt. Ltd. Delhi. Second Reprint 2016.
2. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Reading

- Swarup, K., Gupta, P.K., and Mohan, M. (1984). Operations Research. Sultan Chand.

Based on Undergraduate Curriculum Framework

UNIVERSITY OF DELHI

UNDERGRADUATE PROGRAMMES OF STUDY

STRUCTURE, COURSES & SYLLABI OF SEMESTER-VII and SEMESTER-VIII



Semester VII

<u>S.No.</u>	<u>Content</u>
1	BSc. (Hons.) Computer Sciences DISCIPLINE SPECIFIC CORE (DSC) 1. Compiler Design
2	DISCIPLINE SPECIFIC ELECTIVES (DSE) 1. Digital Image Processing 2. Advanced Algorithms 3. Reinforcement Learning 4. Cyber Forensics
3	GENERIC ELECTIVES (G.E.) 1. Computer Networks 2. Internet Technologies: Mobile App Design and Development 3. Machine Learning 4. Cloud Computing 5. Ethical Hacking 6. Design and Analysis of Algorithms
4	BSc. (Prog.) with Computer Sciences DISCIPLINE SPECIFIC CORE (DSC) 1. Design and Analysis of Algorithms
5	BA (Prog.). with Computer Sciences as Major/Non-major discipline DISCIPLINE SPECIFIC CORE (DSC) 1. Design and Analysis of Algorithms



Department of Computer Science

COURSES OFFERED BY DEPARTMENT OF COMPUTER SCIENCE

(Provide the details of the discipline-specific courses (DSCs) offered by your department for the UG Programme with your discipline as the Single Core Discipline)

[UG Programme for Bachelor in Computer Science (Honours) degree]

DISCIPLINE SPECIFIC CORE COURSE -19 (DSC-19) : Compiler Design

Credit distribution, eligibility and pre-requisites of the course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC19 Compiler Design	4	3	0	1	Pass in Class XII	One course in any Programming Language

Learning Objectives

The basic objective of the compiler design course is to understand the basic principles of compiler design, its various constituent parts, algorithms, and data structures required to be used in the compiler. It also aims to understand the use of basic compiler-building tools.

Learning Outcomes

On successful completion of the course, the students will be able to:

1. Describe the concepts and different phases of compilation.

2. Represent language tokens using regular expressions and context-free grammars.
3. Describe the working of lexical analyzers.
4. Understand the working of different types of parsers and parse a particular string.
5. Describe intermediate code representations using syntax trees and DAG as well as use this knowledge to generate intermediate code in the form of three-address code representations.
6. Apply optimisation techniques to intermediate code and generate machine code for a high-level language program.
7. Use Lex and Yacc automated compiler generation tools.

Syllabus

Unit 1 Introduction: (3 hours)

Overview of compilation, Phases of a compiler.

Unit 2 Lexical Analysis: (10 hours)

Role of a Lexical analyser, Specification and recognition of tokens, Symbol table, Error reporting, Regular expressions and definitions, Lexical Analyser Generator-Lex.

Unit 3 Syntax Analysis: (12 hours)

CFGs, left recursion, left factoring, Top-down parsing- LL parser, Bottom-up parsing- LR parser, Parser Generator-yacc.

Unit 4 Intermediate representations: (10 hours)

Syntax Directed Definitions, Evaluation Orders for Syntax Directed Definitions, Intermediate Languages: Syntax Tree, Three Address Code, Types and Declarations, Translation of Expressions, loops and conditional statements, Type Checking.

Unit 5 Storage organisation & Code generation: (6 hours)

Activation records, stack allocation, Issues in Code Generation – Design of a simple Code Generator.

Unit 6 Code optimisation: (4 hours)

Principal sources of optimisation, Peephole optimisation.

References

1. Aho, A., Lam, M., Sethi, R., & Ullman, J. D. *Compilers: Principles, Techniques, and Tools*, 2nd edition, Addison Wesley, 2006.

Additional References

1. V Raghvan, *Principles of Compiler Design*, TMH, 2010.
2. Santanu Chattopadhyay, *Compiler Design*, PHI, 2005.

Suggested Practical List

1. Write a Lex program to count the number of lines and characters in the input file.
2. Write a Lex program to count the number of vowels and consonants in a given string
3. Write a Lex program that implements the Caesar cipher: it replaces every letter with the one three letters after in alphabetical order, wrapping around at Z.
e.g. a is replaced by d, b by e, and so on z by c.
4. Write a Lex program that finds the longest word (defined as a contiguous string of upper and lower case letters) in the input.
5. Write a Lex program that distinguishes keywords, integers, floats, identifiers, operators, and comments in any simple programming language.
6. Write a Lex program to count the number of words, characters, blank spaces and lines in a C file.
7. Write a Lex specification program that generates a C program which takes a string "abcd" and prints the following output
abcd
abc
a
8. Write a Lex program to recognize a valid arithmetic expression.
9. Write a YACC program to find the validity of a given expression (for operators + - * and /) A program in YACC which recognizes a valid variable which starts with a letter followed by a digit. The letter should be in lowercase only.
8. Write a program in YACC to evaluate an expression (simple calculator program for addition and subtraction, multiplication, division).
9. Write a program in YACC to recognize the string „abbb“, „ab“, „a“ of the language (an $b^n, n \geq 1$).
10. Write a program in YACC to recognize the language (an $b^n, n \geq 10$). (output to say input is valid or not)

Additional Suggestive list of Practical's (can be implemented in C++/Python)

1. Write a program to implement DFAs that recognize identifiers, constants, and operators of the mini language.
2. Write a program to design a Lexical analyzer for the above language. The lexical analyzer should ignore redundant spaces, tabs and newlines. It should also ignore comments. Identifiers may be of restricted length.
3. Write a program to check the types of expressions in a language.
4. Write a translator to translate a 3-address code into assembly code.

COMMON POOL OF DISCIPLINE ELECTIVE COURSES (DSE) COURSES

Computer Science Courses for all Undergraduate Programmes of study with Computer Science as Discipline Elective

DISCIPLINE-SPECIFIC ELECTIVE COURSE: DIGITAL IMAGE PROCESSING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE7a: Digital Image Processing	4	3	0	1	Pass in Class XII	One course in any Programming Language

Course Objective

This course introduces students to the fundamentals of digital image processing, It introduces image processing in the Spatial and frequency domains including techniques for various image

transformations, image enhancement/filtering, image restoration, image compression and segmentation and morphological image processing.

Course Learning Outcomes

On successful completion of the course, students will be able to:

1. Understand the fundamentals of Image Processing and its role and importance in a variety of applications.
2. Write programs to read/write and manipulate images for the purpose of enhancement.
3. Understand the need for image transforms and their properties.
4. Understand different causes for image degradation and use various techniques to restore images.
5. Understand the need and techniques for image compression.
6. Perform morphological image processing and image segmentation.
7. Develop an image processing application.

Syllabus

Unit 1 Introduction

(5 hours)

Digital Image Fundamentals, Brightness, Adaptation and Discrimination, Light and Electromagnetic Spectrum, Image Sampling and Quantization, Some Basic Relationships between Pixels Types of images.

Unit 2 Spatial Domain Filtering

(10 hours)

Some Basic Intensity Transformation Functions, Histogram Equalization, Spatial Correlation and Convolution, Smoothing Spatial Filters-Low pass filters, Order Statistics filters; Sharpening Spatial Filters- Laplacian filter.

Unit 3 Filtering in Frequency Domain

(6 hours)

The Discrete Fourier Transformation (DFT), Frequency Domain Filtering:-Ideal and Butterworth Low pass and High pass filters

Unit 4 Image Degradation/Restoration Process (4 hours)

Noise models, Noise Restoration Filters

Unit 5 Image Compression (5 hours)

Fundamentals of Image Compression, Huffman Coding, Run Length Coding

Unit 6 Morphological Image Processing (10 hours)

Erosion, Dilation, Opening, Closing, Hit-or-Miss Transformation, Basic Morphological Algorithms.

Unit 7 Image Segmentation (5 hours)

Point, Line and Edge Detection, Thresholding.

References

1. Gonzalez, R. C., & Woods, R. E. *Digital Image Processing*, 4th edition, Pearson education, 2017 .

Additional References

1. Castleman, K. R. *Digital Image Processing*, 1st edition, Pearson Education, 2007.
2. Gonzalez, R. C., Woods, R. E., & Eddins, S. *Digital Image Processing using MATLAB*, Pearson Education Inc., 2004.
3. Jain, A. K. *Fundamentals of Digital Image Processing*, 1st edition, Prentice Hall of India, 1988.

Suggested Practical List

The practicals are to be conducted using Python. The objective is to become familiar with basic Python libraries for Image Processing, like OpenCV, Scikit-Image, etc.

1. Perform the following:
 - a. Read and display an image.
 - b. Resize a given image.
 - c. Convert a given color image into a corresponding gray-scale image.
 - d. Convert a given color/gray-scale image into black & white image
 - e. Draw the image profile.
 - f. Separate a given color image into three R, G & B planes.
 - g. Create a color image using separate three R, G and B planes.
 - h. Write given 2-D data in an image file.

2. To write and execute image processing programs using point processing method:
 - a. Obtain Negative image
 - b. Obtain Flip image
 - c. Thresholding
 - d. Contrast stretching
3. To write and execute programs for image arithmetic operations:
 - a. Addition of two images
 - b. Subtract one image from other image
 - c. Calculate mean value of image
 - d. Different Brightness by changing mean value
4. To write and execute programs for image logical operations:
 - a. AND operation between two images
 - b. OR operation between two images
 - c. Calculate intersection of two images
 - d. Water Marking using X-OR operation
 - e. NOT operation (Negative image)
5. To write and execute a program for histogram calculation and equalization:
 - a. Using inbuilt function
 - b. Without using inbuilt function
6. To write and execute a program performing the following geometric transformations on an image:
 - a. Translation
 - b. Scaling
 - c. Rotation
 - d. Shrinking
 - e. Zooming
7. To understand various image noise models and to write programs for:
 - a. Image restoration
 - b. Remove Salt and Pepper Noise
 - c. Minimize Gaussian noise
 - d. Median filter and Weiner filter
8. Write and execute programs to remove noise from images using spatial filtering.
 - a. Understand 1-D and 2-D convolution process

- b. Use 3x3 Mask for low pass filter and high pass filter
9. Write and execute programs for image frequency domain filtering.
 - a. Apply FFT on given image
 - b. Perform low pass and high pass filtering in frequency domain
 - c. Apply IFFT to reconstruct image
10. Write and execute a program for edge detection using different edge detection mask.
11. Write and execute a program for image morphological operations erosion and dilation

DISCIPLINE SPECIFIC ELECTIVE COURSE: Advanced Algorithms

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE7b: Advanced Algorithms	4	3	1	0	Pass in Class XII	Design and Analysis of Algorithms

Course Objective

This course is designed to provide exposure to more sophisticated algorithms for some tractable problems, some advanced topics in algorithms such as NP Completeness and how to handle NP hard problems in practice.

Learning Outcomes

On successful completion of the course, students will be able to:

1. Understand and develop more sophisticated algorithms using some of the known design techniques.
2. Identify NP hard problems.

3. Use polynomial time reductions to prove NP hardness of problems.
4. Design approximation algorithms for NP hard problems and find their approximation ratio.

Syllabus

Unit 1 More applications of Divide and Conquer, Greedy and Dynamic Programming approaches: (9 hours)

Counting Inversions, Closest pair of points, Integer Multiplication, Huffman Code, Segmented Least Squares etc.

Unit 2 Network Flows: (2 hours)

Ford-Fulkerson algorithm for the max flow problem.

Unit 3 Backtracking: (3 hours)

Constructing All Subsets, Constructing All Permutations, and constructing all paths in a graph.

Unit 3 Polynomial time reductions via gadgets: (6 hours)

SAT and 3-SAT problems; Reducing 3-SAT to Independent set, Clique, and Vertex cover.

Unit 4 Proving NP completeness: (7 hours)

Circuit satisfiability, 3-SAT, Sequencing Problems, Graph coloring, Subset sum.

Unit 5 Introduction to Approximation Algorithms: (8 hours)

Definition, Concept of approximation factor, Bounding the optimal solution, concept of tight example.

Unit 6 Combinatorial Approximation Algorithms: (6 hours)

Set cover, Minimizing makespan, k-center.

Unit 7 LP-based Approximation Algorithms: (4 hours)

Approximation algorithms for Vertex cover/Set cover via LP rounding.

References

1. Kleinberg, J., Tardos, E. *Algorithm Design*, 1st edition, Pearson, 2013.
2. Vazirani, V. V. *Approximation Algorithms*, 1st edition, Springer, 2001.

Additional References

1. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. *Introduction to Algorithms*, 4th edition, Prentice Hall of India, 2022.
2. Williamson, D. P., Shmoys, D. B. *The Design of Approximation Algorithms*, 1st edition, Cambridge University Press, 2011.

Tutorials

Tutorials based on Theory

DISCIPLINE SPECIFIC ELECTIVE COURSE: Reinforcement Learning

Credit distribution, Eligibility, and prerequisites of the Course.

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE7c: Reinforcement Learning	4	3	1	0	Pass in Class XII	Machine Learning/Artificial Intelligence

Course Objective

The objectives of this course are:

1. to prepare students to visualize reinforcement learning problems
2. to introduce students to the concepts based on Markov Decision Process, Dynamic Programming, Monte Carlo methods, and Temporal-Difference learning.
3. recognize current advanced techniques and applications in Reinforcement Learning

Learning Outcomes

On successful completion of the course, students will be able to:

1. learn Reinforcement Learning task formulations and the core principles behind Reinforcement Learning.
2. work on problem-solving techniques based on Dynamic Programming, Monte Carlo, and Temporal-Difference.
3. implement in code common algorithms following code standards and libraries used in Reinforcement Learning.
4. learn the policy gradient methods from vanilla to relatively complex cases.

Syllabus

Unit 1 Introduction

(8 hours)

Historical perspective of Reinforcement Learning (RL), Basics of RL: definition, how reinforcement learning happens, examples, terminology, notation, and assumptions, Elements of RL: policies, value function, reward Functions and Bellman Equation, different techniques for solving RL problem, Code Standards and Libraries used in RL using Python/Keras/TensorFlow/MATLAB.

Unit 2 Markov Decision Process (MDP) and Dynamic Programming (DP) (10 hours)

Markov property, Introduction to Markov decision process (MDP), creating MDPs, goals and rewards, returns and episodes, optimality of value functions and policies, Bellman optimality equations. Overview of dynamic programming for MDP, principle of optimality, iterative policy evaluation, Policy Improvement, policy iteration, value iteration, generalized policy iteration, Asynchronous DP, Efficiency of DP.

Unit 3 Monte Carlo (MC) Methods

(7 hours)

Monte Carlo methods (First visit and every visit Monte Carlo), Monte Carlo control, On policy and off policy learning, Importance sampling.

Unit 4 Temporal Difference (TD) Learning

(10 hours)

Temporal-Difference learning methods - TD (0), SARSA, Q-Learning and their variants. Markov reward process (MRP), Overview of TD (1) and TD(λ).

Unit 5 Approximation Methods and Policy Gradient

(10 hours)

Function approximation methods (Gradient MC and Semi-gradient TD (0) algorithms), Eligibility traces, After-states, Least squares TD. Policy Approximation and its advantages, Naive REINFORCE algorithm, bias and variance in Reinforcement Learning, Reducing variance in policy gradient estimates, baselines, advantage function, actor-critic methods, an introduction to Deep Reinforcement Learning

References

1. Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction* 2nd Edition, MIT Press, 2018.
2. Enes Bilgin *Mastering Reinforcement Learning with Python: Build next-generation, self-learning models using reinforcement learning techniques and best practices*, 1st edition, Packt Publishing, 2020.

Additional References

1. Phil Winder *Reinforcement Learning: Industrial Applications of Intelligent Agents*, O'Reilly Media, 2020.
2. Alexander Zai, Brandon Brown *Deep Reinforcement Learning in Action*, 1st edition, Manning Publications, 2020.

Suggested Practical List

Implement the following exercises using Python/Keras/TensorFlow/MATLAB.

1. Dynamic Programming Policy Evaluation algorithm.
2. Dynamic Programming Policy Iteration algorithm.
3. Dynamic Programming Value Iteration algorithm.
4. Monte Carlo Prediction
5. Off-Policy Monte Carlo Control with Importance Sampling
6. SARSA On policy TD learning algorithm
7. Q-learning OFF policy TD learning algorithm.
8. Policy Gradient REINFORCE algorithm

9. Policy Gradient Actor-Critic method algorithm

**For exercises 1 to 7, consider the following environments for testing: GridWorld, Blackjack, WindyGridWorld*

**For exercises 8 onward, consider the following environments for testing: CartPole, CartPoleRaw*

DISCIPLINE SPECIFIC ELECTIVE COURSE: Cyber Forensics

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE7d: Cyber Forensics	4	3	1	0	Pass in Class XII	NIL

Course Objective:

This course is to equip students with the knowledge and skills necessary to identify, collect, analyse and present digital evidence in a manner that is admissible in legal proceedings. Students will be able to conduct a thorough investigation of cybercrime incidents, preserve digital evidence, and report findings to relevant stakeholders.

Course Learning Outcomes:

On successful completion of the course, students will be able to:

- demonstrate an understanding of the principles of digital forensics, including legal considerations, recognition, collection, and preservation of digital evidence.
- Use digital forensics tools and techniques, such as creating disk images, conducting keyword and grep searches, and examining the Windows registry.

- Use evidence recovery methods, including deleted file recovery, formatted partition recovery, and data recovery procedures, as well as ethical considerations.
- gain knowledge of cyber forensic investigation tools and techniques, including digital evidence collection, preservation, and password cracking.
- understand cyber laws and crimes, including hacking, viruses, intellectual property, and e-commerce, and the legal system of information technology, including jurisdiction issues and security and evidence in e-commerce.

Unit 1 – Digital Forensics

(8 hours)

Introduction to digital forensics, legal considerations, recognising and collecting digital evidence, preservation of evidence, hash values and file hashing, creating disk images, keyword and grep searches, network basics, reporting and peer review, digital forensics report.

Unit 2 – Windows OS Forensics

(9 hours)

Bits, bytes, Endianness, Disk partition schema, File systems – FAT, NTFS, ex-FAT, windows registry forensics, examining windows registry, NTUser.Dat Hive File Analysis, SAM Hive file, Software Hive file, System Hive File, USRClass.dat Hive File, AmCache Hive File.

Unit 3 – Evidence Recovery

(9 hours)

Introduction to Deleted File Recovery, Formatted Partition Recovery, Data Recovery Tools, Data Recovery Procedures and Ethics, Complete time line analysis of computer files based on file creation, File modification and file access, Recover Internet Usage Data, Recover Swap Files/Temporary Files/Cache Files, Introduction to Encase Forensic Edition, Forensic Tool Kit (FTK), Use computer forensics software tools to cross validate findings in computer evidence.

Unit 4 – Investigation

(10 hours)

Introduction to Cyber Forensic Investigation, Investigation Tools, Digital Evidence Collection, Evidence Preservation, E-Mail Investigation, E-Mail Tracking, IP Tracking, E-Mail Recovery, Encryption and Decryption methods, Search and Seizure of Computers, Recovering deleted evidences, Password Cracking.

Unit 5 – Cyber Crimes and Cyber Laws

(9 hours)

Introduction to IT laws & Cyber Crimes, Internet, Hacking, Cracking, Viruses, Software Piracy, Intellectual property, Legal System of Information Technology, Understanding Cyber Crimes in context of Internet, Indian Penal Law & Cyber Crimes Fraud Hacking Mischief,

International law, E-Commerce-Salient Features On-Line contracts Mail Box rule Privities of, Contracts Jurisdiction issues in E-Commerce Electronic Data Interchange, Security and Evidence in E-Commerce Dual Key encryption Digital signatures security issues.

References:

1. Marjee T. Britz, Computer Forensics and Cyber Crime: An Introduction, Pearson Education, 2013.
2. C. Altheide & H. Carvey Digital Forensics with Open Source Tools, Syngress, 2011. ISBN: 9781597495868.

Additional References:

1. Computer Forensics: Investigating Network Intrusions and Cybercrime" by Cameron H. Malin, Eoghan Casey, and James M. Aquilina
2. Online Course management System: <https://esu.desire2learn.com/>
3. Computer Forensics, Computer Crime Investigation by John R, Vacca, Firewall Media, New Delhi.
4. Computer Forensics and Investigations by Nelson, Phillips Enfinger, Steuart, CENGAGE Learning
5. Real Digital Forensics by Keith j.Jones, Richard Bejtlich, Curtis W.Rose , Addison Wesley Pearson Education

Suggested Practical's

It is suggested that the following tools/e-resources can be explored during the practical sessions

- Wireshark • COFEE Tool • Magnet RAM Capture • RAM Capture • NFI Defragger • Toolsley
- Volatility

1. Study of Network Related Commands (Windows)
2. Study of Network related Commands (Linux)
3. Analysis of windows registry
4. Capture and analyze network packets using Wireshark. Analyze the packets captured.
5. Creating a Forensic image using FTK Imager/ Encase Imager: creating forensic image, check integrity of data, analyze forensic image

6. Using System internal tools for network tracking and process monitoring do the following:

- a. Monitor live processes
- b. Capture RAM
- c. Capture TCP/UDP packets
- d. Monitor Hard disk
- e. Monitor Virtual Memory
- f. Monitor Cache Memory

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

(For all the Generic Elective courses offered by your department, please put it in the format provided below)

GENERIC ELECTIVES (GE-7a): Computer Networks

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE7a: Computer Networks	4	3	0	1	Pass in Class XII	NIL

Course Objective

The course objectives of this paper are to:

- Understand the concepts behind computer networks and data communication.

- Learn the different types of networks, network topologies and their characteristics.
- Learn the working of protocols used at various layers.
- Understand the utility of different networking devices.

Learning Outcomes

Upon successful completion of the course, students will be able to:

- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.
- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

Syllabus

Unit 1 Introduction:

(8 hours)

Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach, OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex, network devices and their role.

Unit 2 Physical Layer:

(9 hours)

Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3 Data Link and MAC Layer:

(10 hours)

Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet.

Unit 4 Network layer:**(8 hours)**

Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Overview of Network Layer protocols- (ARP, IPV4, ICMP, RARP, IPV6)

Unit 5 Transport and Application Layer:**(10 hours)**

Process-to-Process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (Hypertext Transfer Protocol), URL (Uniform Resource Locator), DNS, DHCP, BOOTP.

Essential/recommended readings

1. Tanenbaum, A.S. & Wethrall, D.J. Computer Networks, 5th edition, Pearson Education, 2012.
2. Forouzan, B. A. Data Communication and Networking, 4th edition, McGraw-Hill Education, 2017.

Additional References

1. Comer, D. E.. Computer Networks and Internet, 6th edition, Pearson education, 2015.
2. Stallings, W., Data and Computer Communications, 10th edition, Pearson education India, 2017.

Practicals.

Introduce students to any network simulator tool and do the following:

1. To study basic network command and network configuration commands.
2. To study and perform PC to PC communication.
3. To create Star topology using Hub and Switch.
4. To create Bus, Ring, Tree, Hybrid, Mesh topologies.
5. Perform an initial Switch configuration.
6. Perform an initial Router configuration.
7. To implement Client Server Network.
8. To implement a connection between devices using a router.
9. To perform remote desktop sharing within LAN connection.

GENERIC ELECTIVES (GE-7b): Internet Technologies: Mobile App Design and Development

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE7b: Internet Technologies: Mobile App Design and Development	4	3	0	1	Pass in Class XII	NIL

Course Objective

- To comprehend Android and iOS mobile operating systems, their architecture, and development environments.
- To understand the basics of creating user interfaces in Android, including layouts, views, and UI components, and explore the iOS technology stack for developing intuitive iOS interfaces.
- To learn to use Android Data and Storage APIs, manage data with SQLite, share data between applications using Content Providers, and utilise various Android APIs for multimedia, networking, web, telephony, and location-based services. Understand the Core Data framework in iOS for data persistence and perform CRUD operations.
- To introduce Swift programming language, its data types, variables, control flow, operators, collections, functions, classes, structures, inheritance, and enumerations.
- To develop skills to handle user interactions in both Android and iOS, including controls, gesture recognisers, touch events, location-based services, and integration with Google Maps and iOS sensors.

Learning Outcomes

By the end of the course, students will be able to:

- Demonstrate proficiency in Android and iOS development, including installing and configuring development environments.
- Create effective user interfaces using Android UI components and iOS StoryBoard, applying event listeners, animations, and notifications.
- Manage application data efficiently using Android Data and Storage APIs, SQLite, Content Providers, multimedia, networking, and location-based services. Implement the Core Data framework in iOS for data persistence and CRUD operations.
- Code in Swift, utilising data types, control flow, collections, functions, classes, structures, inheritance, and closures.
- Enhance user interaction in mobile applications through gesture recognition, touch events, location services, and integration of Google Maps and iOS sensors.

Syllabus

Unit 1 Android Systems

(9 hours)

Introduction to mobile devices and applications, Open Handset Alliance (OHA), overview of Android OS and architecture, and installation of Android Studio. Introduction to Android application components, Intents, Android Manifest File and its common settings, Using Intent Filter, Permissions, Activities and intents: understanding activity and its life cycle, Types of intents, intent filter, context, data sharing using intent

Unit 2 Android User Interface

(10 hours)

Basic Android UI, layouts, views and view attributes, buttons, and controls. UI events and event listeners, animations, notifications, progress dialog, Action bar, toolbar, menus and pop-ups, Tab-based UI, Fragment, Types of Fragments, Fragment Lifecycle, communication between fragment and activity

Unit 3 Android Storage and APIs

(9 hours)

Android storage: Using Android Data and Storage APIs, Managing data using SQLite, Sharing Data between Applications with Content Providers

Android APIs: Multimedia, Using Android Networking APIs, Using Android Web APIs, Using Android Telephony APIs, android location-based services

Unit 4 iOS Technology Stack

(9 hours)

Introduction to iOS technology stack: iOS architecture, Storyboard, features of Xcode, components of iOS SDK. Introduction to Swift: data types, variables, control flow and operators, Collections and functions in Swift, classes and structures, inheritance, closure, and enumerations

Unit 5 User interactions

(8 hours)

Controls, gesture organizers, touching views, Core Location and Mapkit, using Google Maps in iOS, and sensors in iOS. Data persistence: Core Data framework for storing persistent data, CRUD operations.

Note: Kotlin will be used for the implementation.

References

1. Meier Reto and Ian Lake, *Professional Android*, 4th edition, Wrox, 2018.
2. Craig Grummitt, *iOS Development with Swift*, Manning publications.
3. Rick Boyer, *Android 9 Development Cookbook*, Packt Publishing Limited, 2018.

Suggested Practical List

1. Set up Android Studio on their computers, create a new project, and run a simple "Hello World" application on an emulator.
2. Create an Android app with a LinearLayout containing a TextView, EditText, and Button. Set up a click listener for the Button to display a Toast message with the text entered in the EditText.
3. Create an Android app that allows users to add, view, and delete notes. Use SQLite to store the notes and display them in a ListView.
4. Set up Xcode on Macs/Mac emulators, create a new project, and run a simple "Hello World" application on an iOS simulator.
5. Create an iOS app with a UILabel, UITextField, and UIButton. Set up an action for the UIButton to update the UILabel with the text entered in the UITextField.
6. Create an iOS app that allows users to add, view, and delete contacts. Store the contacts in Core Data and display them in a UITableView.

7. Create an Android app with two activities. The first activity should have a Button that, when clicked, navigates to the second activity using explicit intent. The second activity should display a message.
8. Create an Android app that uses the Google Maps API to display a map with the user's current location marked.
9. Create an iOS app that recognises and responds to tap and swipe gestures on a UIView. For example, you could change the view's colour on a tap and move it on a swipe.
10. Create an Android app that fetches and displays a list of items from a public API (e.g., JSONPlaceholder) using Retrofit, Volley, or any other networking APIs.

GENERIC ELECTIVES (GE-7c): Machine Learning

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE 7c: Machine Learning	4	3	0	1	Pass in Class XII	Programming using Python/ Object Oriented Programming using Python

Course Objectives

The course aims to introduce the basic concepts and techniques of machine learning so that a student can apply machine learning techniques to a problem at hand.

On successful completion of the course, students will be able to:

- Differentiate between supervised and unsupervised learning tasks.
- State the need of preprocessing, feature scaling and feature selection.
- Formulate classification, regression and clustering problems as optimization problems
- Implement various machine learning algorithms learnt in the course.

SYLLABUS

Unit 1 Introduction:

(5 Hours)

Basic definitions and concepts, key elements, supervised and unsupervised learning, applications of ML.

Unit 2 Preprocessing:

(6 Hours)

Feature scaling, feature selection methods. dimensionality reduction (Principal Component Analysis), class balancing, outlier detection and removal.

Unit 3 Regression:

(12 Hours)

Linear regression with one variable, linear regression with multiple variables, gradient descent, over-fitting, regularization. Regression evaluation metrics.

Unit 4 Classification:

(15 Hours)

Decision trees, Naive Bayes classifier, logistic regression, k-nearest neighbour classifier, perceptron, multilayer perceptron, neural networks, back-propagation algorithm, Support Vector Machine (SVM). Classification evaluation metrics

Unit 5 Clustering:

(7Hours)

Approaches for clustering, distance metrics, K-means clustering, hierarchical clustering.

Essential/recommended readings

1. Mitchell, T.M. Machine Learning, McGraw Hill Education, 2017.
2. James, G., Witten. D., Hastie. T., Tibshirani., R. An Introduction to Statistical Learning with Applications in R, Springer, 2014.
3. Alpaydin, E. Introduction to Machine Learning, MIT press, 2009.

Additional References

1. Flach, P., Machine Learning: The Art and Science of Algorithms that Make Sense of Data, Cambridge University Press, 2015.
2. Christopher & Bishop, M., Pattern Recognition and Machine Learning, New York: Springer-Verlag, 2016.
3. Sebastian Raschka, Python Machine Learning, Packt Publishing Ltd, 2019

Suggested Practical List:

Use Python for practical labs for Machine Learning. Utilize publicly available datasets from repositories like <https://data.gov.in/> and <https://archive.ics.uci.edu/ml/datasets.php>

For evaluation of the regression/classification models, perform experiments as follows:

- Scale/Normalize the data
- Reduce dimension of the data with different feature selection techniques
- Split datasets into training and test sets and evaluate the decision models
- Perform k-cross-validation on datasets for evaluation

Report the efficacy of the machine learning models as follows: • MSE and R2 score for regression models • Accuracy, TP, TN, FP, FN, error, Recall, Specificity, F1-score, AUC for classification models

For relevant datasets make prediction models for the following

1. Naïve Bayes Classifier
2. Simple Linear Regression multiple linear regression
3. Polynomial Regression
4. Lasso and Ridge Regression
5. Logistic regression
6. Artificial Neural Network
7. k-NN classifier
8. Decision tree classification
9. SVM classification
10. K-Means Clustering
11. Hierarchical Clustering

GENERIC ELECTIVES (GE-7d): Cloud Computing

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE 7d: Cloud Computing	4	3	0	1	Pass in Class XII	NIL

Course Objective:

The objective of an undergraduate cloud computing course is to provide students with a comprehensive understanding of cloud computing technologies, services, and applications.

Course Learning Outcomes:

On successful completion of the course, students will be able to:

1. Apply knowledge of the fundamental concepts and principles of cloud computing, including virtualization, scalability, reliability, and security.
2. to design, develop, and deploy cloud-based applications using popular cloud platforms and services.
3. apply knowledge of cloud computing architectures, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).
4. visualize the economic, legal, and ethical implications of cloud computing, including issues related to data privacy, ownership, and security.
5. evaluate and select cloud-based solutions based on their technical, economic, and business requirements.
6. gain an understanding of the broader societal and environmental impacts of cloud-based services and applications.

Syllabus:

Unit 1: Overview of Computing Paradigm (6 hours)

Recent trends in Computing: Grid Computing, Cluster Computing, Distributed Computing, Utility Computing, Cloud Computing,

Unit 2: Introduction to Cloud Computing (7 hours)

Introduction to Cloud Computing, History of Cloud Computing, Cloud service providers, Benefits and limitations of Cloud Computing.

Unit 3: Cloud Computing Architecture (12 hours)

Comparison with traditional computing architecture (client/server), Services provided at various levels, Service Models- Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), How Cloud Computing Works, Deployment Models- Public cloud, Private cloud, Hybrid cloud, Community cloud, Case study of NIST architecture.

Unit 4: Case Studies (7 hours)

Case study of the Service model using Google Cloud Platform (GCP), Amazon Web Services (AWS), Microsoft Azure, and Eucalyptus.

Unit 5: Cloud Computing Management (6 hours)

Service Level Agreements (SLAs), Billing & Accounting, Comparing Scaling Hardware: Traditional vs. Cloud, Economics of scaling.

Unit 6: Cloud Computing Security (7 hours)

Infrastructure Security- Network level security, Host level security, Application level security, Data security and Storage- Data privacy and security Issues, Jurisdictional issues raised by Data location, Authentication in cloud computing.

References:

1. Thomas Erl, Ricardo Puttini and Zaigham Mahmood, Cloud Computing: Concepts, Technology and Architecture, Publisher: PHI, 2013.
2. Rajkumar Buyya, James Broberg, and Andrzej Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2013.

3. Boris Scholl, Trent Swanson, and Peter Jausovec, *Cloud Native: Using Containers, Functions, and Data to Build Next-Generation Applications*, Publisher : Shroff/O'Reilly, 2019.

Additional References:

1. *Cloud Computing Bible*, Barrie Sosinsky, *Wiley-India*, 2010
2. *Cloud Computing: Principles and Paradigms*, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, *Wile*, 2011
3. *Cloud Computing: Principles, Systems and Applications*, Editors: Nikos Antonopoulos, Lee Gillam, *Springer*, 2012
4. *Cloud Security: A Comprehensive Guide to Secure Cloud Computing*, Ronald L. Krutz, Russell Dean Vines, *Wiley-India*, 2010

Suggested Practical List:

1. Introduction to Cloud Platforms

Objective: Familiarize students with cloud platforms and their interfaces.

Steps:

- a) Create free-tier accounts on AWS, Azure, and GCP.
- b) Explore dashboards and identify key services (compute, storage, networking).
- c) Understand pricing calculators on each platform.

2. Launch Your First Amazon EC2 Instance

Objective: Deploy a virtual machine on AWS using Amazon EC2.

Steps:

- a) Launch an EC2 instance from the AWS Management Console.
- b) Use a pre-configured AMI (e.g., Amazon Linux 2).
- c) Configure security groups to allow SSH access.
- d) Connect to the instance using SSH.

3. Set Up a VPC

Objective: Create and configure a Virtual Private Cloud (VPC).

Steps:

- a) Create a custom VPC with a public and private subnet.
- b) Launch an EC2 instance in the public subnet and another in the private subnet.

- c) Configure an Internet Gateway for Internet access in the public subnet.
- d) Use a NAT Gateway to provide internet access for instances in the private subnet.

4. Configure Auto Scaling and Load Balancing

Objective: Set up an auto-scaling group and a load balancer

Steps:

- a) Create an Auto Scaling Group and define a launch template.
- b) Configure scaling policies (e.g., scale up when CPU utilization exceeds 70%).
- c) Deploy an Application Load Balancer (ALB) to distribute traffic.
- d) Test auto-scaling by simulating high traffic.

5. Deploying a Static Website on the Cloud

Objective: Host a static website using cloud storage services.

Steps:

- a) Deploy a static website using any of the following:
 - AWS S3
 - Azure Blob Storage
 - GCP Cloud Storage
- b) Configure permissions and enable public access.

6. Monitor Resources Using AWS CloudWatch

Objective: Use CloudWatch to monitor AWS resources

Steps

- a) Set up CloudWatch metrics for an EC2 instance (e.g., CPU utilization).
- b) Create a CloudWatch Alarm to send notifications when a threshold is exceeded.
- c) Configure an SNS topic for email notifications.
- d) Test the setup by simulating high CPU usage.

7. Install OpenStack

Objective: Set up a local OpenStack environment for practice.

8. Launch Your First Instance

Objective: Create a virtual machine (VM) using OpenStack.

Steps:

- a) Create a project and assign roles to users.
- b) Upload an image (e.g., Ubuntu cloud image) to the Glance service.

- c) Define a flavor to specify VM configurations.
- d) Launch an instance using the Horizon dashboard or CLI.

Resources Needed:

- OpenStack Horizon access or CLI setup.
- Sample Ubuntu or CentOS cloud image (from [Ubuntu Cloud Images](#)).

9. Set Up Networking

Objective: Configure OpenStack Neutron to provide networking for instances.

Steps:

- a) Create a private network and a public network.
- b) Attach a router to connect the private network to the public network.
- c) Assign floating IPs to instances for external access.

10. Cloud Security

Objective: Understand security practices in the cloud.

Steps:

- a) Implement IAM roles and policies for a cloud platform.
- b) Create and assign least-privilege roles to users.
- c) Configure data encryption for storage (e.g., S3 bucket encryption).
- d) Set up a firewall rule and test its functionality.

GENERIC ELECTIVES (GE-7e): ETHICAL HACKING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE 7e: Ethical Hacking	4	3	0	1	Pass in Class XII	NIL

Course Objectives

The objective of this course is to enable students to be part of a team that can conduct the security assessment of an organization through the process of ethical hacking. This course will introduce the students, the idea of security assessment of systems and networks under investigation and how to perform them under the legal and ethical framework. Further, this course will outline the importance of various stages of ethical hacking, including but not limited to tasks such as penetration testing, and usage of various tools at each stage.

Learning outcomes

On successful completion of the course, students will be able to:

1. Understand and acknowledge the relevance of legal, ethical, and professional challenges faced by an ethical hacker.
2. Apply fundamental principles of system, application, and network security to ethically attack / penetrate the system to uncover the security flaws.
3. Perform evaluation of security systems through a systematic ethical hacking process and recommend countermeasures to improve security.
4. Understand and use various tools and techniques used in various stages of the ethical hacking process.

Syllabus

Unit 1

(4 Hours)

Introduction: Overview of information security threats and attack vectors, vulnerability assessment and penetration testing concepts, information security controls, security laws and standards. OWASP top 10 vulnerabilities

Unit 2

(6 hours)

Foot printing and Reconnaissance: Introduction to network reconnaissance tools such as ipconfig, ifconfig, domain tools, nmap, Wireshark, etc.

Unit 3

(8 hours)

Scanning and Enumeration: Network penetration testing, Password cracking techniques and countermeasures, NetBIOS tools

Unit 4

(8 hours)

Gaining and Maintaining Access: Network level attacks and countermeasures, Metasploit framework, Burp Suite

Unit 5 (8 hours)

Exploitation and Covering Tracks: Privilege escalation, social Engineering, identity theft, countermeasures, Covering tracks using attrib command and creating Alternate Data Stream (ADS) in Windows, Erasing evidence from Windows logs, Strategies for maintaining access.

Unit 6 (8 hours)

Advanced stages: Denial of service, Session hijacking, hacking web servers, hacking web applications, sql injection etc.

Unit 7 (8 hours)

NIST Cybersecurity framework and ISO standards: NIST cybersecurity framework, Cyber Kill chain, ISO/IEC 27001 and related standards.

Unit 8 (4 Hours)

Cyber Defense and Reporting: Preparing vulnerability assessment reports, presenting post testing findings, preparing recommendations

References

1. Patrick Engbretson, The Basics of Hacking and Penetration Testing, 2nd Edition, Syngress, 2013.
2. Georgia Weidman, Penetration TEsting: A Hands-On Introduction to Hacking, 1st Edition, No Starch Press, 2014.

Additional References

1. Peter Kim, The Hacker Playbook 3: Practical Guide to Penetration Testing, Zaccheus Entertainment, 2018.
2. Jon Erickson, Hacking: The Art of Exploitation, No Starch Press, 2008.

3. Online Resources: <https://www.sans.org/cyberaces/>, <https://skillsforall.com/>,
<https://www.hackingloops.com/ethical-hacking/>

Suggested Practical List (If any): (30 Hours)

Perform the following activities, record and report in standard form.

(NOTE: Exercise extra caution while performing these exercises and codes)

1. Perform various Virtual Machine based exercises on <https://vulnhub.com/>
2. Perform Capture the Flag (CTF) exercises from <https://www.hacker101.com/>
3. Follow the lessons and activities from <https://www.hackingloops.com/ethical-hacking/>
4. Google site for hacking <https://google-gruyere.appspot.com/>
5. OWASP WebGoat <https://github.com/WebGoat/WebGoat>

GENERIC ELECTIVES (GE-7f): DESIGN AND ANALYSIS OF ALGORITHMS

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE 7f: Design and Analysis of Algorithms	4	3	0	1	Pass in Class XII	Data Structures

Course Objectives

The course is designed to develop an understanding of different algorithm design techniques and use them for problem-solving. The course shall also enable the students to verify the correctness of algorithms and analyse their time complexity.

Learning Outcomes

On successful completion of the course, students will be able to:

1. describe various algorithm design techniques, including iteration, divide and conquer, dynamic programming, and greedy approach algorithms.
2. Compute and compare the asymptotic time complexity of algorithms
3. Use appropriate algorithm design techniques for solving a given problem.
4. model simple problems as graphs and solve them using Graph Algorithms.

Syllabus

Unit 1 (8 hours)

Searching, Sorting, Selection: Linear Search, Binary Search, Insertion Sort, Selection Sort, Bubble Sort, Heapsort, Linear Time Sorting, running time analysis and correctness.

Unit 2 (5 hours)

Graphs: Review of graph traversals, graph connectivity, testing bipartiteness, Directed Acyclic Graphs and Topological Ordering, Minimum Spanning Trees.

Unit 3 (8 hours)

Divide and Conquer: Introduction to divide and conquer technique, Merge Sort, Quick Sort, Randomised quicksort, Maximum-subarray problem, Strassen's algorithm for matrix multiplication.

Unit 4 (5 hours)

Greedy algorithms: Introduction to the Greedy algorithm design approach, application to minimum spanning trees, fractional knapsack problem, and analysis of time complexity.

Unit 5 (5 hours)

Dynamic Programming: Introduction to the Dynamic Programming approach, application to subset sum, integer knapsack problems, and analysis of time complexity.

Unit 6 (4 hours)

Hash Tables Hash Functions, Collision resolution schemes.

Essential/recommended readings

1. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. Introduction to Algorithms, 4th edition, Prentice Hall of India, 2022.
2. Kleinberg, J., Tardos, E. Algorithm Design, 1st edition, Pearson, 2013.

Additional references

1. Basse, S., Gelder, A. V., Computer Algorithms: Introduction to Design and Analysis, 3rd edition, Pearson, 1999.

Practical List (If any): (30 Hours)

1. Write a program to sort the elements of an array using Insertion Sort (The program should report the number of comparisons).
2. Write a program to sort the elements of an array using Merge Sort (The program should report the number of comparisons).
3. Write a program to sort the elements of an array using Heap Sort (The program should report the number of comparisons).
4. Write a program to multiply two matrices using the Strassen's algorithm for matrix multiplication
5. Write a program to sort the elements of an array using Radix Sort.
6. Write a program to sort the elements of an array using Bucket Sort.
7. Display the data stored in a given graph using the Breadth-First Search algorithm.
8. Display the data stored in a given graph using the Depth-First Search algorithm.
9. Write a program to determine a minimum spanning tree of a graph using the Prim's algorithm.
10. Write a program to implement Dijkstra's algorithm to find the shortest paths from a given source node to all other nodes in a graph.
11. Write a program to solve the weighted interval scheduling problem.
12. Write a program to solve the 0-1 knapsack problem.

**(Computer Science Courses for Undergraduate Programme of study with
Computer Science discipline as one of the three Core Disciplines)**

(For e.g. courses for B.Sc. Programme with Computer Science as discipline)

DISCIPLINE-SPECIFIC CORE COURSE (DSC07): Design and Analysis of Algorithms

Credit distribution, eligibility and pre-requisites of the course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC07: Design and Analysis of Algorithms	4	3	0	1	Pass in Class XII	Data Structures

Course Objective

The course is designed to develop an understanding of different algorithm design techniques and use them for problem-solving. The course shall also enable the students to verify the correctness of algorithms and analyze their time complexity.

Learning Outcomes

On successful completion of the course, students will be able to:

1. describe various algorithm design techniques, including iteration, divide and conquer, dynamic programming, and greedy approach algorithms.
2. Compute and compare the asymptotic time complexity of algorithms
3. Use appropriate algorithm design techniques for solving a given problem.
4. model simple problems as graphs and solve them using Graph Algorithms.

Syllabus

Unit 1 (8 hours)

Searching, Sorting, Selection: Linear Search, Binary Search, Insertion Sort, Selection Sort, Bubble Sort, Heapsort, Linear Time Sorting, running time analysis and correctness.

Unit 2 (5 hours)

Graphs: Review of graph traversals, graph connectivity, testing bipartiteness, Directed Acyclic Graphs and Topological Ordering, Minimum Spanning Trees.

Unit 3 (8 hours)

Divide and Conquer: Introduction to divide and conquer technique, Merge Sort, Quick Sort, Randomised quicksort, Maximum-subarray problem, Strassen's algorithm for matrix multiplication.

Unit 4 (5 hours)

Greedy algorithms: Introduction to the Greedy algorithm design approach, application to minimum spanning trees, fractional knapsack problem, and analysis of time complexity.

Unit 5 (5 hours)

Dynamic Programming: Introduction to the Dynamic Programming approach, application to subset sum, integer knapsack problems, and analysis of time complexity.

Unit 6 (4 hours)

Hash Tables Hash Functions, Collision resolution schemes.

Essential/recommended readings

1. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. Introduction to Algorithms, 4th edition, Prentice Hall of India, 2022.
2. Kleinberg, J., Tardos, E. Algorithm Design, 1st edition, Pearson, 2013.

Additional references

1. Basse, S., Gelder, A. V., Computer Algorithms: Introduction to Design and Analysis, 3rd edition, Pearson, 1999.

Practical List (If any): (30 Hours)

1. Write a program to sort the elements of an array using Insertion Sort (The program should report the number of comparisons).
2. Write a program to sort the elements of an array using Merge Sort (The program should report the number of comparisons).
3. Write a program to sort the elements of an array using Heap Sort (The program should report the number of comparisons).
4. Write a program to multiply two matrices using the Strassen's algorithm for matrix multiplication
5. Write a program to sort the elements of an array using Radix Sort.
6. Write a program to sort the elements of an array using Bucket Sort.
7. Display the data stored in a given graph using the Breadth-First Search algorithm.
8. Display the data stored in a given graph using the Depth-First Search algorithm.
9. Write a program to determine a minimum spanning tree of a graph using the Prim's algorithm.
10. Write a program to implement Dijkstra's algorithm to find the shortest paths from a given source node to all other nodes in a graph.
11. Write a program to solve the weighted interval scheduling problem.
12. Write a program to solve the 0-1 knapsack problem.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines

(For e.g. courses for B.A. Programmes with Computer Science as Major/Non-major discipline)

DISCIPLINE SPECIFIC CORE COURSE (DSC07): Design and Analysis of Algorithms

Credit distribution, eligibility and pre-requisites of the course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC07: Design and Analysis of Algorithms	4	3	0	1	Pass in Class XII	NIL

Course Objectives

The course is designed to develop understanding of different algorithm design techniques and use them for problem solving. The course shall also enable the students to verify correctness of algorithms and analyze their time complexity.

Learning Outcomes

On successful completion of the course, students will be able to:

1. describe various algorithm design techniques, including iteration, divide and conquer, dynamic programming, and greedy approach algorithms.
2. Compute and compare the asymptotic time complexity of algorithms
3. Use appropriate algorithm design techniques for solving a given problem.
4. model simple problems as graphs and solve them using Graph Algorithms.

Unit 1**(8 hours)**

Searching, Sorting, Selection: Linear Search, Binary Search, Insertion Sort, Selection Sort, Bubble Sort, Heapsort, Linear Time Sorting, running time analysis and correctness.

Unit 2**(5 hours)**

Graphs: Review of graph traversals, graph connectivity, testing bipartiteness, Directed Acyclic Graphs and Topological Ordering, Minimum Spanning Trees.

Unit 3**(8 hours)**

Divide and Conquer: Introduction to divide and conquer technique, Merge Sort, Quick Sort, Randomised quicksort, Maximum-subarray problem, Strassen's algorithm for matrix multiplication.

Unit 4**(5 hours)**

Greedy algorithms: Introduction to the Greedy algorithm design approach, application to minimum spanning trees, fractional knapsack problem, and analysis of time complexity.

Unit 5**(5 hours)**

Dynamic Programming: Introduction to the Dynamic Programming approach, application to subset sum, integer knapsack problems, and analysis of time complexity.

Unit 6**(4 hours)**

Hash Tables Hash Functions, Collision resolution schemes.

Essential/recommended readings

1. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. Introduction to Algorithms, 4th edition, Prentice Hall of India, 2022.
2. Kleinberg, J., Tardos, E. Algorithm Design, 1st edition, Pearson, 2013.

Additional references

1. Basse, S., Gelder, A. V., Computer Algorithms: Introduction to Design and Analysis, 3rd edition, Pearson, 1999.

Practical List (If any): (30 Hours)

1. Write a program to sort the elements of an array using Insertion Sort (The program should report the number of comparisons).
2. Write a program to sort the elements of an array using Merge Sort (The program should report the number of comparisons).

3. Write a program to sort the elements of an array using Heap Sort (The program should report the number of comparisons).
4. Write a program to multiply two matrices using Strassen's algorithm for matrix multiplication
5. Write a program to sort the elements of an array using Radix Sort.
6. Write a program to sort the elements of an array using Bucket Sort.
7. Display the data stored in a given graph using the Breadth-First Search algorithm.
8. Display the data stored in a given graph using the Depth-First Search algorithm.
9. Write a program to determine a minimum spanning tree of a graph using the Prim's algorithm.
10. Write a program to implement Dijkstra's algorithm to find the shortest paths from a given source node to all other nodes in a graph.
11. Write a program to solve the weighted interval scheduling problem.
12. Write a program to solve the 0-1 knapsack problem.

Semester VIII

<u>S.No.</u>	<u>Content</u>
1	BSc. (Hons.) Computer Sciences DISCIPLINE SPECIFIC CORE (DSC) 1. Information Security
2	DISCIPLINE SPECIFIC ELECTIVES (DSE) 1. Information and Image Retrieval 2. Natural Language Processing 3. Blockchain and Its Applications 4. Distributed Algorithms 5. Cloud Computing
3	GENERIC ELECTIVES (G.E.) (1) Information Security (2) Digital Marketing and Social Media Analytics (3) Introduction to Parallel programming (4) Cyber Forensics
4	BSc. (Prog.) with Computer Sciences DISCIPLINE SPECIFIC CORE (DSC) 1. Information Security
5	BA (Prog.). with Computer Sciences as Major/Non-major discipline DISCIPLINE SPECIFIC CORE (DSC) 1. Design and Analysis of Algorithms



Department of Computer Science

COURSES OFFERED BY DEPARTMENT OF COMPUTER SCIENCE

(Provide the details of the Discipline Specific Courses offered by your department for the UG Programme with your discipline as the Single Core Discipline)

[UG Programme for Bachelor in Computer Science (Honours) degree]

DISCIPLINE SPECIFIC CORE COURSE -20 (DSC-20) : Information Security

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC20 Information Security	4	3	0	1	Pass in Class XII	NIL

Course Objective

The goal of this course is to make a student learn basic principles of information security. Over the due course of time, the student will be familiarized with cryptography, authentication and access control methods along with software security. Potential security threats and vulnerabilities of systems are also discussed along with their impacts and countermeasures. This course also touches upon the implications of security in cloud and Internet of Things (IoT).

Learning Outcomes

On successful completion of this course, a student will be able to

- Identify the major types of threats to information security.

- Describe the role of cryptography in security.
- Discover the strengths and weaknesses of private and public key cryptosystems.
- Identify and apply various access control and authentication mechanisms.
- Discuss data and software security and related issues.
- Describe network security threats and attacks.
- Articulate the need for security in cloud and IoT.

Syllabus

Unit 1

(3 hours)

Overview: Computer Security Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Fundamental Security Design Principles.

Unit 2

(6 hours)

Cryptographic tools: Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions, Public-Key Encryption, Digital Signatures and Key Management, Random and Pseudorandom Numbers, Practical Application: Encryption of Stored Data.

Unit 3

(10 hours)

User authentication and Access Control: Digital User Authentication Principle, Password-Based Authentication, Remote User Authentication, Security Issues for User Authentication Access Control Principles, Subjects, Objects, and Access Rights, Discretionary Access Control, Example: UNIX File Access Control, Role-Based Access Control, Attribute-Based Access Control, Identity, Credential, and Access Management, Trust Frameworks.

Unit 4

(5 hours)

Database and Data Center Security:

The Need for Database Security, SQL Injection Attacks, Database Access Control.

Unit 5

(8 hours)

Software Security: Types of Malicious Software, Advanced Persistent Threat, Propagation: Infected Content - Viruses, Vulnerability Exploit - Worms, Social Engineering — SPAM E-Mail, Trojans, Payload: System Corruption, Attack Agent — Zombie, Bots, Information Theft **45**

— Keyloggers, Phishing, Spyware, Stealthing — Backdoors, Rootkits, Countermeasures. Overflow Attacks - Stack Overflows, Defending Against Buffer Overflows, Other Forms of Overflow Attacks. Software Security Issues - Handling Program Input, Writing Safe Program Code.

Unit 6

(6 hours)

Network Security: Denial-of-Service Attacks, Flooding Attacks, Distributed Denial-of-Service Attacks, Overview of Intrusion Detection, Honeypots, The Need for Firewalls, Firewall Characteristics and Access Policy, Types of Firewalls, Public-Key Infrastructure.

Unit 7

(7 hours)

Wireless, Cloud and IoT Security: Cloud Computing, Cloud Security Concepts, Cloud Security Approaches, The Internet of Things, IoT Security. Wireless Security Overview, Mobile Device Security.

References

1. W. Stallings, L. Brown, *Computer Security: Principles and Practice*, 4th edition, Pearson Education, 2018.

Additional References

1. Pfleeger C.P., Pfleeger S.L., Margulies J. *Security in Computing*, 5th edition, Prentice Hall, 2015.
2. Lin S., Costello D.J., *Error Control Coding: Fundamentals and applications*, 2nd edition, Pearson Education, 2004.
3. Stallings W. *Cryptography and network security*, 7th edition, Pearson Education, 2018.
4. Berlekamp E. *Algebraic Coding Theory*, World Scientific Publishing Co., 2015.
5. Stallings W. *Network security essentials Applications and Standards*, 6th edition, Pearson Education, 2018.
6. Whitman M.E., Mattord H.J., *Principle of Information Security*, 6th edition, Cengage Learning, 2017.
7. Bishop M., *Computer Security: Art and Science*, 2nd Revised edition, Pearson Education, 2019.

8. Anderson R.J., *Security Engineering: A guide to building Dependable Distributed Systems*, 2nd edition, John Wiley & Sons, 2008.

Suggested Practical List

1. Demonstrate the use of Network tools: ping, ipconfig, ifconfig, tracert, arp, netstat, whois.
2. Use of Password cracking tools : John the Ripper, Ophcrack. Verify the strength of passwords using these tools.
3. Use nmap/zenmap to analyze a remote machine.
4. Use Burp proxy to capture and modify the message.
5. Implement caesar cipher substitution operation.
6. Implement monoalphabetic and polyalphabetic cipher substitution operation.
7. Implement playfair cipher substitution operation.
8. Implement hill cipher substitution operation.
9. Implement rail fence cipher transposition operation.
10. Implement row transposition cipher transposition operation.
11. Implement product cipher transposition operation.

COMMON POOL OF DISCIPLINE ELECTIVE COURSES (DSE) COURSES

Computer Science Courses for all Undergraduate Programmes of study with Computer Science as a Discipline Elective

DISCIPLINE SPECIFIC ELECTIVE COURSE: Information and Image Retrieval

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE8a: Information and Image Retrieval	4	3	0	1	Pass in Class XII	Digital Image Processing

Course Objective

This course introduces students to the fundamentals of information retrieval extending into image retrieval. It lays the theoretical foundation of various essential concepts related to image searches, together with examples of natural and texture image types. It will provide insight to content-based image retrieval, understanding of the technologies, and solutions of content-based image retrieval.

Course Learning Outcomes

On the successful completion of the course, the student would be able to:

1. Understand the concept of information retrieval and the information retrieval models.
2. Understand the working of text-based and content-based image retrieval systems.

3. Identify and evaluate the use of content-based features in the indexing and retrieval of various types of media content
4. Extract different visual features from images
5. Understand indexing and the semantics of visual data
6. Understand query specification and evaluate the retrieval

Syllabus

Unit 1

(5 hours)

Introduction to IR: An example information retrieval problem, the extended Boolean model versus ranked retrieval, The term vocabulary and postings lists: Tokenization, stop words, Normalization (equivalence classing of terms), Stemming and lemmatization, term weighting model: Inverse document frequency, Tf-idf weighting, Information retrieval system evaluation.

Unit 2

(10 hours)

CBIR and feature extraction: Image Retrieval: Multimedia Information Retrieval, Text-Based Image Retrieval (TBIR), Content-Based Image Retrieval (CBIR), Hybrid systems. Architecture of a typical CBIR system, Low-level features of an image: Colour – colour space, colour moments, colour histogram, colour coherence vector (CCV), colour correlogram, invariant colour features.

Texture – Tamura features, coarseness, contrast, SAR Model, Wavelet transform feature. Shape- Moment invariants, turning angles, Fourier descriptors.

Unit 3

(10 hours)

Similarity measures and Performance evaluation: Similarity measures used in content-based image retrieval: Minkowski-form distance, Mahalanobis distance, Canberra distance, Earth Mover distance, Quadratic form distance

Performance evaluation used in content-based image retrieval: user Comparison, precision and recall, P-R graph, Average Precision, F-measure, Average Normalized Modified Retrieval Rank (ANMRR)

Unit 4

(10 hours)

CBIR systems: QBIC: Query by Image Content, VIR, VisualSEEK, WebSEEK, NeTRA, MARS: Multimedia Analysis and Retrieval System, SIMPLicity.

Unit 5

(10 hours)

Content-Based Image Retrieval-Challenges: Semantic gap: Introduction to the semantic gap. Bridging the semantic gap: Relevance feedback, multi-modal fusion. Semantic similarity: WordNet.

“Curse of Dimensionality”: Feature Dimensionality reduction, Methods for dimensionality reduction: Principal Component Analysis (PCA), Fisher Linear Discriminant Analysis (FLDA), Local Fisher Discriminant Analysis (LFDA), Isometric Mapping (ISOMAP), Locally Linear Embedding (LLE), and Locality Preserving Projections (LPP).

References

1. C. Manning, P. Raghavan, and H. Schutze *Introduction to Information Retrieval* Cambridge University Press, 2009 .
2. Vipin Tyagi *Content-Based Image Retrieval: Ideas, Influences, and Current Trends*, Springer, 2018.

Suggested Practical List

To be implemented in Python

1. Write a program to compute the edit distance between strings s1 and s2. (Hint. Levenshtein Distance)
2. Write a program to Compute Similarity between two text documents.
3. Write a program for Pre-processing of a Text Document: stop word removal.
4. Consider 3 documents as below:-
Doc 1: Ben studies about computers in Computer Lab.
Doc 2: Steve teaches at Brown University.
Doc 3: Data Scientists work on large datasets.
Perform search on these documents with the following query: Data Scientists and, calculate $tf * idf$ for data and Scientists in all the documents.
5. Write a program to find out the similarity between document d1 and d2 (refer question#4) using cosine similarity method.

6. Write a program to calculate the color moments, color histogram, color coherence vector (CCV), color correlogram for an image.
7. Write a program to find out the similarity between two images using:-
 - a. Minkowski-form distance
 - b. Mahalanobis distance
 - c. Canberra distance
 - d. Earth Mover distance
 - e. Quadratic form distance
8. Given a confusion matrix

		ACTUAL	
		Negative	Positive
PREDICTION	Negative	60	8
	Positive	22	10

Write a program to find precision and recall, Average Precision, F-measure, Average Normalized Modified Retrieval Rank (ANMRR).

DISCIPLINE SPECIFIC ELECTIVE COURSE: Natural Language Processing

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE8b: Natural	4	3	0	1	Pass in Class XII	Machine Learning

Language Processing						
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Course Objective

The objectives of this course are:

1. To introduce foundational understanding in natural language
2. To understand the principles and methods of statistical natural language processing
3. To develop an in-depth understanding of the algorithms available for the processing and analysis of natural languages
4. To perform statistical analysis of textual data and find useful patterns from the data

Course Learning Outcomes

On successful completion of the course, students will be able to:

1. Grasp the significance of natural language processing in solving real-world problems
2. Preprocess and Analyze text using mathematical techniques.
3. Apply machine learning techniques used in NLP - HMM, RNN
4. Understand approaches to syntax and semantics analysis in NLP
5. Gain practical experience of using NLP toolkits

Syllabus

Unit 1

(5 hours)

Introduction and Basic Text Processing: Knowledge in Speech and Language Processing, The problem of ambiguity, Typical NL Tasks, Tokenisation, Stemming, Lemmatization, Stop-word removal

Unit 2.

(10 hours)

Formal Language Modeling: Regular Expressions, Text Normalization, and Edit Distance, Unigrams, Bigrams, N-grams, N-gram Language Models, Smoothing and Entropy

Unit 3

(10 hours)

Sequence Labeling for Parts of Speech Tagging: Part-of-Speech Tagging, Named Entities and Named Entity Tagging/Recognition, Hidden Markov Model (Forward and Viterbi algorithms and EM training)

Unit 4 (8 hours)

Vector Semantics and Embedding: Lexical Semantics, Vector Semantics, Words and Vectors, TF-IDF: Weighing terms in the vector and its applications, Learning Word Embeddings - Word2vec and Gensim, Vector Space Models

Unit 5 (5 hours)

Applications of Text Mining: Text classification, Sentiment Analysis

Unit 6 (7 hours)

Deep Learning Models for NLP: Feedforward Neural Networks, Recurrent Neural Networks, and LSTM

References

1. Daniel Jurafsky and James H. Martin *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*, 3rd edition, Pearson, 2022.
2. Christopher D. Manning and Hinrich Schütze *Foundations of Statistical Natural Language Processing*, MIT Press, 1999.
3. Steven Bird, Ewan Klein, and Edward Loper *Natural Language Processing with Python – Analyzing Text with the Natural Language Toolkit*, 1st edition, O'Reilly Media, 2009.

Additional Reference

1. Yoav Goldberg *A Primer on Neural Network Models for Natural Language Processing*, 2022.

Suggested Practical List

Python Packages like Scikit (SKLearn), NLTK, spaCy, gensim, PyTorch, transformers (HuggingFace) etc. may be used for programming

1. Prepare/Pre-process a text corpus to make it more usable for NLP tasks using tokenization, filtration of stop words, removal of punctuation, stemming and lemmatization.
2. List the most common words (with their frequency) in a given text excluding stopwords.
3. Extract the usernames from the email addresses present in a given text. .
4. Perform POS tagging in a given text file. Extract all the nouns present in the text. Create and print a dictionary with frequency of parts of speech present in the document. Find the similarity between any two text documents
5. Perform dependency analysis of a text file and print the root word of every sentence.
6. Create the TF-IDF (Term Frequency -Inverse Document Frequency) Matrix for the given set of text documents
7. Extract all bigrams , trigrams using ngrams of nltk library
8. Identify and print the named entities using Name Entity Recognition (NER) for a collection of news headlines.
9. Find the latent topics in a document using any LDA and display top 5 terms that contribute to each topic along with their strength. Also visualize the distribution of terms contributing to the topics.
10. Classify movie reviews as positive or negative from the IMDB movie dataset of 50K movie reviews. (Link for dataset:

<https://www.kaggle.com/datasets/lakshmi25npathi/imdb-dataset-of-50k-movie-reviews>)
11. Build and train a text classifier for the given data (using textblob or simpletransformers library)
12. Generate text using a character-based RNN using an appropriate dataset. Given a sequence of characters from a given data (eg "Shakespear"), train a model to predict the next character in the sequence ("e").

DISCIPLINE SPECIFIC ELECTIVE COURSE: Blockchain and its Applications

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE8c: Blockchain and its Applications	4	3	0	1	Pass in Class XII	A course in any Programming Language, Database Management Systems

Course Objective

This course covers the basic concepts behind blockchain and presents Bitcoin and other cryptocurrencies as the motivation for blockchain technologies. It provides a substantive discussion about different technologies behind blockchain and cryptocurrencies.

Course Learning Outcomes

On successful completion of the course, students will be able to:

1. understand the applications of blockchain in different domains
2. learn the practical applications of cryptocurrency such as Bitcoin and Ethereum
3. understand basic technologies like cryptographic hash functions, blocks, merkel trees, elliptic curve cryptography and digital signatures.
4. to have knowledge of decentralized consensus algorithms like proof of work, proof of stack, proof of capacity etc.
5. to learn how to record transactions in blockchain, computing bitcoin address etc.

6. to learn about smart contracts and their applications
7. to learn about permissioned and permission less blockchain and hyperledgers.
8. to gain knowledge of real world aspects of Bitcoin, such as wallets and mining techniques with the Bitcoin network.

Syllabus

Unit 1

(5 hours)

Introduction: History of money, Digital Currencies, Ledgers, Cryptography, Centralized and Decentralized systems, peer to peer systems, the purpose of Blockchain, types of blockchain (public, private and semi-private blockchain), application of blockchain (in government, healthcare, real estate, voting, insurance, non-fungible tokens, metaverse, Web 3.0).

Unit 2

(5 hours)

Cryptocurrency and Design: Concept of cryptocurrency, History of Bitcoin, mining concept, challenges of blockchain/bitcoin design (performance, scalability, efficiency, security, governance, public policy and legal framework).

Unit 3

(10 hours)

Blockchain Technology: Properties of hash functions, Cryptographic hash functions, hashes (as names, references and commitments), Blocks, Block Headers, Merkel Trees, chain forks, Asymmetric Cryptography, Digital signatures.

Unit 4

(8 hours)

Decentralized Network Consensus: Introduction to decentralized networks, Native Currency, consensus, proof of work (PoW), proof of stake (PoS), proof of capacity (PoC), proof of burn (PoB), Practical Byzantine Fault Tolerance (pBFT), Proof of Elapsed Time (PoET).

Unit 5

(7 hours)

Permissioned and Permissionless blockchain: Blockchain systems vs. traditional databases, introduction to permissioned/permissionless blockchains and their applications, Advantages and disadvantages, Solidity.

Unit 6

(5 hours)

Blockchain and Money Transactions: Satoshi and Bitcoin, Recording of transactions in blockchain, transaction inputs, outputs and format, Bitcoin address.

Unit 7

(5 hours)

Smart contracts (Ethereum and other currencies): Overview of smart contracts, tokens and Ethereum as a platform for smart contracts, blockchain technology as regulatory authority.

References

1. Imran Bashir *Mastering blockchain Distributed ledger technology, decentralization, and smart contracts explained*, 2nd edition, Packt Publication, 2018.
2. Lorne Lantz and Daniel Cawrey *Mastering Blockchain Unlocking the Power of Cryptocurrencies, Smart Contracts, and Decentralized Applications*, 1st edition, O'Reilly Publication, 2020.
3. Chris Dannen *Introducing Ethereum and Solidity Foundations of Cryptocurrency and Blockchain Programming for Beginners*, 1st edition, Apress Publication, 2017.

Additional Reference

1. Daniel Drescher *Blockchain Basics: A Non-Technical Introduction in 25 Steps*, 1st edition, Apress Publication, 2017.

Suggested Practical List

Use any programming language to implement the following:

1. Using SHA256, obtain the message digest of string "Blockchain Developer".
2. Write a program to encrypt and decrypt the message "Hello World" using SHA256.
3. Implement RSA cryptographic algorithm.
4. Create a simple blockchain using Proof of Work (PoW).
5. Demonstrate sending a digitally signed document.

6. Create a blockchain block containing block hash, transaction history, and time of creation.
7. Create a blockchain having 5 nodes and print the hash values of each block.
8. Create a blockchain having 5 nodes and check its validity.
9. Implement a smart contract using solidity programming language.
10. Create a simple permissioned blockchain using Hyperledger Fabric.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Distributed Algorithms

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE8d: Distributed Algorithms	4	3	0	1	Pass in Class XII	Data Structures, Design and Analysis of Algorithms

Course Objective

The course introduces the students to distributed algorithms in synchronous and asynchronous network models. The course would give the students hands-on practice to write programs for distributed algorithms using Remote Procedure Call (RPC) or Message Passing Interface (MPI)

Course Learning Outcomes

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

1. Describe Network Models for distributed Algorithms
2. Develop elementary synchronous distributed algorithms

3. Develop elementary asynchronous distributed algorithms

Syllabus

Unit 1

(5 hours)

System Model/Network Models: Synchronous Network Model, Asynchronous System Model, Asynchronous Network Model

Unit 2

(20 hours)

Synchronous Network Algorithms: Distributed problems in Synchronous Networks such as Leader Election in a Synchronous Ring. Algorithms in General Synchronous Networks (for example Leader Election in a General Network, Breadth-First Search, Maximal Independent Set etc). Problems of reaching consensus in a distributed network namely, distributed consensus with link failures coordinated Attack Problem (Deterministic Version and Randomized Version) and distributed consensus with link failures (Stopping failures, Introduction to Byzantine Failures). More Consensus Problems such as the k-Agreement etc.

Unit 3

(20 hours)

Asynchronous Network Algorithms: Basic Asynchronous Network Algorithms such as Leader Election in a Ring, Leader Election in an Arbitrary Network etc. Logical Time Asynchronous Networks, Adding Logical Time to Asynchronous Algorithms, Applications such as Banking System etc. Basics of Network Resource Allocation (mutual Exclusion, resource allocation etc) and Basics of Asynchronous Networks with Process Failures such as k-Agreement etc.

References

1. Lynch, N. *Distributed Algorithms*, Morgan Kaufmann Publishers, Inc., 1996.
2. M. van Steen, A. S. Tanenbaum, *Distributed Systems, CreateSpace Independent Publishing Platform*, 2017.

Additional References

1. Garg, V. *Elements of Distributed Computing*, Wiley, 2014.

Suggested Practical List

1. Implement Leader Election in a Synchronous Ring.
2. Implement Leader Election in a General Network (Synchronous Network)

3. Implement Breadth-First Search (Synchronous Network)
4. Implement Maximal Independent Set (Synchronous Network)
5. Implement Leader Election in an Asynchronous Ring.
6. Implement Asynchronous Banking System (Optional)
7. Implement distributed consensus with link failure (Synchronous Network)
8. Implement distributed consensus with Process failure (Synchronous Network)

DISCIPLINE SPECIFIC ELECTIVE COURSE: Cloud Computing

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSE8e: Cloud Computing	4	3	0	1	Pass in Class XII	

Course Objective:

The objective of an undergraduate cloud computing course is to provide students with a comprehensive understanding of cloud computing technologies, services, and applications.

Course Learning Outcomes:

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

1. Apply the fundamental concepts and principles of cloud computing, including virtualisation, scalability, reliability, and security.
2. design, develop, and deploy cloud-based applications using popular cloud platforms and services.

- 
3. understand cloud computing architectures, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).
 4. Visualise the economic, legal, and ethical implications of cloud computing, including issues related to data privacy, ownership, and security.
 5. evaluate and select cloud-based solutions based on their technical, economic, and business requirements.
 6. understand of the broader societal and environmental impacts of cloud-based services and applications.

Syllabus:

Unit 1: (6 hours)
Overview of Computing Paradigm: Recent trends in Computing - Grid Computing, Cluster Computing, Distributed Computing, Utility Computing, Cloud Computing,

Unit 2: (7 hours)
Introduction to Cloud Computing :History of Cloud Computing, Cloud service providers, Benefits and limitations of Cloud Computing,

Unit 3: (12 hours)
Cloud Computing Architecture: Comparison with traditional computing architecture (client/server), Services provided at various levels, Service Models- Infrastructure as a Service(IaaS), Platform as a Service(PaaS), Software as a Service(SaaS), How Cloud Computing Works, Deployment Models- Public cloud, Private cloud, Hybrid cloud, Community cloud, Case study of NIST architecture.

Unit 4: (7 hours)
Case Studies :Case study of Service model using Google Cloud Platform (GCP), Amazon Web Services (AWS), Microsoft Azure, Eucalyptus.

Unit 5: (6 hours)
Cloud Computing Management : Service Level Agreements(SLAs), Billing & Accounting, Comparing Scaling Hardware: Traditional vs. Cloud, Economics of scaling.

Unit 6:

(7 hours)

Cloud Computing Security: Infrastructure Security- Network level security, Host level security, Application level security, Data security and Storage- Data privacy and security Issues, Jurisdictional issues raised by Data location, Authentication in cloud computing.

References:

1. Thomas Erl, Ricardo Puttini and Zaigham Mahmood, Cloud Computing: Concepts, Technology and Architecture, Publisher: PHI, 2013.
2. Rajkumar Buyya, James Broberg, and Andrzej Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2013.
3. Boris Scholl, Trent Swanson, and Peter Jausovec, Cloud Native: Using Containers, Functions, and Data to Build Next-Generation Applications, Publisher : Shroff/O'Reilly, 2019.

Additional References:

1. *Cloud Computing Bible*, Barrie Sosinsky, Wiley-India, 2010
2. *Cloud Computing: Principles and Paradigms*, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, Wile, 2011
3. *Cloud Computing: Principles, Systems and Applications*, Editors: Nikos Antonopoulos, Lee Gillam, Springer, 2012
4. *Cloud Security: A Comprehensive Guide to Secure Cloud Computing*, Ronald L. Krutz, Russell Dean Vines, Wiley-India, 2010

Suggested Practical List:

1. Introduction to Cloud Platforms

Objective: Familiarize students with cloud platforms and their interfaces.

Steps:

- d) Create free-tier accounts on AWS, Azure, and GCP.
- e) Explore dashboards and identify key services (compute, storage, networking).
- f) Understand pricing calculators on each platform.

2. Launch Your First Amazon EC2 Instance

Objective: Deploy a virtual machine on AWS using Amazon EC2.

Steps:

- e) Launch an EC2 instance from the AWS Management Console.
- f) Use a pre-configured AMI (e.g., Amazon Linux 2).
- g) Configure security groups to allow SSH access.
- h) Connect to the instance using SSH.

3. Set Up a VPC

Objective: Create and configure a Virtual Private Cloud (VPC).

Steps:

- a) Create a custom VPC with a public and private subnet.
- b) Launch an EC2 instance in the public subnet and another in the private subnet.
- c) Configure an Internet Gateway for Internet access in the public subnet.
- d) Use a NAT Gateway to provide internet access for instances in the private subnet.

4. Configure Auto Scaling and Load Balancing

Objective: Set up an auto-scaling group and a load balancer

Steps:

- e) Create an Auto Scaling Group and define a launch template.
- f) Configure scaling policies (e.g., scale up when CPU utilization exceeds 70%).
- g) Deploy an Application Load Balancer (ALB) to distribute traffic.
- h) Test auto-scaling by simulating high traffic.

5. Deploying a Static Website on the Cloud

Objective: Host a static website using cloud storage services.

Steps:

- c) Deploy a static website using any of the following:
 - AWS S3
 - Azure Blob Storage
 - GCP Cloud Storage
- d) Configure permissions and enable public access.

6. Monitor Resources Using AWS CloudWatch

Objective: Use CloudWatch to monitor AWS resources

Steps

- e) Set up CloudWatch metrics for an EC2 instance (e.g., CPU utilization).

- f) Create a CloudWatch Alarm to send notifications when a threshold is exceeded.
- g) Configure an SNS topic for email notifications.
- h) Test the setup by simulating high CPU usage.

7. Install OpenStack

Objective: Set up a local OpenStack environment for practice.

8. Launch Your First Instance

Objective: Create a virtual machine (VM) using OpenStack.

Steps:

- e) Create a project and assign roles to users.
- f) Upload an image (e.g., Ubuntu cloud image) to the Glance service.
- g) Define a flavor to specify VM configurations.
- h) Launch an instance using the Horizon dashboard or CLI.

Resources Needed:

- OpenStack Horizon access or CLI setup.
- Sample Ubuntu or CentOS cloud image (from [Ubuntu Cloud Images](#)).

9. Set Up Networking

Objective: Configure OpenStack Neutron to provide networking for instances.

Steps:

- d) Create a private network and a public network.
- e) Attach a router to connect the private network to the public network.
- f) Assign floating IPs to instances for external access.

10. Cloud Security

Objective: Understand security practices in the cloud.

Steps:

- e) Implement IAM roles and policies for a cloud platform.
- f) Create and assign least-privilege roles to users.
- g) Configure data encryption for storage (e.g., S3 bucket encryption).
- h) Set up a firewall rule and test its functionality.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

(For all the Generic Elective courses offered by your department, please put it in the format provided below)

GENERIC ELECTIVES (GE-8a): Information Security

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE8a: Information Security	4	3	0	1	Pass in Class XII	NIL

Course Objective

The goal of this course is to make a student learn basic principles of information security. Over the due course of time, the student will be familiarized with cryptography, authentication and access control methods along with software security. Potential security threats and vulnerabilities of systems are also discussed along with their impacts and countermeasures. This course also touches upon the implications of security in cloud and Internet of Things (IoT).

Learning Outcomes

On successful completion of this course, a student will be able to

- Identify the major types of threats to information security.
- Describe the role of cryptography in security.
- Discover the strengths and weaknesses of private and public key cryptosystems.
- Identify and apply various access control and authentication mechanisms.
- Discuss data and software security and related issues.

- Describe network security threats and attacks.
- Articulate the need for security in cloud and IoT.

Syllabus

Unit 1 (3 hours)

Overview: Computer Security Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Fundamental Security Design Principles.

Unit 2 (6 hours)

Cryptographic tools: Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions, Public-Key Encryption, Digital Signatures and Key Management, Random and Pseudorandom Numbers, Practical Application: Encryption of Stored Data.

Unit 3 (10 hours)

User authentication and Access Control: Digital User Authentication Principle, Password-Based Authentication, Remote User Authentication, Security Issues for User Authentication Access Control Principles, Subjects, Objects, and Access Rights, Discretionary Access Control, Example: UNIX File Access Control, Role-Based Access Control, Attribute-Based Access Control, Identity, Credential, and Access Management, Trust Frameworks.

Unit 4 (5 hours)

Database and Data Center Security:

The Need for Database Security, SQL Injection Attacks, Database Access Control.

Unit 5 (8 hours)

Software Security: Types of Malicious Software, Advanced Persistent Threat, Propagation: Infected Content - Viruses, Vulnerability Exploit - Worms, Social Engineering — SPAM E-Mail, Trojans, Payload: System Corruption, Attack Agent — Zombie, Bots, Information Theft — Keyloggers, Phishing, Spyware, Stealthing — Backdoors, Rootkits, Countermeasures. Overflow Attacks - Stack Overflows, Defending Against Buffer Overflows, Other Forms of Overflow Attacks. Software Security Issues - Handling Program Input, Writing Safe Program Code.

Unit 6 (6 hours)

Network Security: Denial-of-Service Attacks, Flooding Attacks, Distributed Denial-of-Service Attacks, Overview of Intrusion Detection, Honeypots, The Need for Firewalls, Firewall Characteristics and Access Policy, Types of Firewalls, Public-Key Infrastructure.

Unit 7

(7 hours)

Wireless, Cloud and IoT Security: Cloud Computing, Cloud Security Concepts, Cloud Security Approaches, The Internet of Things, IoT Security. Wireless Security Overview, Mobile Device Security.

References

1. W. Stallings, L. Brown, *Computer Security: Principles and Practice*, 4th edition, Pearson Education, 2018.

Additional References

1. Pfleeger C.P., Pfleeger S.L., Margulies J. *Security in Computing*, 5th edition, Prentice Hall, 2015.
2. Lin S., Costello D.J., *Error Control Coding: Fundamentals and applications*, 2nd edition, Pearson Education, 2004.
3. Stallings W. *Cryptography and network security*, 7th edition, Pearson Education, 2018.
4. Berlekamp E. *Algebraic Coding Theory*, World Scientific Publishing Co., 2015.
5. Stallings W. *Network security essentials Applications and Standards*, 6th edition, Pearson Education, 2018.
6. Whitman M.E., Mattord H.J., *Principle of Information Security*, 6th edition, Cengage Learning, 2017.
7. Bishop M., *Computer Security: Art and Science*, 2nd Revised edition, Pearson Education, 2019.
8. Anderson R.J., *Security Engineering: A guide to building Dependable Distributed Systems*, 2nd edition, John Wiley & Sons, 2008.

Suggested Practical List

1. Demonstrate the use of Network tools: ping, ipconfig, ifconfig, tracert, arp, netstat, whois.

2. Use of Password cracking tools : John the Ripper, Ophcrack. Verify the strength of passwords using these tools.
3. Use nmap/zenmap to analyze a remote machine.
4. Use Burp proxy to capture and modify the message.
5. Implement caesar cipher substitution operation.
6. Implement monoalphabetic and polyalphabetic cipher substitution operation.
7. Implement playfair cipher substitution operation.
8. Implement hill cipher substitution operation.
9. Implement rail fence cipher transposition operation.
10. Implement row transposition cipher transposition operation.
11. Implement product cipher transposition operation.

GENERIC ELECTIVES (GE-8b): Digital marketing and Social Media Analytics

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE8b: Digital Marketing and Social Media Analytics	4	3	0	1	Pass in Class XII	Knowledge of HTML and Python Programming

Course Objective:

This Course provides an introduction to various tools and technologies required to extract social media data. After completing this course, students will be able to execute end-to-end social media analytics projects and integrate them with existing business applications.

Course Learning Outcomes:

On successful completion of the course, students will be able to:

1. Understand the importance of data available in social media platforms.
2. Collections of data from various social media platforms like YouTube, Twitter etc. using API's and Python.
3. Data processing involving cleaning, structuring and analysis.
4. Case Study involving text mining and sentiment Analysis.
5. Development of complete social media recommendation system.

Syllabus

Unit 1

(4 hours)

Introduction: Marketing in the Digital World, Introduction to Digital Marketing, Online Marketplace analysis, Data mining, Predicting and influencing strategies, Big data concepts.

Unit 2

(7 hours)

Online Macro Environment: Introduction to Internet Technology, URL, Web page standards, Web Application frameworks and application servers, Approaches to develop secure systems.

Unit 3

(11 hours)

SEO and SEM: Crawling, Indexing, Ranking, SEO tools, On page optimization and off page optimization. Advertisements in social media platforms, Paid search Marketing, Search engine Analytics.

Unit 4

(11 hours)

Social Media Analytics: Role of email marketing, types of emails, email marketing objective, Build an automated email campaign, Analytics of Social Media Platforms.

Unit 5

(12 hours)

Analytics using Python: learn to analyze marketing campaigns data, measure customer engagement, and predict how customer approaches to buy products, develop systems to crawl and predict.

Practical Exercise:

Q1. Go to a website that you visit regularly and access the source code of the page. (Right click on the page text and select View Source Code.)

1. Complete a search in the source code by pressing Ctrl F.

- Does the web page include an H1?
- Is the H1 the main page headline?
- Does the H1 include a core message for the user?
- Is there any sign that the H1 is optimized for searching (are there any keywords included in it)?
- Is the site using the additional headings H2 through H6 ? Is it creating correct page and content structure?

2. Search for the title. It should be placed near the top of the page (`<title> title text </title>`).

This is the meta title for the page.

- Is the target keyword included in the title?
- Is the title under 60 characters?

3. Search for the description. It should be placed near the top of the page (`<meta-name="description" content="description text"/>`). This is the meta description for the page.

- Is there a description visible?
- Is the target keyword included?
- Is it under 160 characters?

Q2. Create an email marketing campaign using split testing. Send your email to a select number of email addresses. From here test subject lines, content, and sender details. Using this information, decide which split is performing better and why.

Q3. Create an email marketing campaign for a leading Holistic Living App incorporating:

- Optimize your subject lines, preheader text, email content, CTA, and landing pages through A/B tests
- Measure performance (open rate, CTR rate, response, and bounce rate)

Q4. You are the Social Media Analyzer for a Holistic Living App. You have been asked to prepare a comparative analysis of competitive brands in market to understand the branding value and user sentiments.

To develop the analysis, perform following:

- Extract all the posts of related apps permitted by the Facebook API
- Extract the metadata for each post: Timestamp, number of likes, number of shares, and number of comments
- Extract the user comments under each post and the metadata
- Process the posts to retrieve the most common keywords, bi-grams, and hashtags
- Process the user comments using the Alchemy API to retrieve the emotions Analyze all the results obtained from the preceding steps to derive conclusions

Q5. Perform the following on current trending twitter account and establish a case study:

- Fetching data from Twitter
- Cleaning of data
- Sentiment Analysis
- Customized Sentiment Analysis

References:

1. Chaffey, D., & Ellis-Chadwick, F. (2022). Digital Marketing: Strategy, implementation and practice. Pearson.
2. Dodson, I. (2016). The Art of Digital Marketing: The definitive guide to creating strategic, targeted, and measurable online campaigns. Wiley.
3. Chatterjee, S., & Krystyanczuk, M. (2017). Python social media analytics analyze and visualize data from Twitter, YouTube, GitHub, and more. Packt.

GENERIC ELECTIVES (GE-8c): Introduction to Parallel Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE8c: Introduction to Parallel Programming	4	3	0	1	Pass in Class XII	Computer System Architecture/A course in C++ at class XII/Data Structures, Operating Systems

Course Objective

The course introduces the students to the basic concepts and techniques of parallel programming. It enables them to design and implement parallel algorithms. The course would give the students hands-on practice to write parallel programs using shared and distributed memory models using OpenMP and Message Passing Interface (MPI).

Course Learning Outcomes

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

1. Appreciate the need of Parallel algorithms
2. Describe architectures for parallel and distributed systems.
3. Develop elementary parallel algorithms in shared memory models.
4. Develop elementary parallel algorithms in distributed memory models.

Syllabus

Unit 1

(10 hours)

Introduction to Parallel Computing: Trends in microprocessor architectures, memory system performance, dichotomy of parallel computing platforms, physical organization of parallel platforms, communication costs in parallel machines, SIMD versus MIMD

architectures, shared versus distributed memory, PRAM shared-memory model, distributed-memory model.

Unit 2

(15 hours)

OpenMP programming for shared memory systems: Thread Basics, Controlling Thread and Synchronization Attributes, Multi-thread and multi-tasking, Context Switching, Basic OpenMP thread functions, Shared Memory Consistency Models and the Sequential Consistency Model, Race Conditions, Scoping variables, work-sharing constructs, critical sections, atomic operations, locks, OpenMP tasks, Introduction to tasks, Task queues and task execution, Accessing variables in tasks, Completion of tasks and scoping variables in tasks.

Unit 3

(12 hours)

MPI programming for distributed memory systems: MPI basic communication routines (Introduction to MPI and basic calls, MPI calls to send and receive data, MPI call for broadcasting data, MPI Non-blocking calls, Introduction to MPI Collectives, Types of interconnects (Characterization of interconnects, Linear arrays, 2D mesh and torus, cliques)

Unit 4

(8 hours)

Applications: Matrix-matrix multiply, Odd-Even sorting, distributed histogram, Breadth First search, Dijkstra's algorithm.

References

1. Grama, A., Gupta, A., Karypis, G., Kumar, V., *Introduction to Parallel Computing*, 2nd edition, Addison-Wesley, 2003.
2. Quinn, M., *Parallel Programming in C with MPI and OpenMP*, 1st Edition, McGraw-Hill, 2017.
3. Revdikar, L., Mittal, A., Sharma, A., Gupta, S., *A Naïve Breadth First Search Approach Incorporating Parallel Processing Technique For Optimal Network Traversal*, International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 5, May 2016

Additional references

1. B. Parhami, *Introduction to Parallel Processing: Algorithms and Architectures*, Plenum, 1999, Springer.

Suggested Practical List

1. Implement Matrix-Matrix Multiplication in parallel using OpenMP
2. Implement distributed histogram Sorting in parallel using OpenMP
3. Implement Breadth First Search in parallel using OpenMP
4. Implement Dijkstra's Algorithm in parallel using OpenMP

GENERIC ELECTIVES (GE-8d): Cyber Forensics

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE8d: Cyber Forensics	4	3	0	1	Pass in Class XII	

Course Objective:

This course is to equip students with the knowledge and skills necessary to identify, collect, analyze and present digital evidence in a manner that is admissible in legal proceedings. Students will be able to conduct a thorough investigation of cybercrime incidents, preserve digital evidence, and report findings to relevant stakeholders.

Course Learning Outcomes:

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

- demonstrate an understanding of the principles of digital forensics, including legal considerations, recognition, collection, and preservation of digital evidence.
- digital forensics tools and techniques, such as creating disk images, conducting keyword and grep searches, and examining Windows registry.
- Learn evidence recovery methods, including deleted file recovery, formatted partition recovery, and data recovery procedures, and ethical considerations.
- Apply gained knowledge of cyber forensic investigation tools and techniques, including digital evidence collection, preservation, and password cracking.

- understand cyber laws and crimes, including hacking, viruses, intellectual property, and e-commerce, and the legal system of information technology, including jurisdiction issues and security and evidence in e-commerce.

Unit 1

(8 hours)

Digital Forensics: Introduction to digital forensics, legal considerations, recognising and collecting digital evidence, preservation of evidence, hash values and file hashing, creating disk images, keyword and grep searches, network basics, reporting and peer review, digital forensics report.

Unit 2

(8 hours)

Windows OS Forensics: Bits, bytes, Endianness, Disk partition schema, File systems – FAT, NTFS, ex-FAT, windows registry forensics, examining windows registry, NTUser.Dat Hive File Analysis, SAM Hive file, Software Hive file, System Hive File, USRClass.dat Hive File, AmCache Hive File.

Unit 3

(10 hours)

Evidence Recovery: Introduction to Deleted File Recovery, Formatted Partition Recovery, Data Recovery Tools, Data Recovery Procedures and Ethics, Complete time line analysis of computer files based on file creation, File modification and file access, Recover Internet Usage Data, Recover Swap Files/Temporary Files/Cache Files, Introduction to Encase Forensic Edition, Forensic Tool Kit (FTK), Use computer forensics software tools to cross validate findings in computer evidence.

Unit 4

(9 hours)

Investigation: Introduction to Cyber Forensic Investigation, Investigation Tools, Digital Evidence Collection, Evidence Preservation, E-Mail Investigation, E-Mail Tracking, IP Tracking, E-Mail Recovery, Encryption and Decryption methods, Search and Seizure of Computers, Recovering deleted evidences, Password Cracking.

Unit 5

(10 hours)

Cyber Crimes and Cyber Laws: Introduction to IT laws & Cyber Crimes, Internet, Hacking, Cracking, Viruses, Software Piracy, Intellectual property, Legal System of Information Technology, Understanding Cyber Crimes in context of Internet, Indian Penal Law & Cyber Crimes Fraud Hacking Mischief, International law, E-Commerce-Salient Features On-Line contracts Mail Box rule Privities of, Contracts Jurisdiction issues in E-Commerce Electronic Data Interchange, Security and Evidence in E-Commerce Dual Key encryption Digital signatures security issues.

References:

1. Marjee T. Britz, Computer Forensics and Cyber Crime: An Introduction, Pearson Education, 2013.
2. C. Altheide & H. Carvey Digital Forensics with Open Source Tools, Syngress, 2011. ISBN: 9781597495868.

Additional References:

1. Computer Forensics: Investigating Network Intrusions and Cybercrime" by Cameron H. Malin, Eoghan Casey, and James M. Aquilina
2. Online Course Management System: <https://esu.desire2learn.com/>
3. Computer Forensics, Computer Crime Investigation by John R. Vacca, Firewall Media, New Delhi.
4. Computer Forensics and Investigations by Nelson, Phillips, Enfinger, Stuart, CENGAGE Learning
5. Real Digital Forensics by Keith J. Jones, Richard Bejtlich, Curtis W. Rose, Addison Wesley Pearson Education

Suggested Practicals

It is suggested that the following tools/e-resources can be explored during the practical sessions

- Wireshark • COFEE Tool • Magnet RAM Capture • RAM Capture • NFI Defragger • Toolsley
- Volatility

1. Study of Network Related Commands (Windows)
2. Study of Network related Commands (Linux)
3. Analysis of windows registry
4. Capture and analyze network packets using Wireshark. Analyze the packets captured.
5. Creating a Forensic image using FTK Imager/ Encase Imager: creating forensic image, check integrity of data, analyze forensic image
6. Using System internal tools for network tracking and process monitoring do the following:
 - a. Monitor live processes
 - b. Capture RAM

- c. Capture TCP/UDP packets
- d. Monitor Hard disk
- e. Monitor Virtual Memory
- f. Monitor Cache Memory

**(Computer Science Courses for Undergraduate Programme of study with
Computer Science discipline as one of the three Core Disciplines)**

(For e.g. courses for B.Sc. Programme with Computer Science as discipline)

DISCIPLINE SPECIFIC CORE COURSE (DSC08): Information Security

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectur e	Tutoria l	Practical/ Practice		
DSC08: Information Security	4	3	0	1	Pass in Class XII	NIL

Course Objective

The goal of this course is to make a student learn basic principles of information security. Over the due course of time, the student will be familiarized with cryptography, authentication and access control methods along with software security. Potential security threats and vulnerabilities of systems are also discussed along with their impacts and countermeasures. This course also touches upon the implications of security in cloud and Internet of Things (IoT).

Learning Outcomes

On successful completion of this course, a student will be able to

- Identify the major types of threats to information security.
- Describe the role of cryptography in security.
- Discover the strengths and weaknesses of private and public key cryptosystems.
- Identify and apply various access control and authentication mechanisms.
- Discuss data and software security and related issues.

- Describe network security threats and attacks.
- Articulate the need for security in cloud and IoT.

Syllabus

Unit 1 (3 hours)

Overview: Computer Security Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Fundamental Security Design Principles.

Unit 2 (6 hours)

Cryptographic tools: Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions, Public-Key Encryption, Digital Signatures and Key Management, Random and Pseudorandom Numbers, Practical Application: Encryption of Stored Data.

Unit 3 (10 hours)

User authentication and Access Control: Digital User Authentication Principle, Password-Based Authentication, Remote User Authentication, Security Issues for User Authentication Access Control Principles, Subjects, Objects, and Access Rights, Discretionary Access Control, Example: UNIX File Access Control, Role-Based Access Control, Attribute-Based Access Control, Identity, Credential, and Access Management, Trust Frameworks.

Unit 4 (5 hours)

Database and Data Center Security:

The Need for Database Security, SQL Injection Attacks, Database Access Control.

Unit 5 (8 hours)

Software Security: Types of Malicious Software, Advanced Persistent Threat, Propagation: Infected Content - Viruses, Vulnerability Exploit - Worms, Social Engineering — SPAM E-Mail, Trojans, Payload: System Corruption, Attack Agent — Zombie, Bots, Information Theft — Keyloggers, Phishing, Spyware, Stealthing — Backdoors, Rootkits, Countermeasures. Overflow Attacks - Stack Overflows, Defending Against Buffer Overflows, Other Forms of Overflow Attacks. Software Security Issues - Handling Program Input, Writing Safe Program Code.

Unit 6 (6 hours)

Network Security: Denial-of-Service Attacks, Flooding Attacks, Distributed Denial-of-Service Attacks, Overview of Intrusion Detection, Honeypots, The Need for Firewalls, Firewall Characteristics and Access Policy, Types of Firewalls, Public-Key Infrastructure.

Unit 7

(7 hours)

Wireless, Cloud and IoT Security: Cloud Computing, Cloud Security Concepts, Cloud Security Approaches, The Internet of Things, IoT Security. Wireless Security Overview, Mobile Device Security.

References

1. W. Stallings, L. Brown, *Computer Security: Principles and Practice*, 4th edition, Pearson Education, 2018.

Additional References

1. Pfleeger C.P., Pfleeger S.L., Margulies J. *Security in Computing*, 5th edition, Prentice Hall, 2015.
2. Lin S., Costello D.J., *Error Control Coding: Fundamentals and applications*, 2nd edition, Pearson Education, 2004.
3. Stallings W. *Cryptography and network security*, 7th edition, Pearson Education, 2018.
4. Berlekamp E. *Algebraic Coding Theory*, World Scientific Publishing Co., 2015.
5. Stallings W. *Network security essentials Applications and Standards*, 6th edition, Pearson Education, 2018.
6. Whitman M.E., Mattord H.J., *Principle of Information Security*, 6th edition, Cengage Learning, 2017.
7. Bishop M., *Computer Security: Art and Science*, 2nd Revised edition, Pearson Education, 2019.
8. Anderson R.J., *Security Engineering: A guide to building Dependable Distributed Systems*, 2nd edition, John Wiley & Sons, 2008.

Suggested Practical List

1. Demonstrate the use of Network tools: ping, ipconfig, ifconfig, tracert, arp, netstat, whois.

2. Use of Password cracking tools : John the Ripper, Ophcrack. Verify the strength of passwords using these tools.
3. Use nmap/zenmap to analyze a remote machine.
4. Use Burp proxy to capture and modify the message.
5. Implement caesar cipher substitution operation.
6. Implement monoalphabetic and polyalphabetic cipher substitution operation.
7. Implement playfair cipher substitution operation.
8. Implement hill cipher substitution operation.
9. Implement rail fence cipher transposition operation.
10. Implement row transposition cipher transposition operation.
11. Implement product cipher transposition operation.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines

(For e.g. courses for B.A. Programmes with Computer Science as Major/Non-major discipline)

DISCIPLINE SPECIFIC CORE COURSE (DSC08): Information Security

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC08: Information Security	4	3	0	1	Pass in Class XII	NIL

Course Objective

The goal of this course is to make a student learn basic principles of information security. Over the due course of time, the student will be familiarized with cryptography, authentication and access control methods along with software security. Potential security threats and vulnerabilities of systems are also discussed along with their impacts and countermeasures. This course also touches upon the implications of security in cloud and Internet of Things (IoT).

Learning Outcomes

On successful completion of this course, a student will be able to

- Identify the major types of threats to information security.
- Describe the role of cryptography in security.
- Discover the strengths and weaknesses of private and public key cryptosystems.
- Identify and apply various access control and authentication mechanisms.
- Discuss data and software security and related issues.

- Describe network security threats and attacks.
- Articulate the need for security in cloud and IoT.

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Unit 1 (3 hours)

Overview: Computer Security Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Fundamental Security Design Principles.

Unit 2 (8 hours)

Cryptographic tools: Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions, Public-Key Encryption, Digital Signatures and Key Management, Random and Pseudorandom Numbers, Practical Application: Encryption of Stored Data.

Unit 3 (10 hours)

User authentication and Access Control: Digital User Authentication Principle, Password-Based Authentication, Remote User Authentication, Security Issues for User Authentication Access Control Principles, Subjects, Objects, and Access Rights, Discretionary Access Control, Example: UNIX File Access Control, Role-Based Access Control, Attribute-Based Access Control, Identity, Credential, and Access Management, Trust Frameworks.

Unit 4 (5 hours)

Database and Data Center Security: The Need for Database Security, SQL Injection Attacks, Database Access Control.

Unit 5 (6 hours)

Software Security: Types of Malicious Software, Advanced Persistent Threat, Propagation: Infected Content - Viruses. Vulnerability Exploit - Worms. Social Engineering — SPAM E-Mail, Trojans. Payload: System Corruption, Software Security Issues. Writing Safe Program Code, Handling Program Input.

Unit 6 (6 hours)

Network Security: Denial-of-Service Attacks, Flooding Attacks, Distributed Denial-of-Service Attacks, Overview of Intrusion Detection, Honeypots, The Need for Firewalls, Firewall Characteristics and Access Policy, Types of Firewalls, Public-Key Infrastructure.

Unit 7 (7 hours)

Wireless, Cloud and IoT Security: Cloud Computing, Cloud Security Concepts, Cloud Security Approaches, The Internet of Things, IoT Security. Wireless Security Overview, Mobile Device Security.

References

1. W. Stallings, L. Brown, *Computer Security: Principles and Practice*, 4th edition, Pearson Education, 2018.

Additional References

1. Pfleeger C.P., Pfleeger S.L., Margulies J. *Security in Computing*, 5th edition, Prentice Hall, 2015.
2. Lin S., Costello D.J., *Error Control Coding: Fundamentals and applications*, 2nd edition, Pearson Education, 2004.
3. Stallings W. *Cryptography and network security*, 7th edition, Pearson Education, 2018.
4. Berlekamp E. *Algebraic Coding Theory*, World Scientific Publishing Co., 2015.
5. Stallings W. *Network security essentials Applications and Standards*, 6th edition, Pearson Education, 2018.
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7. Bishop M., *Computer Security: Art and Science*, 2nd Revised edition, Pearson Education, 2019.
8. Anderson R.J., *Security Engineering: A guide to building Dependable Distributed Systems*, 2nd edition, John Wiley & Sons, 2008.

Suggested Practical List

Demonstrate the use of Network tools: ping, ipconfig, ifconfig, tracert, arp, netstat, whois.

1. Use of Password cracking tools : John the Ripper, Ophcrack. Verify the strength of passwords using these tools.
2. Use nmap/zenmap to analyze a remote machine.
3. Use Burp proxy to capture and modify the message.

4. Implement caesar cipher substitution operation.
5. Implement monoalphabetic and polyalphabetic cipher substitution operation.
6. Implement playfair cipher substitution operation.
7. Implement hill cipher substitution operation.
8. Implement rail fence cipher transposition operation.
9. Implement row transposition cipher transposition operation.
10. Implement product cipher transposition operation.

UNIVERSITY OF DELHI

CNC-II/093/1/Misc./2025/525

Dated: 17.03.2025

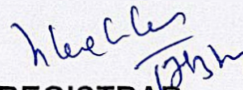
NOTIFICATION

Sub: Amendment to Ordinance V

Following addition be made to Appendix-II-A to the Ordinance V (2-A) of the Ordinances of the University;

Add the following:

The syllabus of a Discipline Specific Elective (DSE) paper titled "Research Methodology" to be offered in Semester-VI/VII, by the Department of Computer Science under Faculty of Mathematical Sciences, based on Undergraduate Curriculum Framework-2022, is notified herewith for the information of all concerned as per **Annexure-1**.


REGISTRAR

Annexure-1

Syllabus of Discipline Specific Elective VI/VII Semester (NEP UGCF 2022)

(Effective from Academic Year 2024-25)

DISCIPLINE SPECIFIC ELECTIVE (DSE): Research Methodology

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/Practice		
Research Methodology	4	3	0	1	Pass in Class XII	NIL

Course Objective

This course allows the students to acquire the necessary skills to conduct research in computer science. It enables the students to understand the entire process of research from problem identification, literature review, designing the project to documenting the outcome.

Course Learning Outcomes

On the successful completion of the course, the student would be able to:

- Identify the problem after conduct of a literature survey.
- Define goals, approach, and scope of the research.
- Explore, download and interpret datasets.
- Effectively record study findings in a research paper format.

Syllabus of DSE

Unit 1 : 8 Hours

Research Fundamentals: Meaning and significance of research, requirements and characteristics of research, types of research - basic, applied analytical, conceptual, empirical, experimental, non-experimental, prospective, retrospective, exploratory / descriptive, qualitative, quantitative, mixed method. Research process, induction and deduction in research, introduction to research tools, qualities of a good researcher.

Unit 2 : 5 Hours

Problem Identification: Choosing an appropriate problem area, identifying sources of research articles, literature review – stating and evaluating the research problem, techniques and methodologies, state of the art.

Unit 3 : 12 Hours

Data Analytics: Exploring and organizing data sets, pre-processing data, interpreting the data. Choosing appropriate statistics. Descriptive statistics - measures of central tendency and variability, measures of association. Inferential statistics – estimating population parameters, testing hypothesis.

Unit 4 : 10 Hours

Presenting research outcomes: Essential elements of a research paper - explanation of the research problem, description of methods and data, data analysis and its interpretation, identification of possible weaknesses of the study, presenting and summarizing the research output, drawing conclusions.

Unit 5 : 5 Hours

Publication: Process of journal submission and review. Peer review process - single, blind and double blind. Professional research societies, scientometric analysis - citation index and analysis, plagiarism, plagiarism checker.

Unit 6 : 5 Hours

Research Ethics: Ethical issues in research, protection from harm, voluntary and informed participation, right to privacy, conflict of interest, honesty with professional colleagues, professional code of ethics, intellectual property rights, fraud and misconduct in science.

Essential/recommended readings

1. Thomas, C. G. (2021). Research Methodology and Scientific Writing, 2nd Ed. Springer.
2. Leedy, P. D., & Ormrod, J. E. (2016). Practical Research: Planning and Design, 11th Ed. Pearson.

Additional References:

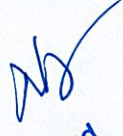
1. Ghezzi, C. *Being a Researcher: An Informatics Perspective*. Springer
2. Locharoenrat, K. (2018). *Research Methodologies for Beginners*. PAN Stanford Publication.
3. <https://www.unesco.org/en/articles/what-you-need-know-about-unescos-new-ai-competency-frameworks-students-and-teachers?hub=32618>

Suggested Practical List

Capstone Project: Students must choose an area of interest for research, based on the curriculum (but not limited by it) covered in the program. They should identify a research problem to solve. During the semester the students must document the research journey in the form of a report, which will be evaluated at the end of the semester. The students are encouraged to write a research paper based on the report, under the guidance of the teacher. The practical class for research methodology course should be utilized to perform the following tasks in the research process.

1. Search the research papers related to the chosen problem using academic search engines like Google Scholar, Scopus search, Web of Science database, etc.

- a. Evaluate the venue of the source of research paper - Journals using citation metrics like CiteScore, SCImago Journal Rank (SJR)), Source Normalized Impact per Paper (SNIP) etc., Conferences venues are evaluated using indexing information, Core Ranking etc.
 - b. Summarize the reviewed papers in a tabular format with columns: Paper Title, Author(s), Year, Key Findings, and Citation Count.
 - c. Explore reference management tools like Mendley / Zotero / EndNote to organize, store, and manage references.
2. Practice data analysis techniques taught in the class and identify a suitable technique required to solve the chosen research problem.
 3. Write the research report and prepare to write the research paper.
 - a) Choose a document writing software and prepare the report as per the format given by the teacher.
 - b) Use the plagiarism check tool to assess the similarity index of the report and ensure that it is less than 10%.
 - c) Explore the journal finder tools available for the publishers and select a suitable journal to submit the manuscript


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The amendments made under this notification are applicable to the University's Notification dated 30.07.2025 (Refer Pg 1 above)

UNIVERSITY OF DELHI

CNC-II/093/1/Misc./2025/6

Dated: 10.06.2025

NOTIFICATION

Sub: Amendment to Ordinance V

The following modifications/ amendments in the syllabi of Department of Computer Science under Faculty of Mathematical Science based on UGCF 2022 are notified herewith for the information of all concerned:

1. Renaming of Courses in computer science programs under UGCF (for the academic session 2025-2026 onwards)

Existing	Replace with
Programming Using Python	Object Oriented Programming using Python. (As per Annexure-I)
Python Programming for Data Handling	Object Oriented Programming using Python
Data Exploration and Visualization	Data Analysis and Visualization using Python
Data Mining for Knowledge Discovery (DMKD) in Sem V	Data Mining-I
Applied Network Analytics	Social Network Analytics
Foundations of Computer Graphics	Computer Graphics
Data Interpretation and Visualization using Python	Data Analysis and Visualization using Python

2. DSEs to be added/deleted in the pool of Semester VII, VIII in UG Curriculum (Admissions 2022 and 2023)

Semester	Add/Delete in the pool of DSEs	Remarks
VII	Research Methodology (to be added)	These courses have already been approved in the AC/EC meetings.
	Machine learning (to be added)	

	Deep learning (to be added)	
	Reinforcement Learning (to be shifted to Semester VIII)	
	Computer Graphics (to be added)	
	Social Network Analytics (to be added)	
VIII	Reinforcement Learning (to be added)	
	Ethical Hacking (to be added)	

3. Revised syllabus of "Object Oriented Programming Using Python" as per **Annexure I**.
4. Replace "Data Structures using Python" with "Data Structures using C++" everywhere.
5. W.e.f. from admission year 2024, in BSc(H) Computer Science
 - a. Replace Computer Graphics with Artificial Intelligence in Semester III
 - b. Replace Theory of Computing with Machine Learning in Semester V.
 - c. Replace Artificial Intelligence with Theory of Computing in Semester -VI
 - d. Replace Machine Learning with Computer Graphics in Semester VI.
 - e. Replace Cloud Computing with Deep Learning in Semester VI.
 - f. Replace Compiler Design with Cloud Computing in Semester VII.
6. W.e.f. from admission year 2024, in BSc(P)/BSc(Math. Sc.)/BA(P) with Computer Science
 - a. Replace Design and Analysis of Algorithms (DAA) with Software Engineering in Semester VII.
 - b. Replace Computer system Architecture with Design and Analysis of Algorithms in Semester III
7. W.e.f. admission year 2024, List of DSEs

Odd		Even	
Sem III		Sem IV	
Object Oriented Programming using Python, Data Mining, Artificial Intelligence Android Programming using		Data Analysis and Visualization using Python, Artificial Intelligence, Combinatorial Optimization, Introduction to Web	

Java, Cyber Security		Programming Graph Theory Network Security	
Sem V		Sem VI	
Algorithms and Advanced Data Structures Machine Learning, Data Mining, Data Privacy Web Programming Unix Network Programming Web Design and Development Quantum Computing		Theory of Computation , Deep Learning Computer Graphics Ethical Hacking, Social Network Analytics, Research Methodology Cyber Forensics	
Sem VII		Sem VIII	
Digital Image Processing Advanced Algorithms Cyber Forensics Research Methodology Machine learning Deep learning Computer Graphics Social Network Analytics Compiler Design		Information and Image Retrieval Natural Language Processing BlockChain and its application Cloud Computing Reinforcement Learning Ethical Hacking Deep learning Computer Graphics	

8. W.e.f. admission year 2024, list of GE's (no change in first year)

Odd		Even	
Sem I		Sem II	
Programming Using Python		Data Analysis and Visualization using Python	
Programming Using C++		Data Analysis and Visualization using Spreadsheet	
		Computer System Architecture	
Sem III		Sem IV	
Database Management Systems		Data structures using C++	
JAVA Programming		Introduction to Web Programming	
		Software Engineering	
Sem V		Sem VI	
Operating Systems		Computer Networks	
Advanced Web Programming		Advanced Web Programming	
Java Based Web App Development		Artificial Intelligence	
		Data Privacy	

9. Syllabus of Data Mining as per **Annexure II**.

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Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC 01	4	3	0	1	Pass in Class XII	
Object Oriented Programming using Python						

Course Objective

This course is designed as the first course that introduces object oriented programming concepts using Python to Computer Science students. The course focuses on the development of Python programming to solve problems of different domains using object- oriented programming paradigm.

Course Learning Outcomes

On successful completion of the course, students will be able to:

1. Understand the basics of programming language
2. Develop, document, and debug modular Python programs.
3. Apply suitable programming constructs and built-in data structures to solve a problem.
4. Use and apply various data objects in Python.
5. Use classes and objects in application programs and handle files.
6. apply OOPs concepts such as encapsulation, inheritance and polymorphism in writing programs.

Syllabus

Unit 1

(4 hours)

Introduction to Programming: Problem solving strategies; Structure of a Python program; Syntax and semantics; Executing simple programs in Python.

Unit 2

(10 hours)

Creating Python Programs: Identifiers and keywords; Literals, numbers, and strings; Operators; Expressions; Input/output statements; Defining functions; Control structures (conditional statements, loop control statements, break, continue and pass, exit function), default arguments.

Unit 3

(15 hours)

Built-in data structures: Mutable and immutable objects; Strings, built-in functions for string, string traversal, string operators and operations; Lists creation, traversal, slicing and splitting operations, passing list to a function; Tuples, sets, dictionaries and their operations.

Unit 4

(10 hours)

Object Oriented Programming: abstraction, encapsulation, objects, classes, methods, constructors, inheritance, polymorphism, static and dynamic binding, overloading, abstract classes, interfaces and packages.

Unit 5

(6 hours)

File and exception handling: File handling through libraries; Errors and exception handling.

References

1. Allen B. Downey, **Think Python: How to Think Like a Computer Scientist**, O'Reilly Media, 2024.
2. J.V. Guttag, **Introduction to Computation and Programming Using Python: With Application to Understanding Data**, MIT Press, 2016.
3. Robert Sedgewick, Kevin Wayne, Robert Dondero, **Introduction to Programming in Python: An Interdisciplinary Approach**, Addison-Wesley Professional, 2015
4. Tony Gaddis, **Starting Out with Python**, Pearson, 2021.

Additional References

- (i) Brown, Martin C. *Python: The Complete Reference*, 2nd edition, McGraw Hill Education, 2018.

Suggested Practical List



1. WAP to find the roots of a quadratic equation
2. WAP to accept a number 'n' and
 - a. Check if 'n' is prime
 - b. Generate all prime numbers till 'n'
 - c. Generate first 'n' prime numbers

This program may be done using functions

3. WAP to create a pyramid of the character '*' and a reverse pyramid

```

*
***
*****
*****
*****

```

```

*****
*****
*****
***
*

```

4. WAP that accepts a character and performs the following:
 - a. print whether the character is a letter or numeric digit or a special character
 - b. if the character is a letter, print whether the letter is uppercase or lowercase
 - c. if the character is a numeric digit, prints its name in text (e.g., if input is 9, output is NINE)
5. WAP to perform the following operations on a string
 - a. Find the frequency of a character in a string.
 - b. Replace a character by another character in a string.
 - c. Remove the first occurrence of a character from a string.
 - d. Remove all occurrences of a character from a string. WAP to swap the first n characters of two strings.
6. Write a function that accepts two strings and returns the indices of all the occurrences of the second string in the first string as a list. If the second string is not present in the first string then it should return -1.
7. WAP to create a list of the cubes of only the even integers appearing in the input list (may have elements of other types also) using the following:
 - a. 'for' loop
 - b. list comprehension

8. WAP to read a file and
- Print the total number of characters, words and lines in the file.
 - Calculate the frequency of each character in the file. Use a variable of dictionary type to maintain the count.
 - Print the words in reverse order.
 - Copy even lines of the file to a file named 'File1' and odd lines to another file named 'File2'.
9. Define a class *Employee* that stores information about employees in the company. The class should contain the following:
- (1) data members- count (to keep a record of all the objects being created for this class) and for every employee: an employee number, Name, Dept, Basic, DA and HRA.
 - (2) function members:
 - `__init__` method to initialize and/or update the members. Add statements to ensure that the program is terminated if any of Basic, DA and HRA is set to a negative value.
 - function salary, that returns salary as the sum of Basic, DA and HRA.
 - `__del__` function to decrease the number of objects created for the class
 - `__str__` function to display the details of an employee along with the salary of an employee in a proper format.
10. Write a program to define a class "2DPoint" with coordinates x and y as attributes. Create relevant methods and print the objects. Also define a method distance to calculate the distance between any two point objects.
11. Write a function that prints a dictionary where the keys are numbers between 1 and 5 and the values are cubes of the keys.
12. Inherit the above class to create a "3Dpoint" with additional attribute z. Override the method defined in "2DPoint" class, to calculate distance between two points of the "3DPoint" class.
13. Consider a tuple `t1=(1, 2, 5, 7, 9, 2, 4, 6, 8, 10)`. WAP to perform following operations:
- Print half the values of the tuple in one line and the other half in the next line.

- b. Print another tuple whose values are even numbers in the given tuple.
 - c. Concatenate a tuple $t_2=(11,13,15)$ with t_1 .
 - d. Return maximum and minimum value from this tuple
14. WAP to accept a name from a user. Raise and handle appropriate exception(s) if the text entered by the user contains digits and/or special characters.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Data Mining -

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Data Mining	4	3	0	1	Pass in Class XII	Programming using Python

Learning Objectives

This course aims to introduce data mining techniques and their application on real-life datasets. The students will learn to pre-process the dataset and make it ready for application of data mining techniques. The course will focus on three main techniques of data mining i.e. Classification, Clustering and Association Rule Mining. Different algorithms for these techniques will be discussed along with appropriate evaluation metrics to judge the performance of the results delivered.

Learning outcomes

On successful completion of the course, students will be able to:

1. Pre-process the data for subsequent data mining tasks
2. Apply a suitable classification algorithm to train the classifier and evaluate its performance.
3. Apply appropriate clustering algorithm to cluster the data and evaluate clustering quality
4. Use association rule mining algorithms and generate frequent item-sets and association rules

SYLLABUS OF DSE

Unit 1 (7 hours)

Introduction to Data Mining: Motivation and challenges for data mining, types of data mining tasks, applications of data mining, data measurements, data quality, supervised vs. unsupervised techniques

Unit 2 (8 hours)

Data Pre-processing: Data aggregation, sampling, dimensionality reduction, feature subset selection, feature creation, variable transformation.

Unit 3 (11 hours)

Cluster Analysis: Basic concepts of clustering, measure of similarity, types of clusters and clustering methods, Distance-based method: K-means algorithm, measures for cluster validation, determine optimal number of clusters. Density-Based Method: DBSCAN Algorithm, Comparison of these two methods

Unit 4 (8 hours)

Association Rule mining: Transaction data-set, frequent itemset, support measure, rule generation, confidence of association rule, apriori principle, apriori algorithm

Unit 5 (11 hours)

Classification: Naive bayes classifier, nearest neighbour classifier, decision tree, overfitting, confusion matrix, evaluation metrics and model evaluation

Text Book:

1. Tan P.N., Steinbach M, Karpatne A. and Kumar V. Introduction to Data Mining, Second edition, Sixth Impression, Pearson, 2023.

Additional References:

1. Han J., Kamber M. and Pei J. *Data Mining: Concepts and Techniques*, 3rd edition, 2011, Morgan Kaufmann Publishers.
2. Zaki M. J. and Meira J. Jr. *Data Mining and Machine Learning: Fundamental Concepts and Algorithms*, 2nd edition, Cambridge University Press, 2020.
3. Aggarwal C. C. *Data Mining: The Textbook*, Springer, 2015

Datasets may be downloaded from :

1. <https://archive.ics.uci.edu/datasets>
2. <https://www.kaggle.com/datasets?fileType=csv>
3. <https://data.gov.in/>
4. <https://ieee-dataport.org/datasets>

Suggested Practical Exercises

1. Apply data cleaning techniques on any dataset (e.g., Paper Reviews dataset in UCI repository). Techniques may include handling missing values, outliers and inconsistent values. A set of validation rules can be prepared based on the dataset and validations can be performed.
2. Apply data pre-processing techniques such as standardization/normalization, transformation, aggregation, discretization/binarization, sampling etc. on any dataset
3. Run Apriori algorithm to find frequent item sets and association rules on 2 real datasets and use appropriate evaluation measures to compute correctness of obtained patterns
 - a) Use minimum support as 50% and minimum confidence as 75%
 - b) Use minimum support as 60% and minimum confidence as 60 %
4. Use Naive bayes, K-nearest, and Decision tree classification algorithms to build classifiers on any two datasets. Pre-process the datasets using techniques specified in Q2. Compare the Accuracy, Precision, Recall and F1 measure reported for each dataset using the abovementioned classifiers under the following situations:
 - i. Using Holdout method (Random sampling):
 - a) Training set = 80% Test set = 20%
 - b) Training set = 66.6% (2/3rd of total), Test set = 33.3%

- ii. Using Cross-Validation:
 - a) 10-fold
 - b) 5-fold
- 5. Apply simple K-means algorithm for clustering any dataset. Compare the performance of clusters by varying the algorithm parameters. For a given set of parameters, plot a line graph depicting MSE obtained after each iteration.
- 6. Perform density-based clustering algorithm on a downloaded dataset and evaluate the cluster quality by changing the algorithm's parameters

Project: *Students should be promoted to take up one project on using dataset downloaded from any of the websites given above and the dataset verified by the teacher. Preprocessing steps and at least one data mining technique should be shown on the selected dataset. This will allow the students to have a practical knowledge of how to apply the various skills learnt in the subject for a single problem/project.*