NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Program Name
Master of Technology in Operations Research
Effective from the Academic Year: 2022-2023

MULTIDISCIPLINARY PROGRAM

Participating Departments:

(1) Department of Mathematics

(2) Department of Management Studies

(3) Department of Computer Science and Engineering

Coordinating Departments: Dept. of Mathematics and Dept. of Management Studies

Recommended by Joint DPAC	: 24.02.2022
Recommended in PGAC	: 11.04.2022
Approved by the Senate	: 19.04.2022
Approved by the BoG	: 24.05.2022

CURRICULUM

(Effective from the Academic Year: 2022-2023)

First Semester

Sl. No.	Sub. Code	Subject Name	L-T-S	Credits	Hours
1	MA1001	Probability and Statistics	3-1-0	4	4
2	MS1101	Economics	2-0-0	2	2
3	MA1002	Operations Research	3-1-0	4	4
4	CS1002	Advanced Algorithms	3-1-0	4	4
5	MA90XX / CS9XXX	**Elective-I:** Shall be floated from Pool-I & Pool-II (at least 1 paper from each pool)	3-0-0	3	3
6	MS90XX	**Elective-II:** Shall be floated from Pool-III (at least 2 papers)	3-0-0	3	3
7	MA1051	**Laboratory 1:** Algorithm Laboratory	0-0-4	2	4
TOTAL				**22**	**24**

Second Semester

Sl. No.	Sub. Code	Subject Name	L-T-S	Credits	Hours
1	MS2101	Operations Management	3-1-0	4	4
2	MA2001	Advanced Optimization Techniques	3-1-0	4	4
3	MA90XX	**Elective-III:** Shall be from Pool I (at least 2 papers)	3-0-0	3	3
4	CS9XXX	**Elective-IV:** Shall be from Pool II (at least 2 papers)	3-0-0	3	3
5	MS90XX	**Elective-V:** Shall be from Pool III (at least 2 papers)	3-0-0	3	3
6	MS2151	**Laboratory 2:** R-Laboratory	0-0-4	2	4
7	CS2151	**Laboratory 3:** Modeling & Simulation Laboratory	0-0-4	2	4
TOTAL				**21**	**25**

Third Semester

Sl. No.	Sub. Code	Subject	L-T-S	Credits	Hours
1	OR907X	Audit Lectures/ Workshops	0-0-0	0	2
2	OR3051	Dissertation – I	0-0-22	11	22
3	OR3052	Seminar – Non-Project / Evaluation of Summer Training	0-0-4	2	4
TOTAL				**13**	**28**

Fourth Semester

Sl. No.	Sub. Code	Subject	L-T-S	Credits	Hours
1	OR4051	Dissertation – II / Industrial Project	0-0-24	12	24
2	OR4052	Project Seminar	0-0-4	2	4
TOTAL				**14**	**28**
Total Program Credit				**70**	**105**

LIST OF ELECTIVES

Pool –I (Mathematics)

MA9031	Soft Computing	3-0-0	3
MA9032	Graph Theory	3-0-0	3
MA9033	Advanced Numerical Methods	3-0-0	3
MA9034	Fuzzy Logic & Fuzzy Decision Making	3-0-0	3
MA9035	Advanced Statistical Methods-I	3-0-0	3
MA9036	Reliability Theory	3-0-0	3
MA9037	Mathematical Foundations of Machine Learning	3-0-0	3
MA9038	Advanced OR	3-0-0	3

Pool –II (Computer Science and Engineering)

CS9029	Data Warehousing	3-0-0	3
CS9030	Data Mining	3-0-0	3
CS9031	Big Data Analytics	3-0-0	3
CS9032	Big Data Modelling and Management	3-0-0	3
CS9033	Statistical Learning for Data Science	3-0-0	3
CS9034	Business Process Modelling & Analysis	3-0-0	3
CS9035	Time Series Analysis	3-0-0	3
CS9038	Pattern Recognition	3-0-0	3
CS9045	Deep Learning	3-0-0	3
CS9040	Applied AI	3-0-0	3
CS9043	Knowledge Based System Engineering	3-0-0	3
CS9047	Information Retrieval	3-0-0	3
CS9071	Game Theory and its Applications	3-0-0	3
CS9072	Randomized Algorithms	3-0-0	3
CS9078	Data Stream Algorithms	3-0-0	3
CS9079	Online Algorithms	3-0-0	3

Pool –III (Management Sciences)

MS9031	Supply Chain Management	3-0-0	3
MS9032	Marketing Research	3-0-0	3
MS9033	Marketing Analytics	3-0-0	3
MS9034	Advanced Statistical Methods II	3-0-0	3
MS9035	Decision Making Through Simulation	3-0-0	3
MS9036	Decision Modeling	3-0-0	3

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MASTER OF TECHNOLOGY IN OPERATIONS RESEARCH

(DEPARTMENT OF MATHEMATICS, DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING AND DEPARTMENT OF MANAGEMENT STUDIES)

SYLLABUS

SEMESTER 1:

<table>
<tr><th colspan="8">Department of Mathematics</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MA1001</td><td>Probability & Statistics</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA)</td></tr>
<tr><td colspan="3">Knowledge of probability at 10+2 level</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Understand the concept and identify the field of application of probability
CO2: Apply the knowledge of probability in real life problem solving
CO3: Handle the collected data related to the field of inquiry
CO4: Analyse and interpret the collected data</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Probability:
Historical development of the subject and basic concepts, random numbers. [2]
Random variables and probability distributions, binomial and multinomial distribution, geometric distribution, hypergeometric distribution, normal distribution, beta & gamma distribution, exponential distribution. [8]
Two dimensional distribution, joint and marginal distribution, conditional distribution [5]
Expected value and variance of a random variable, covariance, correlation. [4]
Transformation of Random variables: one dimensional & two dimensional RVs [3]
Distribution of sum of independent random variables, convergence of a sequence of random variables, convergence in distribution, convergence in probability, convergence in L^p, Chebyshev's inequality, law of large numbers. [6]
Statistics:
Basic Concepts:
Frequency Distribution, Measures of Central Tendency, Measures of Dispersion. [4]
Random Sampling & Methods of Sampling:
Sampling Distribution & Standard Error, Sampling Distribution of the Sample Mean, Central Limit Theorem, Sampling Distribution of the Sample Proportion, Sampling Distribution of the difference between two sample means and sampling distribution of the difference between two sample proportion [6]

Estimation:
Biased & Unbiased Estimators, Point Estimation, Interval Estimation, Confidence Interval, Large Sample Confidence Interval for a Population Mean μ, Large Sample Confidence Interval for a Population Proportion, Estimating The Difference Between Two Population Means, Estimating The Difference Between Two Binomial Proportions, Maximum Likelihood Estimation. [5]

Testing of Hypothesis:
Null hypothesis & alternative hypothesis, Type-I error & Type-II error, Level of significance & the concept of p value , Large sample test about a population mean, Large sample test of Hypothesis for the Difference Between Two Population Means, Large sample test for a Binomial Proportion, Large sample test of hypothesis for the difference between two Binomial proportions, Student's t-distribution, Small sample inferences concern in ga population mean, Inferences for the difference between two means. [8]
Correlation & Linear Regression:
Scatter plot, Correlation coefficient & its properties, Rank correlation coefficient, Estimation of the regression lines, Properties of the Least Square Estimators. [5]</td></tr>
</table>

Text Books and/or reference material	**TEXT BOOKS:** 1. **William Mendenhall, Robert J. Beaver, B. M. Beaver,** *Introduction to Probability & Statistics* (Twelfth Edition, India Edition, Thomson) 2. **Ronald E Walpole, Sharon L Myers & Keying Ye,** *Probability & Statistics for Engineers & Scientists* (Eighth Edition, Pearson) 3. **Grinstead and J. Snell,** *Introduction to Probability* (American Mathematical Society) **REFERENCE BOOKS:** 1. **Montgomery,** *Applied Statistics and Probability for Engineers* (Fourth Edition, Wiley India Pvt. Ltd.) 2. **Gary Smith**, *Essential Statistics, Regression & Econometrics* (Second Edition)

Program Outcome↓ → Course outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	2	2	1	2
CO2	3	1	1	2	3	2	2
CO3	2	1	2	1	2	1	2
CO4	2	1	1	1	2	1	2

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS1101	**ECONOMICS**	PCR	2	0	0	2	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT + EA					

Course Outcomes	**CO1**: To make students aware of the economic aspects of consumer choice employing optimization **CO2:** To make students understand how to use optimization concept in case of economic operations based on production and cost concept. **CO3**: To make students conversant about various structure and output decision with the help of principle of optimization.
Topics Covered	**Production and Cost Concept:** Concept of Production function, Production with one and two variable inputs. Cobb Douglas Form. Law of Diminishing Marginal Return and Marginal Rate of Technical Substitution. Concept of Return to Scale. Different types of Cost: Fixed, variable, Sunk, opportunity, Marginal and Average Cost. Relationship between Short Run and Long Run Cost. Economies of Scale and Scope. Cost Minimization: conceptualization and mathematical treatment. **Theory of Market:** Marginal Cost, Marginal revenue and Profit Maximization by a competitive Firm, Short run and long run output decision, Monopoly market features and monopolist's output decision, Comparing Monopoly with Monophony, Price Discriminating Monopoly, Duopoly as special case of Oligopoly, Cournot Model, Cournot's equilibrium with linear demand curve, Stakleberg model and first mover's advantage
Text Books and/or reference material	**TEXT BOOK:** 1. **R S Pindyck, D L Rubinfeld and PL Mehta**, *Microeconomics,* (Pearson Education) 2. **A Koutsoyanis**, *Modern Microeconomics*, (Macmilan Education) **REFERENCE BOOKS:** 1. **P Tandon,** *A Text Book of Microeconomic Theory*, (Sage Publication). 2. **S A Greenlaw and D Shapiro,** *Principle of Micro Economics*, Open Stax (Rice University).

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	2	3	2	3
CO2	3	1	2	2	3	2	3
CO3	3	1	2	2	3	2	3

<table>
<tr><td colspan="8">Department of Mathematics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MA1002</td><td>Operations Research</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods: Continuous (CT) and end assessment (EA)</td></tr>
<tr><td colspan="2">Overview of Operations Research and basic concept of Linear Programming and Its applications</td><td colspan="6">CT + EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To provide comprehensive knowledge about different techniques of Operations Research
CO2: To understand different situations and be able to form the appropriate mathematical model
CO3: To apply the methods to solve different industrial and managerial problems</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Quick Revision of Basic concepts of Linear Algebra & Linear Programming:
Matrices, Rank of a matrix, Euclidean Space, Linear Dependence of Vectors, Spanning set & basis, Representation of a matrix in terms of vectors, System of Linear Equations, Basic Solution, Basic feasible Solution. Structure of a Linear Programming (LP) Model, General form of a LP model, Model Formulation & Graphical Method of Solution, Simplex Method (Maximization case), Big M Method, Two Phase Method of Solution for Minimization case, Duality in LP, Formulation of Dual LPP, Principle of complementary slackness [6]

Extension of Linear Programming:
Revised simplex method, Dual simplex method, Sensitivity Analysis [8]

Integer Programming:
Cutting plane method for pure and mixed Integer Programming problems, Branch and bound algorithm, Zero-one programming problem, Travelling salesman problem [8]

Dynamic Programming:
Bell man’s principle of optimality, recursive relationship of dynamic programming for various optimization problems [6]

Deterministic Inventory Management:
Concept of Inventory and various Inventory parameters, EOQ models for various cases with demand rate uniform or non-uniform, replenishment rate finite or infinite, shortage swallowed /not allowed, multi-item inventory [8]

Game Theory:
Min-max principle, Two person zero sum game with saddle point, Pure strategy, Game problems without saddle point, mixed strategy, solution of 2 X 2 game problem without saddle point, solution of M X 2 or 2 X M game problem using method of sub games and graphical method, Dominance rule, Algebraic method if solution without saddle point, reduction of a game problem without saddle point to linear programming problem. Non-zero sub games, concept of Nash equilibrium, Safety value and calculus method of solution, Lemke’s algorithm or solving bi-matrix games [8]

Network Analysis:
Introduction to network analysis, shortest path problem, construction of minimal spanning tree, maximal flow problem, Definition of a project, construction of arrow diagrams, Job and events, determination of critical paths and calculation of floats (PERT and CPM), resource allocation and least cost planning, use of network flows for least cost planning, crashing [10]</td></tr>
</table>

	Non-Linear Programming (NLPP): Lagrangian function, NLPP with equality constraint, NLPP with inequality constraint, Kuhn-Tucker conditions **[2]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **J. K. Sharma**: *Operations Research-Theory and applications, Macmillan* 2. **Prem Kumar Gupta & D. S. Hira**, *Operations Research, S Chand publication* **REFERENCE BOOKS:** 1. **F. S. Hiller & G. J. Leiberman**: *Introduction to Operations Research, McGraw Hill* 2. **E. N. Barron** *"Game Theory an Introduction" John Wiley & Sons publication.* 3. **Ravindran, Phillips and Solberg**, *Operations Research – Principles & Practice, John Wiley &Sons*

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	-	3	3	2	3	2
CO2	2	-	2	3	3	1	2
CO3	3	1	2	3	3	1	3

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS1002	**Advanced Algorithms**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Some course on Algorithms and Data structures, Discrete mathematics, Probability.		CT+EA					
Course Outcomes	**CO1:** Can have the efficiency in the complexity analysis of the algorithms. **CO2:** Detecting and applying the algorithmic structures in many different fields of engineering. **CO3:** Will have the knowledge for state of the art development in the field of algorithms.						
Topics Covered	**Introduction to Algorithm**: Motivations, Asymptotic notations, solution to recurrence relations, Amortized running time complexity **[6]** **Parallel Algorithms**: Motivation for parallel algorithm, Parallel addition, Parallel implementation of Quick sort, Energy complexity of parallel algorithms - Derivation of asymptotic energy complexities of parallel algorithms, Analysis of parallel algorithms. Selection problem - Sequential selection, Parallel selection on EREW SM SIMD machine and its analysis, Searching problem - Parallel search - implementation of K-ary search and its analysis, Graph algorithms - Parallel formulation for finding Connected components of a graph, finding Maximum Independent Set of a graph - parallel implementation **[12]**						

	Advanced Data Structures: Van Emde Boas Trees, Augmented Data structure, Heavy hitters problem- Bloom filters and Count-Min sketch **[6]** **Network Flow:** Flow networks, Augmenting paths, Ford- Fulkerson Algorithm, Edmonds - Karp algorithm, Max flow min-cut theorem, Push-relabel algorithm, Maximum bipartite matching, Some applications of network flow **[6]** **Randomized Algorithm:** Las Vegas and Monte Carlo algorithms, Five essential mathematical tools for Randomized algorithms: Linearity of expectation, Markov inequality, Chebyshev's inequality, Chernoff bound, and Union bound with examples to Randomized algorithm design. Examples and analysis of: Randomized Quick Sort, Min Cut problem, and Skip list **[6]** **Online Algorithms:** Overview, Online scheduling and online Steiner tree, Online Bipartite matching, Online learning and multiplicative weights algorithm **[6]** **NP Completeness**: Classes of P, NP, NP-Hard, NP-Complete, Co-NP; Reduction; Cook's Theorem, SAT, NP-Completeness proof of different problems: CLIQUE, VERTEX COVER, INDEPENDENT SET, SET COVER **[6]** **Approximation Algorithms**: Constant factor approximation algorithm: VERTEX COVER and TSP; Christofides algorithm on TSP with 1.5 approximation factor; SET-COVER problem with log n factor approximation algorithm; PTAS and FPTAS, Linear programs and approximation algorithms **[8]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **Rajeev Motwani and Prabhakar Raghavan,** *Randomized Algorithms*, 2nd Edition, Cambridge University press, Cambridge, MA, 1995. 2. **Thomas H. Cormen, Charles Leiserson, Ronald Rivest and Clifford Stein,** *Introduction to Algorithms*, 3rd ed. MIT Press, 2009, ISBN: 9780262033848. 3. **S. G. Akl,** *The Design and Analysis of Parallel Algorithms*, Prentice-Hall, 1989. 4. **M. J. Quinn,** *Designing Efficient Algorithms for Parallel Computers*, McGraw Hill Higher Education, 1987, ISBN: 978-0070510715. 5. **J. Kleinberg and E. Tardos,** *Algorithm Design*, Pearson. 6. **D. V. Williamson and D. B. Shmoys,** *The Design of Approximation Algorithms*, Cambridge University Press. 7. **S. Arora and B. Barak,** *Computational Complexity: A Modern Approach*, Cambridge University Press. **REFERENCE BOOKS:** 1. **Dimitri P. Bertsekas and John N. Tsitsiklis,** *Introduction to Probability*, 2nd Edition, Athena Scientific**,** July 2008. 2. **M. Mitzenmacher and E. Upfal,** *Probability and Computing: Randomized Algorithms and Probabilistic Analysis*, Cambridge University Press. 3. **T. Roughgarden,** CS261: *A Second Course in Algorithms* (Stanford University), 2016. 4. **T. Roughgarden,** CS168: *Modern Algorithmic Toolbox* (Stanford University), 2017.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	3	3	2	3	2
CO2	3	1	3	3	2	2	3
CO3	2	1	2	3	2	2	2

5. **Elective-I from Pool-I & Pool-II (at the end)**

6. **Elective-II from Pool-III (at the end)**

Department of Mathematics

Course Code	Title of course	Program Core (PCR) /Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA1051	**Algorithm Lab.**	PCR	0	0	4	4	2

Prerequisite	Course Assessment Method (End assessment (EA))
Fundamental ideas about computer programming	EA
Course Outcomes	**CO1:** Understand different algorithm design techniques. **CO2:** Understand basic analysis techniques of algorithm **CO3:** Design and solve complex problems using algorithmic approach
Course Content	**UNIT I:** [4] Basic idea of design technique like Divide and Conquer, Quick Sort, Merge Sort **UNIT II:** [4] Basic idea of design techniques like Dynamic Programming, Matrix Chain Multiplication **UNIT III:** [6] Time complexity analysis of simple algorithms with basic design techniques **UNIT IV:** [4] Basic concepts of greedy algorithms and its implementations. [6] **UNIT V:** Implementations of simple graph algorithms like Single Source shortest Path, Minimum Spanning Tree, All pairs Shortest Paths

	UNIT VI: Implementation of different searching techniques like linear Search, Binary Search	[4]
	UNIT VII: Basic idea of evolutionary algorithms and implementation of genetic algorithm related problems	[6]
Text Books and/or reference material	**TEXT BOOKS:** 1. **R. S. Salaria,** *Data Structures and Algorithms using C*, Khanna Publisher, 2018 2. **Thomash Cormen & others**, *Introduction to Algorithms*	

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	3	2	1	2	3	3
CO2	3	2	2	1	2	3	3
CO3	3	3	3	2	1	2	3

SEMESTER 2

1.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS2101	**OPERATIONS MANAGEMENT**	PCR	4	0	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	**CO1:** To make the students comprehend the need, definition, function, basic concept of OM **CO2:** To make the students understand different ways of aligning operations as per the strategy of the concern. **CO3:** To develop and improve the analytical ability of the students to take managerial decisions in the domain of OM.
Topics Covered	**Operations Strategy & Managing Change with a Quality Perspective:** Introduction – Basic model of OM, OR & OM, Brief on various types of systems, Role of Quality (with various views of Juran, Deming, Crosby), Productivity in OM, Measurement of Productivity using DEA, Competitive Advantage Model, Various strategies of OM [6] **Quality dimensions:** Product quality, acceptance sampling, control chart preparation, process capability measurement, Service Quality (in brief) [6] **Product Design:** A brief on Product Development, QFD with case study, Value Analysis [1] **Demand Forecasting:** Introduction to forecasting, Time series, Application of Exponential Smoothing, Double Exponential Smoothing, Seasonality models, ARIMA models, forecasting using SPSS, EVIEWS, FORECASTING OF INNOVATIVE GOODS, STYLE GOODS, Forecasting using Fuzzy techniques [14] **Inventory Control Systems:** Classification of inventory into A, B and C (X, Y and Z) class items, Study of various Inventory Control Systems, identification of various cost components, single & multi-period probabilistic models, Derivation and application of EOQ, EPQ, EMQ& MEOQ models [13] **Process Selection and Design:** Process Design, Analysis, Job Design, Method Study, Time Study, Work Measurement, manufacturing [2] **Operations scheduling & control:** Loading, Sequencing and Scheduling using advanced optimization techniques & heuristics, application of Queuing models [14]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Buffa & Sarin,** *Modern Production / Operations Management* 2. **Chase, Jacobs,** *Operations Management for Competitive Advantage* **REFERENCE BOOKS:** 1. **Bedi,** *Quality Management* 2. **Evans,** *TQM*

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	3	1	3	3	1	1
CO2	2	2	2	2	1	1	1
CO3	3	3	3	3	3	3	3

2.

<table>
<tr><th colspan="8">Department of Mathematics</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MA2001</td><td>Advanced Optimization Techniques</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA)</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Ability to apply the theory of optimization methods and algorithms to develop and for solving various types of optimization problems
CO2: To represent the problems in mathematical models
CO3: To be able to do research by applying optimization techniques in problems of Engineering and Technology</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Advanced Non-Linear Programming:
Convex Sets & Convex functions, Quadratic Programming, Separable programming [7]
Goal Programming:
Concept of goal programming, Modelling Multiple objective problems, Goal programming model formulation (Single goal with multiple sub goals, equally ranked multiple goals, Priority ranked goals, General goal programming models), Graphical method of goal programming, Simplex method in goal programming, Post optimality analysis [7]
Stochastic Programming:
Stochastic programming with one objective function. Stochastic linear programming. Two stage programming technique. Chance constrained programming technique, Stochastic dynamic programming [8]
Geometric Programming:
Polynomial; Unconstrained geometric programming problem (GPP) using Calculus; Unconstrained GPP using Arithmetic – Geometric Inequality; Constrained GPP [8]
Search and Heuristic Methods:
Introduction and Overview of Heuristic and Meta-Heuristic Search: General optimization problems, Fitness functions, Local search vs. Meta-heuristic search, Combinatorial algorithms for generic data structures, Visualization of the Search Landscape. Specific Search Algorithms: Hill Climbing, Simulated Annealing, Tabu Search, Genetic Algorithms, Ant Colony Optimization [18]
Multi-objective Optimization:
Optimization with multiple objectives, Pareto optimal solution, Exact solution methods for multi-objective problems, Multi-objective Meta heuristics-NSGA-II, SPEA2 [8]</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:
1.A. Ravindran, K. M. Ragsdell and G. V. Reklaitis, Engineering Optimization-Methods and Applications, Wiley-India Edition.
2.Singiresu S. Rao, Engineering Optimization -Theory and Practice, New Age International (P) Limited.
REFERENCE BOOKS:
1.R. Fletcher, Optimization, Academic Press, 1969.
2.D. G. Luenberger, Introduction to Linear and Nonlinear Programming, Addison Wesley, 1973.
3.Z.S. Kambo, Mathematical Programming Techniques, East West Press, 1997</td></tr>
</table>

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	3	2	1	3
CO2	1	1	2	3	3	2	2
CO3	-	2	2	3	2	2	2

3. **ELECTIVE-III from Pool I (at the end)**
4. **ELECTIVE-IV from Pool II (at the end)**
5. **ELECTIVE-V from Pool II (at the end)**
6. **Lab. 2**

Department of Management Science							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS2151	**R Lab.**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
Linear Algebra, Basic Statistics, LPP		CT+EA					

Course Outcomes	CO1: The ability to apply the theory of optimization methods and algorithms to develop and for solving various types of optimization problems. CO2: Ability to apply optimization techniques in business problems. CO3: Ability to analyse the mathematical results and numerical techniques of optimization theory to concrete business management problems by using R.
Topics Covered	**UNIT I:** Basic fundamentals, installation and use of software, data editing, use of R as a calculator, functions and assignments, Use of R as a calculator, functions and matrix operations, missing data and logical operators, Conditional executions and loops, data management with sequences, Data management with repeats, sorting, ordering, and lists, Data frames, import of external data in various file formats, statistical functions, compilation of data [12] **UNIT II:** Programming, data handling, transformations, sub setting, exploratory data analysis, probability distributions and simulations, regression and linear models, summarising data, how to handle large data sets, effective graphics. -modern concepts of statistics based on simulations and writing a report of a quantitative analysis [20] **UNIT III:** GOAL PROGRAMMING, Construction of Goal Programming Models, Goal Programming Algorithms using R software of different fuzzy techniques. [12] **UNIT IV:** Ranking of Performance Appraisal of different homogeneous sector using DEA techniques for different methods. [12]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Hans-Jürgen Zimmermann,** *Fuzzy Set Theory—and Its Applications*, Springer 2. **Ali Emrouznejad and Madjid Tavana,** *Performance Measurement with Fuzzy Data Envelopment Analysis*

	3. **ROBERT I. KABACOFF,** *R in Action Data analysis and graphics with R*, MANNING, Shelter Island **REFERENCE BOOKS:** 1. **Subhash C. Ray,** *Data Envelopment Analysis: Theory and Techniques for Economics and Operations Research* 2. **Lotfi A. Zadeh,** *Fuzzy Sets*, June 1965 3. **Hadley Wickham,** *Advanced R*, CRC Press, 2015 4. **Zed Shaw,** *Learn Python 3 the Hard Way*: *A Very Simple Introduction to the Terrifyingly Beautiful World of Computers and Code*, Addison-Wesley Professional, 2017.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	3	2	3	2	3
CO2	3	2	2	2	2	2	2
CO3	3	2	2	2	3	2	3

7. Lab. 3.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS2151	**Modelling and Simulation Laboratory**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and End assessment (EA))					
		CT+EA [CT: 60%, EA(Laboratory assignment + Viva Voce): 40%]					
Course Outcomes	**CO1:** Demonstrate the characteristics of mathematical modelling and Python packages. **CO2:** Understand the concepts of mathematical modelling for a problem. **CO3**: Understand the user-friendly editor of Python and various libraries for simulation of the problems. **CO4:** Developed and implement the mathematical problems using Python.						
Topics Covered	**UNIT I:** Study the basic concepts of mathematical formulation for a problem. Week 1-2 **UNIT II:** Study the characteristics and packages of Python programming language. Week 3 **UNIT III:** Modelling and simulation of linear programming problems. Week 4-5 a. Graphical Method b. Simplex Method **UNIT IV:** Modelling and simulation of Transportation problem. Week 6-8 a. Different initialization solution techniques b. Balanced and Unbalanced c. Degenerate problem **UNIT V:** Modelling and simulation of Assignment problem. Week 9 **UNIT VI:**						

	Modelling and simulation of travelling salesman problem. Week 10 **UNIT VII:** Modelling and simulation of network flow problem. Week 11 **UNIT VIII:** Modelling and simulation to find the dual of a primal problem. Week 12 **UNIT IX:** Modelling and simulation to determine optimal strategy for a two person zero game. Week 13-14 a. Pure Strategy b. Mixed strategy
Text Books, and/or reference material	**TEXT BOOKS:** 1. **Rardin**, *Optimization in Operation Research*, Pearson Publications. 2. **Handy A Taha**, *Operations Research – An Introduction*, Prentice Hall of India, New Delhi. 3. **Hillier & Lieberman**, *Introduction to Operations Research, TMH*.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	3	1	3	2	1
CO2	3	1	3	1	3	3	3
CO3	2	1	2	1	1	1	1
CO4	3	1	3	1	3	2	2

Electives:

Pool-I (Mathematics)

1.

Department of Mathematics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9031	**Soft Computing**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					

Course Outcomes	**CO1:** Understand various concepts of Soft Computing methods including Artificial Neural Networks, Fuzzy Logic, probabilistic reasoning and Evolutionary Algorithms. **CO2:** Provide the mathematical background for carrying out the optimization methods associated with neural network learning. **CO3:** Ability to develop some familiarity with current research problems and methods in Soft Computing by working on a research or design project.
Topics Covered	**UNIT I:** Introduction of Soft Computing, Concepts and applications. **[4]** **UNIT II:** Biological and artificial neuron, Neural networks, Adaline, Perceptron, Madaline and BP (Back Propagation) neural networks, Adaptive feedforward multilayer networks, RBF and RCE neural networks, Topologic organized neural networks, competitive learning, Kohonen maps, Solving

	optimization problems using neural networks, Stochastic neural networks, Boltzmann machine. **[16]** **UNIT III:** Fuzzy sets, Fuzzy logic and fuzzy inference, Fuzzy decision-making. **[8]** **UNIT IV:** Probabilistic reasoning, Rough sets. **[8]** **UNIT V:** Genetic algorithms, Genetic programming, Evolutionary algorithm. **[8]** **UNIT VI:** Swarm intelligence algorithms. **[6]** **UNIT VII:** Hybrid approaches (neural networks, fuzzy logic, genetic algorithms and rough sets), Engineering optimization problem solving using genetic algorithm, Neural network approaches, fuzzy and rough approaches. **[6]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **D. K. Pratihar**, *Soft Computing*, Narosa, 2008. 2. **D. E. Goldberg**, *Genetic Algorithms in Search, Optimization and Machine learning*, Pearson Education, Inc.1989. **REFERENCE BOOKS:** 1. **S. N. Sivanandam and S. N. Deepa**, *Principles of Soft Computing*, Wiley, 2012. 2. **M. Dorigo and T. Stutzle**, *Ant Colony Optimization*, Prentice Hall India Pvt. Ltd, 2005. 3. **E. Bonabeau, M. Dorigo and G. Theraulaz,** *Swarm Intelligence: From Natural to Artificial Systems*, New York, Oxford University Press, 1999.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	2	2	3	2
CO2	3	1	2	2	3	2	3
CO3	2	2	2	3	2	2	2

2.

Department of Mathematics

Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9032	**Graph Theory**	PEL	3	0	0	3	3

Prerequisite	Course Assessment methods (Continuous (CT) and end assessment (EA)
Nil	CT+EA
Course Outcomes	**CO1:** understand various kind of Graphs and its properties **CO2:** learn the properties of trees, planar Graphs and non-planar graphs **CO3:** understand application of Graphs in various fields
Course Content	**Preliminaries:** Definition of graph, Basic terminology, Types of graphs, Graph isomorphism, Sumand product of graphs, Components, Connected and disconnected graphs, Euler path, Euler circuit and Euler theorem, Hamiltonian path and circuit. [6] **Connected graphs:** Walks, trails, paths, connected graphs, disconnected graphs, components, weighted graph. [4] **Trees:** Definition, Properties of trees, Distance, radius, diameter and centre of graphs and trees, Binary tree, Binary tree traversal, Application. [6] **Planar graphs:** Definition, Planar and non-planar graphs, Kuratowaski's two graphs, Homeomorphic graphs, Geometric and combinatorial duals, Applications of planar graphs. [5] **Cut-set and cut-vertices:** Definition of cut-set and cut vertices, Rank and nullity, Fundamental circuits and fundamental cut-sets, Connectivity and separability, Cut Edge and bridge, Network flow problem, Applications. [6] **Coloring and Matching:** Definition, Chromatic number and Chromatic polynomial, Bipartite graph, Chromatic partitioning, Matching and its application, Covering, Five- colour and Four- colour theorems, Applications. [5] **Graph Algorithms:** Matrix representation of graphs, Shortest path algorithms: Dijkstra and Floyd's algorithms, Spanning tree and minimum spanning tree, Prim's and Kruskal's algorithms to find spanning tree, Binary tree traversal, DFS and BFS of a graph. [6] **Intersection graphs:** Interval graph, Circular-arc graphs, Permutation graphs, Trapezoid graphs, Chordal graphs, Applications. [4]
Text Books and/or Reference material	**TEXT BOOKS:** 1. **B. West Douglas,** *Introduction to Graph Theory*, Prentice Hall of India, 2009 2. **Narsingh Deo,** *Graph Theory With Applications to Engineering & Computer Science*, Prentice Hall of India, 1979 3. **R. Balakrishnn, K. Ranganathan,** *A Text Book of Graph Theory*, University Text, 2000 **REFERENCE BOOKS:** 1. **Bela Bollobas,** *Model Graph Theory*, Springer, 1998 2. **M. C. Golumbic,** *Algorithmic Graph Theory & Par fact Graphs Advanced Linear Algebra*, Elsevier, 1980

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	3	2	2	3	3	2
CO2	3	2	1	3	2	2	2
CO3	3	2	3	2	3	2	2
CO4	1	1	1	2	1	1	3

3.

Department of Mathematics							
Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9033	**Advanced Numerical Methods**	PEL	3	0	0	3	3
Prerequisite		Course Assessment methods (Continuous (CT) and end assessment (EA)					
Elementary ideas of functions, differentiation and integration		CT+EA					
Course Outcomes		**CO1:** Understand various interpolation formula and applications **CO2:** Understand and apply linear polynomial geometric curve fitting **CO3:** Solve system linear and non- linear equations, Eigen value problems, ODE, PDE					

Course Content	**Interpolation:** Central difference formulae of Gauss, Stirling formula, Bessel formula, Cubic spline interpolation. [4] **Approximation of function:** Curve fitting by least square method (linear, polynomial, geometric etc.), Chebyshev polynomial and Minimax property, Use of orthogonal polynomials, Gram-Schmidt orthogonalisation method, Economization of power series. [4] **Numerical integration:** Romberg integration, Gaussian quadrature: Gauss-Legendre and Gauss-Chebyshev quadratures, Comparison of Newton-Cotes and Gaussian quadratures. [6] **Solution of non-linear equations:** Root of a polynomial by Birge-Vieta method, Graeffe's root squaring method, System of non-linear equations: fixed point method and Newton-Raphson methods, Convergence and rate of convergence. [6] **Solution of ordinary differential equation:** Runge-Kutta method to solve a system of equations, Runge-Kutta method to solve second order IVP, Single step and multi-step methods, Predictor-corrector method: Milne's method, Adam-Moulton method, Solution of second order boundary value problem by finite difference method, Stability analysis, Finite element method to solve BVP. [6] **Partial differential equation:** Finite difference scheme, Parabolic equation: Crank-Nicolson method, Elliptic and hyperbolic equations: Iteration method. [6]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Jsames B. Scarbarough,** *Numerical Mathematical Analysis,* Oxford University Press, 1930 2. **S. S. Sastry,** *Introductory Methods of Numerical Analysis,* Prentice Hall of India, 2005 **REFERENCE BOOKS:** 1. **David F. F. Griffiths , Desmond J Higham,** *Numerical Methods for Ordinary Differential Equations,* Springer, 2010 4. **R.W. Hamming,** *Numerical Methods for Scientists and Engineers,* Dover Publications, 1987

Program Outcome → / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	3	2	1	2	3	3
CO2	3	3	2	2	3	3	2
CO3	3	3	3	3	3	2	2

4.

<table>
<tr><th colspan="8">Department of Mathematics</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MA9034</td><td>Fuzzy Logic and Fuzzy Decision Making</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA)</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT + EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the basic ideas of fuzzy sets, operations and properties of fuzzy sets and also about fuzzy relations.
CO2: To understand the basic features of membership functions, fuzzification process and defuzzification process
CO3: To design fuzzy rule based system
CO4: To design about fuzzy decision making process</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Basic Concepts:
Basic concepts of fuzzy sets and fuzzy logic, Motivation, Fuzzy sets and their representations, Membership functions and their designing, Operations on fuzzy sets, Convex fuzzy sets, Alpha-level cuts, Geometric interpretation of fuzzy sets. [8]
.
Fuzzy Numbers:
Fuzzy numbers, Fuzzy numbers in the set of integers, Arithmetic operations on fuzzy numbers. Fuzzy extension principle and its application. [6]

Fuzzy Relations:
Linguistic variables, Linguistic modifiers, Fuzzy rules, Fuzzy relations, Basic properties of fuzzy relations, Fuzzy relational equations, Composition of fuzzy relations, Fuzzy reasoning. [6]

Fuzzification and Defuzzification:
Fuzzification and Defuzzification: Features of the membership functions, various forms, fuzzification, defuzzification to crisp sets, λ-cuts for fuzzy relations. [2]

Fuzzy Logic:
Fuzzy logic, Truth, Propositions of fuzzy logic, Fuzzy logic and probability theory, Possibility and Necessity, Possibility versus probability, Probability of a fuzzy event, Bayes theorem for fuzzy events, Probabilistic interpretation of fuzzy sets. Fuzzy mapping rules and fuzzy implication rules, Fuzzy rule-based models for function approximation, Types of fuzzy rule-based models (Mamdani, TSK, and standard additive models), Fuzzy implications and approximate reasoning. [10]

Fuzzy Decision Making:
Decision making in Fuzzy environment, Fuzzy Multi criteria analysis, Multistage decision making, Decision making using Fuzzy ranking methods, Fuzzy Linear programming, Fuzzy goal programming, Fuzzy Multi-objective decision making [10]</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:

1. H. J. Zimmermann, Fuzzy Set Theory and its Applications, Second Edition, Kluwer Academic Publishers, Boston, 1991
2. K. H. Lee, First Course on Fuzzy Theory and Applications, Springer, 2005</td></tr>
</table>

	REFERENCE BOOKS: 1. **W.Pedrycz**, *Fuzzy sets for Engineering*, CRC Press, 1995 2. **G. J. Klir** and **T. A. Folger**, *Fuzzy sets, Uncertainty and Information*, Prentice Hall, Englewood Cliffs, 1988. 3. **G. J. Klir**, **U. S. Clair** and **B. Yuan**, *Fuzzy Set Theory: Foundation and Application*, Prentice Hall, 1997. 4. **G. Bojadzieve** and **M. Bojadzieve**, *Fuzzy Sets, Fuzzy Logic Applications*, World Scientific, 1995.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	1	2	2	3	1
CO2	1	1	2	2	2	2	1
CO3	2	1	2	2	3	2	2
CO4	3	2	2	3	2	2	2

5.

Department of Mathematics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9035	**Advanced Statistical Methods I**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
Probability & Statistics		CT+EA					
Course Outcomes	**CO1**: To understand the basic concepts of Population & to draw statistical inference. **CO2**: To educate the students in experimental design models & to validate the model using ANOVA **CO3**: To give knowledge about basic features of Statistical Quality Control. **CO4**: To introduce multivariate data & to find the principal components & Factors for further processing.						

Topics Covered	**Testing of Hypothesis**: Introduction, Recapitulation of basic concepts, p-value approach for decision making in tests of hypothesis with reference to the one & two tailed tests, Relationship to confidence interval estimation, Chi- square distribution, test of Goodness of Fit, Test of Independence (Categorical Data), Test for homogeneity, inferences on population variance, F-Distribution, Comparing two population variances [7] **Analysis of Variance:** Single Factor experiments, Fixed Effects Model, Random Effects Model for One-way ANOVA, completely Randomised Block design, Fixed Effects Model & Random Effects Model For Two way ANOVA, Tests for the equality of several variances, randomized Block-Design, Latin Square

	Design, Two factor Experiments-Two factor ANOVA, ANOVA for the Linear Regression Model, Testing the Validity of the Linear Regression Model [10] **Statistical Quality Control & Six Sigma Metrics**: Introduction, Relation between Confidence Interval & Control Limits, Types of Control Charts, Control Charts for Variables, Control Charts for Attributes, Out of Control situation in Control Charts, Process Capability & Process Capability Index, Six Sigma Metrics, Sigma Levels & Process Capabilities [8] **Multivariate Data Analysis:** Introduction, Random Vectors & Matrices, Mean Vectors & Covariance Matrices. Sample Geometry & Random Sampling- Introduction, Geometry of the sample, Random samples & expected values of the sample mean & sample covariance matrix. Introduction to Multivariate Normal Distribution [8] **Principal Component Analysis:** Introduction, Population principal components, Summarizing sample variance by Principal Components Large Influences [5] **Factor Analysis:** Introduction, Orthogonal Factor Model, Methods of orthogonal Factor Model, Methods of Estimation-Principal Component Method, Factor rotation and Factor scores [4]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Parimal Mukhopadhyay,** *Applied statistics*, Books & Allied Ltd 2. **Dean W. Wichern and Richard A. Johnson**, *Applied Multivariate Statistical Analysis*, September 5, 2016 by Routledge published by Upper Saddle River, New Jersey, Pearson, 2019 3. **Romal Walpole, Sharn L L. Meyers, Keying Ye,** *Probability & Statistics for Engineers & Scientists*, Pearson 4. **William Mendenhall, Robert. J. Beaver, B. H. Beaver**, *Introduction to Probability & Statistics* 12thEdition, Indian edition, Thomas. **REFERENCE BOOKS:** 1. **Levin & Rubin,** *Statistics for Management (7th edition*): Prentice Hall/Pearson Education 2. **Dr. J. Ravichandran**, *Probability & Statistics for engineers*, Wiley India

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	1	2	3	-	-
CO2	1	-	1	1	2	1	-
CO3	1	-	2	1	-	-	-
CO4	1	1	2	1	-	2	1

6.

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<tr><th colspan="8">Department of Mathematics</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MA9036</td><td>Reliability Theory</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA)</td></tr>
<tr><td colspan="2">Basic Statistics & Probability</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To educate the students about reliability measures, failure methods & failure distributions.
CO2: To give knowledge about reliability & hazard functions of different distributions & different reliability systems.
CO3: To develop skill on the problem of life testing & testing the validity of models.
CO4: To introduce design & formulation of reliability optimization problems & their solution techniques.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">UNIT I:
Definition of reliability and its measures, concept of failure. General provision of a reliability specification, Methods of achieving reliability, Broad functions of reliability. [3]
UNIT II:
Bath tub curve, causes of early failure and methods to avoid them, failure distributions: exponential, Weibull, truncated normal, lognormal, gamma, inverse Gaussian, their properties and uses. [4]
UNIT III:
Time dependent reliability of components and system-Failure rate versus time curve, modelling of failure rate, estimation of failure rates from empirical data, mean time to failure (MTTF), Reliability & hazard functions for different distribution, expected residual life, Series, parallel and r-out of n configurations; their block diagram. [6]
UNIT IV:
Problem of life testing, estimation of parameters and reliability using standard probability models using complete and censored (type I, II and III) samples, properties of the estimators. Probability plotting and graphical procedures for estimating the parameter and testing validity of model by some standard statistical tests. Life test acceptance sampling plan sin exponential case. Sequential life test in exponential case, accelerated life test. [9]
UNIT V:
Optimal design of plan under Bayesian consideration, truncation of number of failure and cost model based on cost of sampling, testing and decision of acceptance and rejection, sign regular function and monotone plan, posterior risk and minimization of expected regret. [5]
UNIT VI:
Reliability based optimum design-Introduction, Formulation of optimization problem, solution techniques. [6]
UNIT VII:
Failure modes, event tree & fault tree analysis-system safety analysis, Failure modes & effects analysis, Event tree analysis, Fault tree analysis. Minimal cut sets. [9]</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:
1. S. S. Rao, Reliability engineering, Pearson Publication.
2. Bazvosky. I., Prentice Hall, Reliability Theory and Practice, New Jersey.

REFERENCE BOOKS:
1. Gertsbakh I. B. , Statistical Reliability Theory, Marcel Dekker Inc.</td></tr>
</table>

	2. **Sinha S. K.,** *Reliability and Life Testing,* Wiley Eastern Limited. 3. **Polvko A. M.,** *Fundamentals of Reliability Theory,* Academic press, New York. 4. **Barlow, R. E. And Proschan , F,** *Mathematical Theory of Reliability,* John Wiley, New York. 5. **Gnedenko, Yu, Belyayev K and Solovyev, A. D.,** *Mathematical Methods of Reliability Theory,* Academic Press, New York.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	-	1	2	-	1	1
CO2	1	-	2	2	-	2	-
CO3	2	1	3	3	3	-	-
CO4	3	-	2	3	3	2	3

7.

Department of Mathematics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9037	**Mathematical Foundations of Machine Learning**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT + EA					
Course Outcomes	**CO1:** To describe the problem of supervised learning from the point of view of function approximation, optimization, and statistics. **CO2:** To implement mathematical concepts using real-world data. **CO3:** To derive principle component analysis (PCA) from a projection perspective. **CO4:** To have clear understanding on how orthogonal projections work.						
Topics Covered	**Linear Algebra:** Systems of linear equations**,** Matrices, Matrix Operations, Vector space, Linear Independence, Linear Mappings, Affine Spaces, Eigen values & Eigenvectors, Vector Spaces and Norms**,** Eigen decomposition of a matrix, LU Decomposition, QR Decomposition/Factorization, Symmetric Matrices, Orthogonalization & Orthonormalization, Orthonormal Basis, Orthogonal Complement, Angles and Orthogonally, Orthogonal Projections, Principal Component Analysis (PCA), Singular Value Decomposition (SVD). **[14]** **Probability Theory and Statistics:** Probability Rules & Axioms, Bayes' Theorem, Random Variables, Variance and Expectation, Conditional and Joint Distributions, Standard Distributions (Bernoulli, Binomial, Multinomial, Uniform and Gaussian), Moment Generating Functions, Maximum Likelihood Estimation (MLE), Prior and Posterior, Maximum a Posteriori Estimation (MAP) and Sampling Methods, Probabilistic Modeling and Inference. **[10]** **Multivariate Calculus:** Differential and Integral Calculus, Partial Derivatives, Vector-Values Functions, Directional Gradient, Hessian, Jacobian, Laplacian and Lagrangian Distribution**.** **[12]**						

	Algorithms and Optimizations: Convex sets and functions, Properties of convex functions, Conditions for extremum, Unconstrained and constrained optimization, Dynamic Programming, Randomized & Sublinear Algorithm, Gradient/Stochastic Descents, Primal-Dual methods, Information Theory (Entropy, Information Gain). **[6]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **M P Deisenroth**, **A A FaisalandC S Ong**, *Mathematics for Machine Learning*, Cambridge University Press, 2002. (E-book for personal use – licenced: https://mml-book.github.io/book/mml-book.pdf) 2. **S C Gupta and V K Kapoor**, *Fundamentals of Mathematical Statistics*, Tenth Edition, Sultan Chand & Sons, New Delhi 2002 **REFERENCE BOOKS:** 1. **S Biswas**, *Textbook of Matrix Algebra*, Third Edition, Prentice Hall India Learning Private Limited, 2012 2. **T Veerarajan**, *Transforms and Partial differential equations*, McGraw Hill Education (India) Pvt Ltd, 2011 3. **S S Rao**, *Engineering Optimization: Theory and Practice*, John Wiley & Sons; Third edition, 1996 4. **W Cheney**, *Analysis for Applied Mathematics*, Springer, New York, NY, 2001. 5. **S Axler** *Linear Algebra Done Right* (Third Edition), Springer International Publishing, 2015.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	3	2	3	2
CO2	3	1	2	2	3	2	2
CO3	2	1	1	1	3	1	2
CO4	1	2	1	1	2	1	2

8.

Department of Mathematics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MA9038	**Advanced Operations Research**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					
Course Outcomes	**CO1:** To provide a formal quantitative approach to problem solving and an intuition about situations where such an approach is appropriate. **CO2:** To introduce some widely used advanced operations research models. **CO3:** Understand the role of uncertainty in decision-making. **CO4:** Apply appropriate optimization techniques and write codes of optimization models using professional optimization software (i.e., MATLAB, LINGO, or MPL software).						

Topics Covered	**Queuing Theory:** Introduction of Basic Concepts in Stochastic Processes. Markov Chain and Markov Processes. Introduction to waiting line models steady state behaviour of M/M/1 and M/M/C queueing systems, Erlangian Queueing Systems: M/Ek/1 and Ek/M/1. **[10]** **Replacement, Reliability & Maintenance:** Replacement of items that deteriorate, Equipments that suddenly fail, chain of improving equipments, assuming (1) same life for each member in the chain and (2) increasing life, equal to that of deterioration only at infinity. Replacement of items that fail stochastically-individual and common preventive replacements. Basics of reliability classes of life distributions based on notions of ageing, Reliability models of non-maintained & maintained systems, Availability theory and it's modelling for various configurations. **[14]** **Sequencing Analysis:** Two machine and n jobs (no passing) problem and three machine and n jobs (no passing) problems: different routing, 2 jobs and m machines, n jobs and m machines, branch and bound algorithms. **[6]** **Simulation:** Implementation of simulation modelling, Design of simulation models. Generation of random deviates, the uniform distribution and its importance to simulation, Generation of random numbers (Properties of uniformly distributed numbers, Mid-square technique, Mid-product, technique, Fibonacci method). Generating uniform random variates via a congruential method (Mixed method, Multiplicative method, Quadratic congruential method), testing a random number generator (Frequency test, Gap test, Runs test, Poker test). Inverse transform method, (Exponential distribution, Weibull distribution, Geometric distribution), Rejection Techniques (Beta distribution, Gamma distribution), Composition method (Poisson distribution, Erlang distribution, Binomial distribution), Approximation techniques, Special probability distributions (Chi-square distribution, Student's T-distribution, F-distribution). **[12]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **P. K. Gupta & D. S. Hira,** *Operations Research*, S. Chand publication. 2. **Ravindran, Phillips and Solberg,** *Operations Research – Principles & Practice*, John Wiley &Sons **REFERENCE BOOKS:** 1. **H. A. Taha**, *Operations Research: An Introduction*, Pearson 2. **F. S. Hiller & G. J. Leiberman,** *Introduction to Operations Research.* McGraw hill. 3. **N.D. Vohra**, *Quantitative techniques in management*, Mc Graw hill.

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	2	2	1	2	2	2
CO2	3	2	2	2	3	2	3
CO3	2	1	1	1	2	2	2
CO4	2	2	3	1	2	2	3

Pool-II (Computer Science and Engineering)

1.

<table>
<tr><th colspan="8">Department of Computer Science & Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS9029</td><td>Data Warehousing</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-Requisite: Database Management System</td><td colspan="6">Course Assessment methods
(Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2"></td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To introduce basic principles, concepts and applications of data warehousing
CO2: To introduce mathematical statistics foundations in data warehousing
CO3: Understand the design of data warehouse with dimensional modelling
CO4: Apply OLAP operations and its advanced applications</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction:
Moving toward the Information Age, Evolution of Information Technology, Different types of data (Database Data, Data Warehouses, Transactional Data, Other Kinds of Data), Database Systems and Data Warehouses, Data warehousing applications [2]
Getting to Know Your Data:
Data Objects and Attribute Types (Nominal Attributes, Binary Attributes, Ordinal Attributes, Numeric Attributes, Discrete versus Continuous Attributes), Basic Statistical Descriptions of Data (Measuring the Central Tendency: Mean, Median, and Mode, Measuring the Dispersion of Data: Range, Quartiles, Variance, Standard Deviation, and Inter quartile Range), Measuring Data Similarity and Dissimilarity (Data Matrix versus Dissimilarity Matrix, Proximity Measures for Nominal Attributes, Proximity Measures for Binary Attributes, Dissimilarity of Numeric Data: Minkowski Distance, Proximity Measures for Ordinal Attributes, Dissimilarity for Attributes of Mixed Types, Cosine Similarity) [6]
Data Pre-processing:
Data Quality, Major Tasks in Data Pre-processing, Data Cleaning (Missing Values, Noisy Data, Data Cleaning as a Process), Data Integration (Entity Identification Problem, Redundancy and Correlation Analysis, Tuple Duplication, Data Value Conflict Detection and Resolution), Data Reduction (Attribute Subset Selection, Regression and Log-Linear Models: Parametric Data Reduction), Histograms, Data Transformation and Data Discretization (Data Transformation Strategies Overview, Data Transformation by Normalization, Discretization by Binning) [6]
Data Warehouse:
What Is a Data Warehouse? Differences between Operational Database Systems and Data Warehouses, But, Why Have a Separate Data Warehouse?, Data Warehousing: A Multi-tiered Architecture, Data Warehouse Models: Enterprise Warehouse, Data Mart, and Virtual Warehouse, Extraction, Transformation, and Loading, Metadata Repository, Data Warehouse Design and Usage : Data Warehouse Design Process, Data Warehouse Usage for Information Processing, A Business Analysis Framework for Data Warehouse Design [6]
Data Warehouse Modelling:
Data Cube and OLAP, Data Cube: A Multidimensional Data Model, Stars, Snowflakes, and Fact Constellations: Schemas for Multidimensional Data Models, Dimensions: The Role of Concept Hierarchies, Measures: Their Categorization and Computation [4]
OLAP Operations:
Typical operations in OLAP, A Starnet Query Model for Querying Multidimensional Databases, From Online Analytical Processing to Multidimensional Data Mining, Indexing OLAP Data: Bitmap Index and Join Index, Efficient Processing of OLAP Queries, OLAP Server Architectures: ROLAP versus MOLAP versus HOLAP, Data Generalization by Attribute-Oriented Induction:</td></tr>
</table>

	Attribute-Oriented Induction for Data Characterization, Efficient Implementation of Attribute-Oriented Induction, Attribute-Oriented Induction for Class Comparisons [6] **Data Cube Technology:** Data Cube Computation: Preliminary Concepts (Cube Materialization: Full Cube, Iceberg Cube, Closed Cube, and Cube Shell, General Strategies for Data Cube Computation), Data Cube Computation Methods: Multiway Array Aggregation for Full Cube Computation, BUC: Computing Iceberg Cubes from the Apex Cuboid Downward, Star-Cubing: Computing Iceberg Cubes Using a Dynamic Star-Tree Structure, Pre-computing Shell Fragments for Fast High-Dimensional OLAP, Processing Advanced Kinds of Queries by Exploring Cube Technology, Sampling Cubes: OLAP-Based Mining on Sampling Data, Ranking Cubes: Efficient Computation of Top-k Querie [8] **Multidimensional Data Analysis in Cube Space:** Prediction Cubes: Prediction Mining in Cube Space, Multifeature Cubes: Complex Aggregation at Multiple Granularities, Exception-Based, Discovery-Driven Cube Space Exploration [4]
Text Books and/or reference material	**TEXT BOOKS:** 1. **W. H. Inmon**, *Building the Data Warehouse*, Wiley Computer Publication, 3rd Edition. 2. **Chuck Ballard, Dirk Herreman, Don Schau, Rhonda Bell, Eunsaeng Kim, Ann Valencic**, *Data Modelling Techniques for Data Warehousing*, IBM Red Book, February 1998 3. **Ralph Kimball & Margy Ross,** *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modelling*, Wiley Computer Publication, 2nd Edition

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	2	2	2	3	2
CO2	2	2	3	3	2	2	1
CO3	3	1	2	2	2	1	2
CO4	2	1	2	2	1	2	1

2.

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9030	**Data Mining**	PEL	3	0	0	3	3
Pre-Requisite: Database Management System		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	**CO1:** To introduce students to the basic concepts and techniques of Data Mining. **CO2:** To introduce a wide range of clustering, estimation, prediction, and classification algorithms. **CO3:** Introduce mathematical statistics foundations of the Data Mining Algorithms **CO4:** Apply data mining techniques in inter-disciplinary areas						

Topics Covered	**Introduction**: Data Mining as the Evolution of Information Technology, What Kinds of Data Can Be Mined? What Kinds of Patterns Can Be Mined? Technologies Used in data mining, Different Applications in data mining, Major Issues in Data Mining, Data Mining and Society, Basic concepts on Data Warehousing [2] **Mining Frequent Patterns, Associations, and Correlations:** Basic Concepts - Frequent Itemsets, Closed Itemsets, and Association Rule, Apriori Algorithm: Finding Frequent Itemsets by Confined Candidate Generation, Generating Association Rules from Frequent Itemsets, Improving the Efficiency of Apriori, A Pattern-Growth Approach for Mining Frequent Itemsets, Mining Frequent Itemsets using Vertical Data Format, Mining Closed and Max Patterns, Pattern Evaluation Methods [6] **Classification:** Basic Concepts (What Is Classification? General Approach to Classification**),** Decision Tree Induction, Bayes Classification Methods, Rule-Based Classification, Metrics for Evaluating Classifier Performance, Techniques to Improve Classification Accuracy [8] **Advanced classification methods:** Bayesian Belief Networks, Classification by Back propagation, Support Vector Machines, Lazy Learners (k-Nearest-Neighbour Classifier), Multiclass Classification, Semi-Supervised Classification, Basic concepts of Active Learning and Transfer Learning [8] **Cluster Analysis:** Basic Concepts and Methods, Partitioning Methods (k-Means: A Centroid-Based Technique, k-Medoids: A Representative Object-Based Technique), Hierarchical Methods (Agglomerative vs. Divisive Hierarchical Clustering, Distance Measures in Algorithmic Methods, BIRCH: Multiphase Hierarchical Clustering Using Clustering Feature Trees), Density-Based Methods (DBSCAN: Density-Based Clustering Based on Connected Regions with High Density), Grid-Based Methods (CLIQUE: An Apriori-like Subspace Clustering Method), Evaluation of Clustering [8] **Advanced Cluster Analysis:** Probabilistic Model-Based Clustering (Fuzzy Clusters), Clustering High-Dimensional Data (Problems, Challenges, and Major Methodologies), Clustering Graph and Network Data (Applications and Challenges, Similarity Measures, Graph Clustering Methods), Clustering with Constraints [6] **Outlier Detection:** Outliers and Outlier Analysis, Types of Outliers, Challenges of Outlier Detection, Outlier Detection Methods (Supervised, Semi-Supervised, and Unsupervised Methods, Statistical Methods, Proximity-Based Methods, Clustering-Based Approaches, Classification-Based Approaches) [4]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Jiawei Han, Micheline Kamber and Jian Pei, Morgan Kaufmann**, *Data Mining Concepts and Techniques* Publishers, Elsevier, USA. 2. **Mehmed Kantardzic**, *Data Mining Concepts, Methods and Algorithms*, John Wiley and Sons, USA, 2003.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	2	2	3	2	2
CO2	3	1	3	2	3	3	2
CO3	2	2	3	2	2	2	1
CO4	3	2	2	3	3	2	1

3.

<table>
<tr><th colspan="8">Department of Computer Science and Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td>Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td></td></tr>
<tr><td>CS9031</td><td>Big Data Analytics</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Not required.</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Knowledge in handling and analysing extremely large datasets.
CO2: Learns the techniques of uncovering hidden patterns, correlations and other insights out of these datasets.
CO3: Ability to apply the concepts of big data analytics in different domains.
CO4: Ability to contextually integrate and correlate large amounts of information.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Big Data Analytics:
Motivation and significance, Big data analytics and use cases, Structured, unstructured and semi-structured data, Descriptive, diagnostic, predictive and prescriptive analytics [4]
Frequent item sets and Association rules:
Market-basket model, Association rule mining, Apriori algorithm, FP-Growth method [4]
Large-Scale Machine Learning:
Support vector machines, Stochastic gradient descent, K-means clustering algorithm, Decision trees [6]
Analysis of massive graphs:
Link analysis: Page Rank
Centrality measures: Degree, Closeness, Betweenness, etc.
Community structures, Community detection techniques
Quality metrics: Modularity, Normalized mutual information [6]
Recommendation Systems:
Introduction, Collaborative and content-based filtering, Similarity measures, Prediction approaches, Precision, recall and F-measure [6]
Technologies for Handling Big Data:
Introduction to Hadoop, Functioning of Hadoop, Hadoop ecosystem (HDFS, Map-Reduce, etc.), Word count program using Map-Reduce [6]
Big Data Analytics - Case Studies:
Big data analytics in e-commerce, Big data analytics in agriculture, Text and social media big data analytics [8]</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:
1. Rajkumar Buyya, Rodrigo N Calheiros, Amir Vahid Dastjerdi, Elsevier/Morgan Kaufmann , Big Data Principles and Paradigms, Cambridge, MA.
REFERENCE BOOKS:
1. James Lee, Tao Wei, Suresh Kumar Mukhiya, Hands-On Big Data Modelling, Packt Publishing. ISBN: 9781788620901.</td></tr>
</table>

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	0	2	1	2	1	1
CO2	2	2	3	0	2	2	1
CO3	1	1	3	2	1	3	1
CO4	1	0	2	2	3	2	2

4.

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9032	**Big Data Modelling and Management**	PEL	3	0	0	3	3
Pre-Requisite: Database Management System		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	**CO1**: Understand the necessity of Big Data Infrastructure Plan in Information System Design **CO2**: Recognize different types of data elements – structural issues, characterization issues, modelling issues **CO3**: Identify the frequent data operations required for various types of data **CO4**: Apply techniques to handle streaming data
Topics Covered	**Introduction**: Big data attributes and Definitions, Data Variety – Structured, Semi-structured and Unstructured, Defining Big Data from 3Vs to 3^2Vs - Data Domain, Business Intelligent (BI) Domain, Statistics Domain, Introduction of big data platforms: Hadoop, HDFS, Map Reduce, Spark, Google File System (GFS) and HDFS. [4] **Database Techniques for Big Data:** Big data management - Data ingestion, Data storage, Data quality, Data operations, Data scalability and security; Big data management services - Data cleansing, Data integration; Storage models - Block-based storage, File-based storage, Object-based storage; Data Models - Navigational Data Models, Relational Data Models, XML, Canonical Data Model, No SQL Movement, No SQL Solutions for Big Data Management. [6] **No SQL Data Models**: Key-Value Stores, Column-Based Stores, Graph-Based Stores, Document-Based Stores. [6] **Operation on No SQL Databases:** CRUD operations – Creating, Updating, Accessing and Deleting Data; Query – Non-DBMS Vs DBMS Approaches, Declarative Query Language (DQL), Hive Query Language (HQL), Cassandra Query Language (CQL), Spark SQL, Query for Document Store data, MapReduce functionality; Transaction Management – Isolation Levels and Isolation Strategies, BASE Theorem, CAP Theorem. [8] **Modelling Streaming Data:** Data stream and data model versus data format, Use cases of stream processing, Data streaming systems - Data harvesting, Data processing, Data analytics; Importance and implications of streaming data, streaming data solutions, Exploring streaming sensor data, Analyzing the streaming data. [4] **Resource Management in Big Data Processing Systems:**

	Types of Resource Management – CPU, Storage, Network, Big Data Processing Systems and Platforms, Big data and Cloud Resources - Single-Resource Management, Multi-resource Management. [4] **System Optimization for Big Data Processing:** Basic Framework of the Hadoop Ecosystem, Parallel Computation Framework: Map Reduce; Job Scheduling of Hadoop, Performance Optimization of HDFS, Performance Optimization of H Base, Performance Enhancement of Hadoop System. [4] **Security and Privacy in Big Data:** Secure Queries Over Encrypted Big Data - Threat Model and Attack Model, Secure Query Scheme in Clouds, Security Definition of Index-Based Secure Query Techniques, Implementations of Index-Based Secure Query Techniques; Privacy on Correlated Big Data [4]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Rodrigo N Calheiros, Amir Vahid Dastjerdi, Elsevier/Morgan Kaufmann**, *Big Data Principles and Paradigms*, Rajkumar Buyya**,** Cambridge, MA. **REFERENCE BOOKS:** 2. **James Lee, Tao Wei, Suresh Kumar Mukhiya**, *Hands-On Big Data Modelling*, Packt Publishing. ISBN: 9781788620901.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	2	3	3	2	3	2
CO2	3	2	3	3	2	3	3
CO3	3	2	2	3	2	2	2
CO4	2	1	2	2	1	2	2

5.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core(PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9033	**Statistical Learning for Data Science**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic statistical knowledge.		CT+EA					

Course Outcomes	**CO1:** To make the student realize the importance of Big data and the role of data scientist in present-day. **CO2:** To provide overview of the theories and current practice of the statistical models. **CO3:** To familiarize the students with different statistical and machine learning models. **CO4:** To make the student develop the model and justify the idea of selecting the model.
Topics Covered	**Introduction:** Growth of Big Data, Data Mining, Data Science and its deliverables, Statistical Learning in Data Science, Difference between statistical learning and machine learning [1] **Key Concepts of Statistical Learning:** Statistical Learning definition and objectives, Parameters and models, Training and Testing, Assessing Models, MSE, Variance and Bias, Bias-Variance trade-off, Supervised and Unsupervised learning, Parametric vs Non-Parametric Models, Examples of Learning problems [4] **Regression:** Linear Regression, kNN for regression, Multivariate regression, Subset Selection, Ridge Regression, Lasso Regression, Principal Component Regression [6] **Classification:** Linear Classification, Logistic regression, Linear Discriminant Analysis, Bayes Theorem, LDA for p=1, LDA for p>1, Quadratic Discriminant Analysis [5] **Tree Based Method:** Decision tree, Regression tree, Ensemble Methods, Bagging, Stacking, Boosting, Random Forest [5] **Resampling Methods:** Bootstrapping, Cross Validation, Two Class Evaluation Measure, ROC, AUC [5] **Graphical Model:** Naïve Bayes, Bayesian Network, Markov Graphs, Undirected Graphical Models [5] **Support Vector Machines:** Support Vector Classifier, SVM for Classification, SVM for Regression, SVM and Kernels [5] **Unsupervised Learning:** Association Rules, Cluster Analysis, Principal Component Analysis, K-means clustering, Hierarchical clustering [5]

Text Books and/ reference material	**TEXT BOOKS:** 1. **Trevor Hastie, Robert Tibshirani, Jerome H. Friedman,** *The Elements of Statistical Learning* **REFERENCE BOOKS:** 1. **R James G., Witten D., Hastie T., Tibshirani R,** *An Introduction to Statistical Learning with Applications in*

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	0	2	1	0	2	1
CO2	2	1	1	2	3	1	2
CO3	1	1	1	2	1	2	0
CO4	2	0	3	1	3	3	3

6.

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9034	**Business Process Modelling & Analysis**	PEL	3	0	0	3	3
Pre-Requisite: Basic Knowledge of Unified Modelling Language		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	**CO1:** Learn the shared language and notations that are used by Information Technology (IT) specialist to communicate with business stakeholders. **CO2:** To obtain a comprehensive idea to Manage, analyse, design, improve and reengineer business processes in industry setting scenarios. **CO3:** Understand the core concepts of business processes and their components and to apply process analysis concepts and techniques. **CO4:** Understand how the business process model may interface with business process management software suites (BPMS), service-oriented architecture platforms and other modern IT infrastructure platform software						
Topics Covered	**Introduction to Business Process Management:** Ingredients of a Business Process, the business process Lifecycle; Process Identification - Key Processes, Designing a Process Architecture, Construct Case/Function Matrices, Simple Case studies. [2] **Process Modelling Foundation:** Business Process Modelling and Notations (BPMN) core concepts, Branching and Merging, Exclusive Decisions, Parallel Execution, Inclusive Decisions, Information Artefacts. [4] A**dvanced Process Modelling**: Process Decomposition, Process Reuse, Process Rework and Repetition; Handling Events, Handling Exceptions, Processes and Business Rules, Process Choreographies and orchestration. [5] **Process Discovery:**						

	The Setting of Process Discovery, Discovery Methods - Evidence-Based Discovery, Interview-Based Discovery, Workshop-Based Discovery, Strengths and Limitations; Process Modelling Method - Identify the Process Boundaries, Activities, Events, Resources Control Flow and Additional Elements, Process Model Quality Assurance [6] **Process Analysis:** Qualitative analysis - Value-Added Analysis, Root Cause Analysis Cause–Effect Diagram, Why–Why Diagram, Quantitative Analysis - Performance Measures, Flow Analysis, Calculating Cycle Time, Queueing Theory, Process simulation. [6] **Process Based analysis:** Introduction to Analytical Hierarchy Process and Analytical Network Process. [3] **Process Redesign:** The Essence of Process Redesign, Heuristic Process Redesign, Business Process Operation Heuristics, Business Process Behaviour Heuristics, Organization Heuristics, Information Heuristics, Deriving business Process from a Product Data Model [5] **Process Automation:** Automating Business Processes - BPMS and Architecture of BPMS; Workload Reduction, Flexible System Integration Execution Transparency, Rule Enforcement. [5] **Process Intelligence:** Process Execution and Event Logs, Automatic Process Discovery - The α-Algorithm, Robust Process Discovery; Performance Analysis - Time Measurement, Cost Measurement; Quality Measurement, Flexibility Measurement; Conformance Checking - Conformance of Control Flow, Data and Resources. [7]
Text Books and/or reference material	**TEXT BOOKS*:*** 1. **Marlon Dumas Marcello La Rosa, Jan Mendling, Hajo A Reijers**, *Fundamentals of Business Process Management*, Authors: Springer Heidelberg New York, ISBN 978-3-642-33142-8 **REFERENCE BOOKS:** 2. *Business process model and notation specification version 2.0* [https://www.omg.org/spec/BPMN/2.0/About-BPMN/] 3. **John Wiley & Sons, Inc**., *Business Process Management for Dummies*®, 4th IBM Limited Edition Published

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	3	3	3	2	2
CO2	2	2	2	2	3	2	2
CO3	3	1	2	2	1	2	2
CO4	1	1	2	2	1	1	2

7.

<table>
<tr><th colspan="8">Department of Computer Science and Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS9035</td><td>Time Series Analysis</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Introductory probability theory and statistics, calculus and matrix algebra.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the basic time series components and measures to compute them.
CO2: Select appropriate method for analysis and modelling
CO3: Estimate correlation and autocorrelation
CO4: Evaluate the results and performance of the model.
CO5: Understand the concept and importance of spatiotemporal data analysis.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Time Series Analysis [4]
Introduction to time series data, Collection of temporal data, Introduction to basis statistics
Analyzing time series via plot

Regression Analysis [5]
OLS estimation, Test for significance of Regression, Prediction of new observation, Model Accuracy, Residual Plot, Regression model for Time series data

Exponential Smoothing [4]
Simple Exponential Smoothing, Double Exponential Smoothing, Higher order Exponential Smoothing, Forecasting

ARMA Process [8]
Stationarity, White Noise, Backshift Operator, Invertibility, Duality, MA(q) Process, AR(q) Process, Yule Walker Estimation, Partial Autocorrelation Function (PACF), Autoregressive Moving Average Process

ARIMA and Seasonal ARIMA [8]
AIC, Non-Stationarity, Integrated ARIMA, Seasonal ARIMA, Parsimony Principal

Time Series Analysis using Machine Learning [5]
Limitation of ARIMA, kNN, Random Forest

Time Series Analysis using Deep Learning [5]
RNN, LSTM

Introduction to Geostatistics [3]
Concepts of Spatial data, Concept of Spatial and temporal Data, Collection of Spatiotemporal data, Importance of Geostatistics</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:
1. Robert H. Shumway, David S. Stoffer, Time Series Analysis and its Applications: with R Example, Springer
REFERENCE BOOKS:
1. Douglas C. Montgomery, Cheryl L. Jennings, Murat Kulahci, Introduction to Time Series Analysis and Forecasting, Wiley</td></tr>
</table>

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	0	1	0	2	1	1
CO2	1	0	2	1	2	3	3
CO3	1	2	2	1	0	0	0
CO4	3	1	2	2	2	2	3
CO5	1	1	3	1	1	3	1

8.

Department of Computer Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9038	**Pattern Recognition**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Artificial Intelligence		CE+EA					
Course Outcomes		**CO1:** Idea about Pattern and Pattern Class, Design of a Pattern Recognition System **CO2:** Idea of Instar, Outstar, Groups of Instar and Outstar, Different types of Memories. **CO3:** Concept of Feedforward, Feedback and Competitive Learning Network **CO4:** Concept of Complex PR Tasks: RBF, RBF Network for Pattern Classification					
Topics Covered		**Pattern and Pattern Class**: Design of a Pattern Recognition System, Syntactic and Decision Theoretic Approach, Bayesian Decision Theory, Continuous Features, Error, Risk and Loss [5] **Parametric and Non-Parametric Methods**: Histogram Method, Kernel Based Methods, K - Nearest Neighbour Method, K – Nearest Neighbour Classifier [4] **Basics of ANN**: Instar, Outstar, Groups of Instar and Outstar, Different types of Memories [4] **Pattern Recognition Tasks and Pattern Recognition Problems**: Different PR Tasks by FF, FB and Competitive Learning Network, Pattern Clustering, Feature Mapping Problem, Different Feature Mapping Network, Self-Organizing Network [5] **FF ANN:** FF ANN: Pattern Association Network, Hebb's Law, Pattern Classification Network. [4] **Single and Multilayer Network**: Linear and Non Linear Classification, Gradient Descent Procedure, Newton's Algorithm, Fixed Increment Learning, Variable Increment Learning, Support Vector Machine (SVM), Unsupervised Learning [5] **FB ANN:** Pattern Association, Pattern Storage, Pattern Environment Storage, Auto association, Hopfield Network, State Transition Diagram, Stochastic Network and Boltzmann Machine [5] **Competitive Learning Network:** Pattern Storage, Pattern Clustering Network, Minimal Learning, Malsburg Learning and Leaky Learning [5] **Complex PR Tasks:** RBF, RBF Network for Pattern Classification, Advantages of RBF over MLFF ANN, CPN Network [5]					

Text Books, and/or reference material	**TEXT BOOKS:** 1. **Duda, Hart & Stork**, *Pattern Classification*, J. Wiley & Sons. 2. **B. Yegnanarayana**, *Artificial Neural Networks*, PHI **REFERENCE BOOKS:** 1. **C.M. Bishop**, *Neural Networks for Pattern Recognition*, Oxford 2. **S. Theodoridis and K. Koutroumbas**, *Pattern Recognition*, Elsevier

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	0	2	3	2	2	3
CO2	0	0	1	0	0	0	0
CO3	3	1	2	3	2	2	2
CO4	3	1	2	3	2	2	2
CO4	3	1	3	1	3	2	2

9.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9045	**Deep Learning**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Linear algebra, Calculus, Probability and statistics, Machine Learning		CE+EA					
Course Outcomes		**CO1:** To understand the mathematical, statistical and computational challenges of building stable representations for high-dimensional data, such as images, text and data. **CO2:** To obtain a concept of deep learning and its advantages. **CO3:** To understand deep network models, optimization for training of deep models. **CO4:** To achieve the knowledge on some popular deep learning models. **CO5:** To explore the research domain of deep learning.					
Topics Covered		**Machine Learning Basics:** Extracting meaning from data, expert system, learning algorithms, overfitting and underfitting, regularization, hyperparameters and validation sets, estimator, bias and variance, ML estimation, Bayesian statistics, supervised learning, unsupervised learning, Stochastic Gradient Descent, building a machine learning algorithm, challenges motivating Deep Learning [8] **Fundamentals of feedforward networks:** Single-layer and multilayer feedforward networks, Neural Network Graphs, activation functions, deep feedforward networks, hidden units, Learning XOR, gradient-based learning, Back-propagation algorithm and other differentiation algorithms [4] **Regularization for deep learning:** Parameter Norm Penalties, Norm Penalties as Constrained Optimization, Regularization and Under-Constrained Problems, Dataset Augmentation, Early Stopping, Sparse Representations, Dropout					

	[5] **Optimization for Training Deep Models:** How Learning Differs from Pure Optimization, Challenges in Neural Network Optimization, Basic Algorithms, Parameter Initialization Strategies, Algorithms with Adaptive Learning Rates, Approximate Second-Order Methods, Batch Normalization [5] **Convolutional Networks:** The Convolution Operation, Pooling, Variants of the Basic Convolution Function, Structured Outputs, Structured outputs and data types [4] **Sequence Modelling, Recurrent Neural Networks (RNN):** Unfolding Computational Graphs, RNNs, Bidirectional RNNs, LSTM [5] **Autoencoders:** Under complete Autoencoders, Regularized Autoencoders, Stochastic Encoders and Decoders, Denoising Autoencoders, Contractive Autoencoders [5] **Some Popular Deep networks and Applications:** Generative Adversarial Networks, VGG net, Res Net, Inception Net. Applications of deep learning [6]
Text Books and/or reference material	**TEXT BOOKS:** 1. **I. Goodfellow, Y. Bengio and A. Courville**, *Deep Learning*, The MIT Press, 2017. 2. **Charu C. Aggarwal**, *Neural Networks and Deep Learning*, Springer, 2018. **REFERENCE BOOKS:** 1. **A. Glassner**, *Deep Learning, From Basics to Practice, Vol 1 and Vol 2*, Published by The Imaginary Institute, Seattle, WA, 2018 2. **F. Chollet**, *Deep Learning with Python*, Manning Publications Co., 2018 3. **N. Buduma**, *Fundamentals of deep learning: Designing Next-Generation Machine Intelligence Algorithms*, O'REILLY, 2017

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	3	3	3	3	3
CO2	2	2	3	3	3	3	1
CO3	3	1	3	1	1	3	3
CO4	2	2	3	1	2	3	3
CO5	3	3	3	2	2	3	3

10.

<table>
<tr><th colspan="8">Department of Computer Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS9040</td><td>Applied AI</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="2">Artificial Intelligence, Pattern Recognition</td><td colspan="6">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Idea about Artificial Intelligence (AI) and Machine Learning (ML)
CO2: Idea about Expert System (ES) different types of ES and ES Shells and different AI Applications with ES and ES Shells
CO3: Idea about the components and functionality of the different types of ES and ES Shell
CO4: Different Knowledge Acquisition Techniques in ES and ES Shell for their categorization
CO5: Idea about Reasoning under Uncertainty and Uncertainty Management in ES and ES Shell
CO6: AI Applications in different domains with the help of ES and ES Shell.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to AI and ML:
What is AI and ML? Why AI? Different AI Techniques, Search, Knowledge Employment, Machine Learning, Different Goals of AI, Scientific Goal, Engineering Goal, Expert Systems as a general AI and KL application, Different AI and ML Applications with Expert Systems. [5]
Introduction to Expert Systems:
What is an Expert System? Background of ES, Characteristic features of ES, Advantages of ES, General Concepts of ES, Characteristics of ES, ES Application Domains, Elements of ES, Production Systems, Procedural and Non procedural paradigm, ANN, Connectionist ES, Application of Machine Learning in ES [4]
The Different Techniques for Knowledge Representation:
Meaning of Knowledge, Production Systems, Semantic Nets and Frames, Propositional and Predicate Logic, Limitations of Predicate Logic [5]
The Different Methods of Inference:
Trees and Graphs, State and Problem Space, Rules of Inference, Logic Systems, Resolution Systems, Causal Reasoning, Forward Backward and Bidirectional Chaining, Meta knowledge [5]
The Reasoning under Uncertainty and Inexact Reasoning:
Uncertainty, Types of Error, Classical Experimental and Subjective Probability, Compound and Conditional Probabilities, Hypothetical and Temporal Reasoning, Sufficiency and Necessity, Propagation of Probabilities [5]
The Design of Expert Systems Tool and Expert Systems:
Selection of Appropriate Problem, Stages and Errors in Development Stages, The Expert System Life Cycle, A versatile life cycle model [5]

Design of Expert System: [3]
Introduction, Certainty Factors, Decision Trees, Backward Chaining, A Monitoring Problem
AI and ML Applications with Expert Systems:
AI and Expert System Applications – Different Types of Medical Diagnosis – Diagnosis of Complex Electronic systems – Diagnosis of Software Development Systems and Subsystems – Location of Hardware fault finding in Computers, Communication Systems and other electronic system – Identification of chemical compound structures – The design of VLSI System – Very large number of applications related to teaching students some specialized tasks (such as teaching trouble shooting of various Malfunctioning equipment – Applications in Astronomy for terrestrial body image classification (e.g. star, galaxy etc.) with ANN, CNN inside the Knowledge Base of non-production ES [10]</td></tr>
</table>

Text Books and/or reference material	**TEXT BOOKS:** 1. **E. Rich, K. Knight and S. B. Nair,** *Artificial Intelligence*, 3rd Edition, McGraw Hill 2. **N. J. Nilsson,** *Artificial Intelligence A New Synthesis*, Morgan Kauffman Pub 3. **D. W. Paterson**, *Artificial Intelligence and Expert Systems*, PHI **REFERENCE BOOKS:** 1. **J Giarratano and G Riley,** *Expert Systems - Principles and Programming*, Thomson Publishing House 2. **Duda, Hart & Stork,** *Pattern Classification*, J. Wiley & Sons 3. **B. Yegnanarayana,** *Artificial Neural Networks*, PHI 4. **C.M. Bishop,** *Neural Networks for Pattern Recognition*, Oxford

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	0	2	2	3	2	3
CO2	2	0	2	2	2	2	3
CO3	2	0	2	2	2	2	3
CO4	2	0	2	2	2	2	3
CO5	3	0	2	2	2	2	3
CO6	3	0	2	2	2	2	3

11.

Department of Computer Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9043	**Knowledge Based System Engineering**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Artificial Intelligence		CE+EA					
Course Outcomes	**CO1:** Idea about Knowledge Representation and knowledge-base construction **CO2:** Idea of knowledge creation, storage, acquisition, search and organization. **CO3:** Concept of problem identification and solution through Reasoning, decision trees, rule based systems etc. **CO4:** Concept of Expert Systems, knowledge-based decision support and detection systems. **CO5**: Ability to apply knowledge to solve engineering problems.						
Topics Covered	**Fundamentals of knowledge and its types:** Concept of knowledge, types of knowledge, declarative knowledge, procedural knowledge, inheritable knowledge, inferential knowledge, relational knowledge, heuristic knowledge, common-sense knowledge, explicit knowledge, tacit knowledge, expert knowledge, uncertain knowledge. Need for maintaining Knowledge base and its management and engineering, Valuation of Intellectual Capital, Intellectual Capital: Human vs. Structural Capital. The knowledge Life Cycle and its models [5] **Knowledge Representation and understanding:** Data, information and knowledge relation, Knowledge vs Intelligence, the need of knowledge representation, knowledge representation using rules, procedural vs. declarative knowledge.						

	Levels of knowledge representation, granularity of knowledge representation, granularity vs. size of knowledge-base, techniques of knowledge representation, frames, frame-based reasoning, rule-based reasoning, case-based reasoning, frame based knowledge representation, forward vs. backward reasoning [10] **Knowledge Creation, Storage and Acquisition:** Nonaka's Model of Knowledge Creation & Transformation, Knowledge Architecture, knowledge acquisition, indexing techniques, fuzzy distance calculation, issues in knowledge acquisition, requirements of knowledge acquisition techniques, issues in knowledge acquisition in organization, knowledge organization and management, consistency of knowledge representation during creation, storage and acquisition [8] **Knowledge Search:** Dumb search, Heuristic search in Knowledge-Based Systems, depth-first search, breadth-first search, heuristic search, greedy search, A* algorithms, hill climbing [3] **Knowledge organization in knowledge base:** Need of organizing knowledge, techniques of knowledge organization, Application of object-oriented and case-based knowledge organizations with case studies. [4] **Knowledge reuse:** Knowledge reuse technique in the designing of expert systems, components of knowledge engineering based problem solution methodology: problem representation and derivation of solution through reasoning, rule-based systems, case based reasoning (CBR), decision tree etc., weaknesses of rule based systems. Re-Using Past History Explicitly as Knowledge in CBR systems, some Case studies of CBR, Successful vs failed cases, Indexing the case library: Advantages and Disadvantages of Case based systems. Knowledge Based systems as Expert systems, Decision Support Systems (DSS) or Detections Systems (DS); Knowledge Based Systems vs Expert Systems, Advantage and disadvantage of Knowledge Based Systems vs Expert Systems. Practical case studies of expert systems, DSS and DS [12]
Text books/Reference books	**TEXT BOOKS:** 1. **Winston,** *Artificial Intelligence and Knowledge Engineering*, PHI publication, 2004. 2. **R.C Schank,** *Conceptual Information Processing*, Amsterdam North Holland, 2003. 3. **Peter Jackson,** *Introduction to Expert Systems*, Addison Wesley, 3rd. edition. 4. **Russell, Stuart, and Peter Norvig,** *Artificial Intelligence: A Modern Approach*, 4th. ed. Pearson, 2020. **REFERENCE BOOKS:** 1. **Shank and J.G. Carbonell**, *The basic concepts of knowledge engineering*, PHI publication, 2003. 2. **Nillson, N.J.,** *Principles of Artificial intelligence*, Morgan Kaufmann publication, 2004. 3. **Shelda Debowski**, *Knowledge Management*, John Wiley & Sons publication, 4. **Michalski, Bratko, Kubat**, *Machine Learning and Data mining: Methods and Applications*, Wiley.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	0	3	2	3	3	1
CO2	3	1	3	1	3	3	3
CO3	3	1	3	1	2	3	1
CO4	3	1	2	0	3	3	1
CO5	3	2	2	1	2	3	2

12.

<table>
<tr><th colspan="8">Department of Computer Science and Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS9047</td><td>Information Retrieval</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="3">Linear algebra, Probability and statistics, Machine Learning</td><td colspan="5">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the underlined problems related to Information Retrieval
CO2: To be familiar with various algorithms and systems
CO3: Analyse the performance of information retrieval using advanced techniques such as classification, clustering, and filtering
CO4: To understand the evaluation strategies</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Information Retrieval:
Basic concept of information retrieval, Practical issues, The Retrieval process [2]
Modelling:
A Taxonomy of Information Retrieval Models,
Classic Information Retrieval: Basic Concepts, Boolean Model, Vector Model, Probabilistic Model, Comparison of Classic Models
Set Theoretic Models: Fuzzy Set Model, Extended Boolean Model
Algebraic Models: Generalized Vector Space Model, Latent Semantic Indexing Model, Neural Network Model
Probabilistic Models: Bayesian Networks, Inference Network Model, Belief Network Model
Structured Text Retrieval Models: Model Based on Non-Overlapping List, Model Based on Proximal Nodes
Models for Browsing: Flat Browsing, Structure Guided Browsing, the hypertext model [12]
Retrieval Performance Evaluation:
Introduction, Recall and Precision, Alternative Measures, F-measure, kappa measure, [3]
Reference Collections: TREC Collection, CACM and lSI Collections, Cystic Fibrosis Collection
Indexing and Index Compression:
Basic concept, Dictionary, Inverted Index, Forward Index, Partitioning, Caching, Dictionary compression, Posting file compressing [5]
Text Classification and Filtering:
Introduction to text classification. Naive Bayes models. Spam filtering. Vector space classification using hyperplanes; centroids; k Nearest Neighbours. Support vector machine classifiers. Kernel functions. Boosting [7]
Text Clustering:
Clustering versus classification. Partitioning methods. k-means clustering. Mixture of gaussians model. Hierarchical agglomerative clustering. Clustering terms using documents [4]
Advanced Topics:
Multimedia Information Retrieval: Similarity Queries, Feature-based Indexing and Searching, Spatial Access Methods, Searching in Multidimensional Spaces
Web Searching: Introduction, Challenges, Characterizing the Web, Indexing, Spidering/Crawling, Search Engines, Browsing, Meta searchers, Searching using Hyperlinks, XML retrieval, Semantic web [9]</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">TEXT BOOKS:
1. C. D. Manning, P. Raghavan and H. Schutze, Introduction to information retrieval, Cambridge, University Press, 2008.
2. R. Baeza-Yates, B. Ribeiro-Neto, Modern information retrieval, ACM Press / Addison Wesley, 1999</td></tr>
</table>

	REFERENCE BOOKS: 1. **G. Kowalski**, *Information Retrieval Architecture and Algorithms*, Springer, 2011. 2. **S. Buttcher, Charles L. A. Clarke, Gordon V. Cormack**, *Information Retrieval Implementing and Evaluating Search Engines*, The MIT Press, 2010.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	1	2	1	3	2	1
CO2	1	0	2	3	3	2	1
CO3	3	0	3	1	3	2	1
CO4	2	0	3	3	2	2	2

13.

Department of Computer Science and Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9071	**Game Theory and its Applications**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of Algorithms, Data structures, Discrete Mathematics, and Probability.	CT+EA

Course Outcomes	**CO1:** Can have the efficiency to act in a strategic situation. **CO2:** Can analyse the strategic interactions among agents. **CO3:** Can understand the modern state of the art in Game Theory and its applications.
Topics Covered	**Introduction** [1] **Non-Cooperative Game Theory:** Introduction to Game Theory, Extensive Form Games, Strategic Form Games, Dominant Strategy Equilibrium, Pure Strategy Nash Equilibrium, Mixed Strategy Nash Equilibrium, Sperner's Lemma, Fixed Point Theorem and Existence of Nash Equilibrium, Computation of Nash Equilibrium, Complexity of Computing Nash Equilibrium, Matrix Games (Two Players Zero Sum Games), Bayesian Games, Subgame Perfect Equilibrium [10] **Mechanism Design without Money:** One sided and two-sided matching with strict preferences, Voting theory and Participatory democracy [4] **Mechanism Design with Money:** Auction basics, sponsored search auctions, Revenue optimal auctions, VCG Mechanisms [5] **Cooperative Game Theory**:

	Correlated Strategies and Correlated Equilibrium, Two Pearson Bargaining Problem, Coalitional Games, The Core, and The Shapley Value [3] **Repeated Games and its Applications** [3] **Applications:** **Incentive Study in** - P2P Networks, Crowd sourcing, Digital currency, Social networks, Reputation Systems [8] **Some Special Topics -** Fair Division, Price of Anarchy, scoring rules, Hierarchy of equilibrium, Learning in Auction, Synergies between Machine Learning &Game Theory **[**8]
Text Books and/or reference material	**TEXT BOOKS:** 1. **N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani**. *Algorithmic Game Theory. Cambridge University Press*, New York, NY, USA, 2007, ISSN: 978-0521872829. 2. **M. Maschler, E. Solan, and S. Zamir**. *Game Theory, Cambridge UniversityPress; 1st Edition*, ISSN: 978-1107005488, 2013. 3. **Y. Narahari**. *Game Theory and Mechanism Design. World Scientific Publishing Company Pte. Limited, 2014, ISSN: 978-9814525046.* 4. **T. Roughgarden**, *Twenty Lectures on Algorithmic Game Theory*, Cambridge University Press, 2016, ISSN: 978-1316624791. **REFERENCE BOOKS:** 1. **T. Roughgarden**, CS364A: *Algorithmic Game Theory Course* (*Stanford University*), 2013. 2. **T. Roughgarden,** CS269I: *Incentives in Computer Science Course* (Stanford University), 2016. 3. **S. Barman and Y. Narahari**, E1:254 *Game Theory Course* (IISc Bangalore), 2012.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	3	3	3	2	2
CO2	2	1	2	2	3	2	2
CO3	3	1	2	2	1	2	2

15.

<table>
<tr><th colspan="8">Department of Computer Science and Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR)/ Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td>Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td></td></tr>
<tr><td>CS9072</td><td>Randomized Algorithms</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Basics of Algorithms and Probability</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To be able to model a problem using randomized algorithms, if it is necessary.
CO2: Comparing standard randomized algorithm with its non-randomized version through analysis.
CO3: Can learn tools and techniques for designing and analysing randomized algorithms.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Overview and Motivational Examples. [1]
Tools:
· Indicator Random Variable, Linearity of expectation; Markov inequality; Chebyshev's inequality; Chernoff bound; Union bound with examples to Randomized algorithm design. [8]
· Coupon Collection and Occupancy Problems. [2]
· Conditional Expectation and Martingales. [4]
· Balls, Bins and Random Graphs. [3]
· Markov Chains and Random Walks. [4]
· Probabilistic Method. [4]
Applications:
· Sorting; Selection; Data Structure; Graph Problems. [4]
· Metric Embeddings. [3]
· Online Algorithms. [3]
· Algorithms for Massive Data Set include Similarity Search. [4]
· Other Modern Applications. [2]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">TEXT BOOKS:
1. Rajeev Motwani and Prabhakar Raghavan, Randomized Algorithms, 2nd Edition, Cambridge University press, Cambridge, MA, 1995.
2. Thomas H. Cormen, Charles Leiserson, Ronald Rivest, and Clifford Stein. Introduction to Algorithms. 3rd ed. MIT Press, 2009. ISBN: 9780262033848.
3. M. Mitzenmacher and E. Upfal, Probability and Computing: Randomized Algorithms and Probabilistic Analysis, Cambridge University Press.
4. J. Kleinberg and E. Tardos, Algorithm Design, Pearson.

REFERENCE BOOKS:
1. D. Karger, 6.856J/18.416J: Randomized Algorithm (MIT Course), Spring 2019.
2. Siddharth Barman and Arindam Khan, E0 234: Introduction to Randomized Algorithms (IISc.), Spring 2021 (Several links of other courses are provided).
3. A. Goel, CME 309/CS 365: Randomized Algorithm (Stanford Course), Winter 2012-13.
4. G. Valiant, CS265/CME309: Randomized Algorithms and Probabilistic Analysis (Stanford University Course), Fall 2018.
5. Dimitri P. Bertsekas and John N. Tsitsiklis, Introduction to Probability, 2nd Edition,</td></tr>
</table>

	Athena Scientific, July 2008. 6. **T. Roughgarden**, CS261: *A Second Course in Algorithms (Stanford University)*, 2016 and Randomized Algorithms: COMS 4995 (2019)

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	3	3	2	2	3
CO2	1	1	3	2	2	3	2
CO3	3	1	2	2	1	2	2

16.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial(T)	Practical (P)	Total Hours	
CS9078	**Data Stream Algorithms**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Algorithms and Probability		CT+EA					
Course Outcomes	**CO1:** To be able to understand the need for space-efficient algorithm design. **CO2:** Designing faster algorithms for massive data sets. **CO3:** Can analyze the algorithms for data streams.						
Topics Covered	Overview and motivational examples [1] Finding frequent items deterministically [2] Estimating the number of distinct elements [2] A better estimate for distinct elements [2] Approximate counting [3] Finding frequent items via (linear) sketching [3] Estimating frequency moments [2] The tug-of-War sketch [2] Estimating norms using stable distribution [2] Sparse recovery [2] Weight based sampling [2] Finding the median (sublinear) [2] Geometric streams and coresets [3] Metric streams and clustering [3] Graph streams: basic algorithms [2] Finding maximum matching [2] Graph sketching [2] Counting triangles [2] Communication complexity and lower bounds [3]						
Text Books,	**TEXT BOOKS:**						

and/or reference material	1. **Amit Chakraborti**, *Data stream algorithms (draft version).* 2. **S. Muthukrishnan**, *Data Streams: Algorithms and Applications*, (Now publishers Inc) (This survey may supplement the book: *https://www.cs.princeton.edu/courses/archive/spr04/cos598B/bib/Muthu-Survey.pdf*) **REFERENCE BOOKS:** 1. **Amit Chakraborti**, CS 35/135: *Data Stream Algorithms*, Spring 2020 (Dartmouth) 2. **T. Roughgarden**, CS168: *Modern Algorithmic Toolbox (with Greg Valiant)* (Spring 2017)

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	2	3	3	3	3
CO2	3	1	2	3	2	2	3
CO3	2	1	2	2	3	3	2

17.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9079	**Online Algorithms**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Algorithms and Probability		CT+EA					
Course Outcomes	**CO1:** To be able to understand the need for online algorithm design. **CO2:** To be able to recognize a real life problem as an online algorithm design problem. **CO3:** Can analyze the online algorithms.						
Topics Covered	Overview and motivational examples [1] Deterministic Online Algorithms [2] Randomized Online Algorithms [2] Some Classical Problems (list accessing, k-servers) [2] Online Algorithms and Pricing [2] Primal-Dual Method for Online Problems [3] Online Max Sat and Submodular Maximization [2] Advice Model [2] Dynamic Graph Algorithms [2] Real Time Models [2] Revocable Decisions, Parallel Threads, and Multiple Pass Online Models [3] Alternatives to Competitive Analysis [2] Stochastic Inputs [3] Priority Model [3] Online Learning [2] Online Game Theory [2] Online Advertising [2] Finance [2] Networking and Online Navigation [3]						
Text Books, and/or	**TEXT BOOKS:** 1. **Allan Borodin and Denis Pankratov**, *Online Algorithms (draft version)*, 2019.						

reference material	**REFERENCE BOOKS:** 1. **Serge Plotkin**, CS369 - *Online Algorithms*, 2013 2. **T. Roughgarden**, CS261: *A Second Course in Algorithms (Stanford University)*, 2016.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	1	2	2	2	2	3
CO2	3	1	2	3	3	3	3
CO3	2	1	2	2	3	3	2

Pool –III (Management Sciences)

1.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9031	**SUPPLY CHAIN MANAGEMENT**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					

Course Outcomes	**CO1:** To make the students comprehend the need, definition, function, basic concept of Supply chain & Logistics Management. **CO2:** To make the students understand ways of classification of products as per the Supply chain and Logistics management **CO3:** To develop and improve the analytical ability of the students to solve the rigorous problems on VRP, Bin Packing etc.
Topics Covered	**Introduction to SCM:** Definition, its relation with materials management & logistics management, Close loop supply Chain (to understand the basic domain), Impact of not exchanging information & Bullwhip Effect, Relationship between Value chain & Supply Chain, Technological aspects, objective of the course [10] **Existence of Various Supply Chains:** Brief on competitive advantage, various types of products & suitable supply chains, strategic aspects are dealt in order to understand the role of economy of scale, & related case studies [4] **Study of various Strategies:** Push pull & other strategies, understanding of JIT system, MRP System, Job shop System & synchronous manufacturing system and how do they help in making such strategies, risk pooling strategy with examples, Pricing Decisions [10] **Tactical Planning in SCM:** Aggregate Planning, Study of Master Production Schedule & various types of ATPs [3] **Distribution Models:** Study of the inventory systems for the multi-echelon serial supply chains, Measurement of Bullwhip effect and inventory policy, study & application of DRP models, [5] **Supplier Selection:**

	Make or Buy decision**,** Importance of Supplier Selection, study of the way of purchasing, important factors related to supplier selection, mathematical models to carry out it [4] **Information Technology:** Goals and Application of IT for excellence, case studies, RFID, ERP and DSS [2] **Performance Measurement and Improvement:** Background to logistics and supply chain management, Modelling techniques in logistics and supply chain management, Review of logistics and supply chain performance indicators, Analytical performance and benchmarking techniques, Current issues in supply chain performance and optimization [4]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Simchi Levi,** *Designing & managing the Supply Chain*, Mc Graw Hill 2. **Closs**, *Logistical Management: The Integrated Supply Chain Process* by Bowersox, Pearson **REFERENCE BOOKS:** 1. **Chandrasekaran,** *SCM*, Oxford

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	3	1	2	3	1	1
CO2	1	2	2	2	1	1	1
CO3	3	3	3	3	3	3	3

2.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9032	**MARKETING RESEARCH**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					
Course Outcomes	**CO1:** To make students aware and educated about different ways of integrating marketing problem and its quantitative techniques based solutions **CO2:** To make students aware and knowledgeable about various applications of quantitative techniques based software to solve marketing problems **CO3:** To make students aware and educated about optimization concepts applicable in sales management **CO4:** To integrate the above mentioned knowledge with 'Marketing' as one of the functional discipline of management						
Topics Covered	**Unit I:** Application of hypothesis testing techniques in solving marketing problem. Application of independent sample, before –after T, chi- square statistics to solve marketing problem; Guidelines for application of statistical software. [6] **Unit II:** Application of cluster analysis for solving segmentation problem. Making of similarity index from categorical data. Distance and correlation based approach for clustering. K Means and Agglomeration based techniques. Software based application. [9]						

	Unit III: Application of conjoint analysis in designing consumer preference. Discussion of case studies in relation to design new product /service. Application of Bass model for forecasting new product. Quantitative method based application of 'Test Marketing' for new product launching. [8] **Unit IV:** Non-statistical designs and Experimental Designs namely CRD, RBD, LSD and Factorial Design. [6] **Unit V:** Optimization concepts in sales management related problems and solve. [3] **Unit VI:** Software based application of Multi-dimensional scaling for solving relevant marketing problems. Identification of latent variables using principal component analysis for understanding customer need set. Software based learning of the PCA. Naming of identified principal components. [8] **Unit VII:** Marketing application of Discriminant analysis for customer classification [2]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Malhotra N.K,** *Marketing Research: An applied orientation*, Pearson India 2. **Mishra P,** *Business Research Methods*, Oxford University Press 3. **R Nargundkar,** *Marketing Research Text and Cases*, TMH India **REFERENCE BOOKS:** 1. **Joseph F. Hair Jr., William C. Black, Barr y J. Babin, Rolph E. Anderson,** *Multivariate Data Analysis*, Cengage Publication. 2. **R.A Johnson, D.W. Wichern,** *Applied Multivariate Statistical Analysis*, Pearson India 3. **Kotler.P, Lilien.G, Moorthy.S,** *Marketing Models*, Prentice Hall India

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	2	2	3	2	2
CO2	3	1	2	2	3	1	2
CO3	3	1	3	2	3	2	3
CO4	2	1	1	1	3	1	2

3.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9033	**MARKETING ANALYTICS**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					
Course Outcomes	**CO1:** Analysing the role of analytics in formulating marketing strategies. **CO2:** Apply product analytics for identification of suitable customers and develop optimum market offerings						

	CO3: Apply marketing mix analytics for designing suitable price and advertising strategies **CO4:** Design suitable customer strategies applying customer analytics **CO5:** Formulate digital marketing strategies with the help of web analytics
Topics Covered	**Role of Marketing Analytics:** Analyse the role of marketing analytics as an enabler of marketing strategy, examine price and revenue management decisions [5] **Product Analytics:** Formulate market segments using cluster analysis, the anatomy of conjoint analysis, experimental design, data collection, interpretation of conjoint analysis results, optimise offerings using conjoint analysis [11] **Marketing Mix Analytics:** Formulate marketing mix models using simple, multiple and logistic regression analysis, single variable and multiple variable regression models, economic significance of regression output, pricing and advertising models, price elasticity of demand, advertising elasticity of demand, building comprehensive price and advertising elasticity models [12] **Customer Analytics:** Examine customer lifetime value, customer retention and life time value decisions [7] **Web Analytics:** Designing marketing experiments, paid search advertising, formulating digital marketing strategies [7]
Text Books and/or reference material	**TEXT BOOKS:** 1. **Rajkumar Venkatesan, Paul Farris and Ronald T Wilcox**, *Cutting Edge Marketing Analytics: Real World Cases and Data Sets for Hands On Learning*, Pearson FT Press, 2014. **REFERENCE BOOKS:** 1. **Robert C Blattberg, Byung Do Kim and Scott ANeslin,** *Database Marketing: Analysing and Managing Customers*, Springer, 2008. 2. **Peter S H Leeflang, Dick R Wittink, Michel Wedel, Phuppe A Naert,** *Building Models for Marketing Decisions*, Springer, 2000.

Program Outcome→ / Course outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	3	1		1	
CO2	3	2	3	3		3	
CO3	3	2	3	3		3	
CO4	3	2	3	3		3	
CO5	3	2	3	3		3	

4.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9034	**Advanced Statistical Methods II**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
Basic Statistics & Probability		CT+EA					

Course Outcomes	**CO1:** To appraise the students about the importance of mathematics and quantitative methods for problem solving in all aspects of business management. **CO2:** To develop the skills in the students to identify the source of a quantifiable problem, and recognize the issues involved. **CO3:** To inculcate quantitative skills among the students for complex problem solving to derive an appropriate action plan for business decision making. **CO4:** To develop the skills for understanding, calculating and interpreting various descriptive or summary measures of data and explaining their interrelation. **CO5:** To inculcate the notion of probability and random variables and introducing statistical distributions. **CO6:** To educate the students about the concept of population and various ways to draw samples to estimate the population
Topics Covered	**MULTIVARIATE DATA ANALYSIS:** Introduction, Random Vectors & Matrices, Mean Vectors & Covariance Matrices. Sample Geometry & Random Sampling- Introduction, Geometry of the sample, Random samples & expected values of the sample mean & sample covariance matrix [8] **MULTIPLE REGRESSION:** Concept of Correlation, Concept of Simple Regression, Concept of Linear Model, Diagnostics of Multiple Regression, Application with Real Case Study [6] **LOGISTICS REGRESSION:** Concept of Limited Dependent Variable, Concept of Dummy Variable, Concept of Classification Problem, Application with Real Case Study. [6] **DISCRIMINANT ANALYSIS:** Concept of Normality, Concept of Multi collinearity, Posterior Analysis, Explain the problem with real life example with validation of the model. [6] **CLUSTER ANALYSIS:** Hierarchical Clustering k -means clustering and Two Stage Clustering [6] **MULTIDIMENSIONAL SCALING AND CORRESPONDENCE ANALYSIS:** Concept of Singular Value Decomposition, Concept of measurement Scaling. Explain the problem with real life case study. [5] **STRUCTURAL EQUATION MODELLING:** [5] Concept of SEM Concept of Measurement Model Path Analysis, Confirmatory Factor Analysis

Text Books and/or reference material	**TEXT BOOKS:** 1. **Barbara M. Byrne,** *Structural Equation Modelling With AMOS: Basic Concepts, Applications and Programming,* Routledge, September 5, 2016 2. **Parimal Mukhopadhyay,** *Applied statistics,* Books & Allied Ltd 3. **Dean W. Wichern and Richard A. Johnson,** *Applied Multivariate Statistical Analysis,* Routledge, September 5, 2016, Upper Saddle River, New Jersey: Pearson, 2019 4. **Romal E Walpole, Sharn L Meyers, Keying Ye,** *Probability & Statistics for Engineers & Scientists,* Pearson 5. **William Mendenhall, Robert J Beaver, B. H. Beaver,** *Introduction to Probability & Statistics,* 12thEdition, Indian edition, Thomas. 6. **Garath James, Deniela Witten, Trever Hastie, Robert Tibshirani,** *An Introduction of Statistical Learning with Application in R,* Springer Publication. **REFERENCE BOOKS:** 1. **Levin & Rubin**, *Statistics for Management (7th edition*), Prentice Hall/Pearson Education 2. **Keller,** *Statistics for Management and Economics (*Seventh Edition), International Thomso 3. **Niels Blunch,** *Introduction to Structural Equation Modelling Using SPSS and Amos,* Sage Publication.

Program Outcome → / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	3	1	3	2	3
CO2	3	2	1	2	1	2	2
CO3	3	2	2	1	3	2	3
CO4	2	2	3	2	2	2	3

5.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9035	**Decision Making through Simulation**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
Basic Statistics, Probability, Basic Optimization and Management Functional Area		CT+EA					
Course Outcomes	**CO1:** Explain complex decision-making scenarios with conflicting outcomes. **CO2:** Develop skills to evaluate different decision-making options to arrive at a best possible decision. **CO3:** Help students in simulating real life scenarios for pre-implementation phase and analysing all such scenarios using simulation methodologies.						

Topics Covered	**UNIT I:** An Overview of Decision Making Models and Theories [5] **UNIT II:** How People Make Decisions Involving Multiple Objectives? [5] **UNIT III:** Modelling Decision Making under Risk and Uncertainty [10] **UNIT IV:** Decision Trees, Influence Diagrams [8] **UNIT V:** Introduction to Simulation [7] **UNIT VI:** A Potpourri of Simulation Examples [7]
Text Books, and/or reference material	**TEXT BOOKS:** 1. **Harvard Business Essentials,** *Harvard Business Essentials: Decision Making - 5 Steps to Better Results* 2. **Jonathan P. Pinder,** *Introduction to Business Analytics Using Simulation* **REFERENCE BOOKS:** 1. **Roy Nersesian,** *Computer Simulation in Business Decision Making: A Guide for Managers, Planners and MIS Professionals* 2. **Bilash Kanti Bala, Fatimah Mohamed Arshad et al.,** *System Dynamics: Modelling and Simulation (Springer Texts in Business and Economics)*, 2018 3. **Ella Roubtsova,** *Interactive Modelling and Simulation in Business System Design (Simulation Foundations, Methods and Applications*), 2016

Program Outcome→ / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	2	3	2	3	2	3
CO2	3	2	3	2	3	2	3
CO3	3	1	2	2	3	2	3

6.

Department of Management Studies							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MS9036	**DECISION MODELLING**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NIL		CT+EA					
Course Outcomes	**CO1:** To make the students comprehend the need, definition, function, basic concept of OR. **CO2:** To develop and improve the analytical ability of the students to handle complex optimization problems **CO3:** To gain expertise in simulation						
Topics Covered	**Introduction:** An Overview of Management Science and Quantitative Analysis Problem Solving and Decision Making, Quantitative Analysis and Decision Making, Management Science Techniques **[2]** **Convex Optimization:** Theories & definitions (Interior, closure, conjugate functions)**,** Fracas Theorem, Weierstrass theorem,						

	duality theorems (both linear & non-linear), Basics of conic programming, Quadratic Programming **[10]** **LPP:** Linear Programming (ONLY DEFINITION), Complex problem with IF- Then constraints, Interior Point Method, Computer Output, problems will include the followings VRP, TSP, Scheduling Problems, Data Envelopment Analysis, Network Optimization Models, The Minimal Spanning Tree Problem, The Maximal Flow Problem [**10]** **Decision Theory:** Fundamentals of Decision Theory and Analysis, Payoff tables and decision trees; Decision making with and without probabilities; Analytical Hierarchy Process, ANP, Markov Analysis**,** Risk and sensitivity analysis of decision-making, Waiting line systems **[10]** **Non-classical Optimization Techniques:** Development of C or JAVA code for solving problems using Genetic Algorithm, Evolutionary algorithm etc. [**5]** **Simulation Using R** **[5]**
Text Books and/or reference material	**TEXT BOOKS:** 1. **Dimitri P Bertsekas,** *Convex Optimization Theory* 2. **Rao,** *Optimization Techniques* **REFERENCE BOOKS:** 1. **H. Taha,** *Operations Research* 2. **Liberman,** *Operations Research*

Program Outcome → / Course Outcome ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	3	2	2	3	2	1
CO2	1	2	2	2	3	3	3
CO3	3	3	3	2	2	2	2

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