Kerala University of Digital Sciences, Innovation and Technology

M.Tech Computer Science and Engineering
&
M.Sc Computer Science

Scheme and Syllabus
2024 Admission onwards

School of Computer Science and Engineering (SoCSE)

School of Computer Science and Engineering

The School of Computer Science and Engineering (SoCSE) of the Kerala University of Digital Sciences, Innovation, and Technology (KUDSIT) was established in 2020 at the Technopark Phase IV, Thiruvananthapuram. The School offers the academic programs M.Tech Computer Science and Engineering, M.Sc Computer Science, and PhD.

Master of Technology (M.Tech) in Computer Science and Engineering

M.Tech in Computer Science and Engineering has three specializations: Artificial Intelligence, Connected Systems and Intelligence, and Cyber Security Engineering. The students must choose one of the specializations in the second semester. The admission and eligibility requirements for all three specializations are the same.

Master of Science (M.Sc) in Computer Science

M.Sc in Computer Science has two specializations: Cyber Security and Machine Intelligence. The students must choose one of the specializations while taking admission. The admission and eligibility requirements for both specializations are the same.

Program Structure

On average, each master's program is expected to have a maximum of 80 credits and a minimum of 70 credits.

One credit equates to 1 hour of contact classes (lectures or tutorials) per week or 2 hours of student workload (projects, labs, or self-study). Given that there are 15 teaching weeks, 1 hour of contact per week counts for 15 hours in a semester, or, on average, 2 hours of self-learning hours or coursework activities count for 30 hours of activities in a semester.

The normal duration to complete the master's programis24 months, divided into four semesters. However, the student may be allowed to complete the program in 48 months. Zero years are permitted for medical reasons or for engaging in startups. To avail of zero years as part of the startups, the student must be a founder on the director board of a company registered as a startup. Any other reasons for availing of a zero year are accessed on a case-to-case basis by the School committee for consideration of approval by the dean academic. The zero year does not count towards the total duration of the program.

The master programs of the university have the following credit distribution:

Program courses (30 credits)		University courses (20 credits)		Final year Projects	Additional credits beyond mandatory coursework and project		
Program Core (Mandatory)	Program electives (Mandatory)	University Core (Mandatory)	Open electives (Mandatory)	Capstone Project/ Thesis (Mandatory)	Activity credits (Mandatory)	Activity credits (Optional)	Additional courses (Optional)
15 credits	15 credits	5 credits	15 credits	15 credits	5 credits	5 credits	5 credits

- Group projects must be incorporated within the allowed program/open electives.
- Program electives must be chosen from their respective specialization in SoCSE. Program electives must be replaced by program electives in case of lower grades/ failure in program electives.
- Students can take program electives from their respective specializations as open electives.
- M.Tech Computer Science and Engineering (Artificial Intelligence) and M.Sc Computer Science (Machine Intelligence) program students have the option to select open electives from the program electives of M.Tech Computer Science and Engineering (Cyber Security) and M.Sc Computer Science (Cyber Security) program respectively. Likewise, students enrolled in the Cyber Security programs may choose open electives from the Artificial/Machine Intelligence program electives.
- Students can enroll in any number of program electives and open electives in a semester to fulfill the eligibility criteria for awarding the degree.
- Students in all other Schools can enroll in programs and open electives offered by SoCSE as their open electives.
- Project/ Thesis credits from open elective pool can be taken only once in the degree program. To allocate more than three credits for a Project/Thesis in AI/Cyber Security Engineering/Connected Systems and Intelligence within an open elective course, students must present the outcomes of their projects/thesis as publications in reputable Q1 journals/flagship conferences/commercial products capable of generating revenue to the University. Their work will be evaluated by two external (outside of the University) examiners who possess expertise in AI/Cyber Security Engineering/Connected Systems and Intelligence.

Every master's program has a university core that has a single course **Digital Access for Community Empowerment** that covers four components:

A. Two credit modules are called Community Empowerment (CE) / Visits. This is a five-day outbound program where students are exposed to problems facing society and explore ways to use digital technologies to find solutions. At the end of the program, the students are expected to work and report their findings through a short dissertation.

B. One credit module is Design Thinking and Innovation (DTI), where students are exposed to applying innovative thinking in thedigital sciences.

C. One credit module is Digital Transformation of Societal Problems/Social Innovation.

D. One credit module on Personal Development and Scientific Communication (PDSC).

E. The students complete this course through an interdisciplinary group project that covers all four modules. Each project group has faculty mentors who guide the students. The academic office allocates the mentors. Faculty members are responsible for mentorship for at most ten students annually. Each faculty member has a teaching assistant whom the faculty could select for the day-to-day administration of the mentoring program.

The common courses are limited to the following levels:

Course type	**Course level**
University Core/ Program Core /Program Electives/Open Program Electives	100/200/300/400 Level
Project/Thesis	400/500 Level

Credit Requirements for the Master Program

Students must comply with the following credit limits for completing a master's program.

A. Ensure completion of at least 70 credits, with a maximum cap of 80.
B. The students are allowed to take a maximum of 20 credits in a semester.
C. The students are allowed to take a maximum of 12 credits through audit courses. These credits do not count towards the total credits for the program.
D. The students are allowed to obtain a maximum of 12 credits through challenge exams. These credits count towards the total credits for the program.

Pass Criteria

A. There shall be no barrier between year 1 and year 2 of study.
B. The student shall obtain a minimum D grade in all core courses and a C in the project.
C. A minimum CGPA of 5 is required to award the master's degree.
D. All challenge examination courses and MOOC courses are not counted for CGPA computation. However, passing such courses enables them to be counted towards the total credits earned.

E. The project grade is included in the CGPA calculations.

M.Tech in Computer Science and Engineering with Specialization in Artificial Intelligence/Connected Systems and Intelligence/Cyber Security Engineering (AY 2024-25 Onwards)

Semester 1				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M4010000	Digital Access for Community Empowerment I	3		400
M3010002/ M3010009	AI and Machine Learning/ Introduction to Cyber Security	4	3-1-0-0	300
M3010003	Advanced Data Structures and Algorithms	3	2-1-0-0	300
	Open Elective	3 or 4		
M2010000	Mathematics	3	3-0-0-0	200
M2010001	Python Programming Lab	2	0-2-0-0	200
	Activity	1		
Total Credits		19		
Semester 2				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M4010001	Digital Access for Community Empowerment II	2		400
M3010004/ M3010005	Advanced Distributed Systems/Data and Intelligence	3	3-0-0-0	300
	Program/Open Elective	12		300/400
	Activity	2		
Total Credits		19		
Semester 3				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
	Program/Open Elective	15		300/400
	Activity	2		
Total Credits		17		

Semester 4				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/ Project**	**Level**
M4010002	Thesis	15	0-0-0-15	400
Total Credits		15		

Activity: Group project/internship/inter-School courses/approved online courses/extra curricular credits/bridge course/approved certifications.

Program Electives for Artificial Intelligence (Minimum 15 Credits Required)				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M3010000	Stochastic Processes and Models	3	2-1-0-0	300
M3010001	Robotics	3	2-1-0-0	300
M3010023	Data Analytics	3	2-1-0-0	300
M3010024	Digital Image and Video Processing	3	2-1-0-0	300
M3010025	Deep Learning	3	2-1-0-0	300
M3010026	Reinforcement Learning	3	2-1-0-0	300
M3010027	Computer Vision	3	2-1-0-0	300
M3010028	Soft Computing	3	2-1-0-0	300
M3010029	Natural Language Processing	3	2-1-0-0	300
M3010030	Speech Processing	3	2-1-0-0	300
M3010031	Cognitive Computing	3	2-1-0-0	300
M3010032	Big Data Technologies	3	2-1-0-0	300
M3010040	Optimization Techniques	3	2-1-0-0	300

Program Electives for Connected Systems and Intelligence (Minimum 15 Credits Required)				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M3010007	Cloud Security	3	2-1-0-0	300
M3010010	Computer Networks and Security	3	2-1-0-0	300
M3010011	Cryptography	3	2-1-0-0	300
M3010018	Hardware Security	3	2-1-0-0	300
M3010019	IoT Networks and Endpoint Security	3	2-1-0-0	300
M3010021	Systems Security and Risk Analysis	3	2-1-0-0	300
M3010033	Software Defined Networking	3	2-1-0-0	300
M3010034	Social Network Analytics and Security	3	2-1-0-0	300
M3010035	Wireless Sensor Networks	3	2-1-0-0	300
M3010036	Connected Environments and Enabling Technologies	3	2-1-0-0	300

Program Electives for Cyber Security Engineering (Minimum 15 Credits Required)				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M3010007	Cloud Security	3	2-1-0-0	300
M3010010	Computer Networks and Security	3	2-1-0-0	300
M3010011	Cryptography	3	2-1-0-0	300

M3010012	Cyber Analytics	3	2-1-0-0	300
M3010013	Malware Analysis and Reverse Engineering	3	2-1-0-0	300
M3010014	Ethical Hacking and Penetration Testing	3	2-1-0-0	300
M3010015	Digital Forensics	3	2-1-0-0	300
M3010016	Database Security	3	2-1-0-0	300
M3010018	Hardware Security	3	2-1-0-0	300
M3010019	IoT Networks and Endpoint Security	3	2-1-0-0	300
M3010020	Mobile Application Security	3	2-1-0-0	300
M3010021	Systems Security and Risk Analysis	3	2-1-0-0	300
M3010022	Information Security Management System	3	2-1-0-0	300

M. Sc. in Computer Science with Specialization in Cyber Security/Machine Intelligence (AY 2024-25 Onwards)

Semester 1				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M4020000	Digital Access for Community Empowerment I	3		400
M3020002/ M3020009	AI and Machine Learning/Introduction to Cyber Security	4	3-1-0-0	300
M3020003/ M3020006	Advanced Data Structures and Algorithms/Data Structures and Algorithms	3	2-1-0-0	300
M3020008	Database Systems	3	2-1-0-0	300
M2020000	Mathematics	3	3-0-0-0	200
M2020001	Python Programming Lab	2	0-2-0-0	200
	Activity	1		
M0000000	Preparatory Mathematics	0		
Total Credits		19		

Semester 2				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M4020001	Digital Access for Community Empowerment II	2		400
	Program / Open Elective	15		300/400
	Activity	2		
Total Credits		19		

Semester 3				
Course Code	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/**	**Level**

			Seminar/Project	
	Program / Open Elective	15		300/400
	Activity	2		
Total Credits		17		

Semester 4

Course Code	Title of the Course	Credits	Credit Split Lecture/Lab/ Seminar/Project	Level
M40200002	Project	15	0-0-0-15	400
Total Credits		15		

Activity: Group project/internship/inter-School courses/approved online courses/ extra-curricular credits/bridge course/approved certifications

Program Electives for Cyber Security (Minimum 15 Credits Required)

Course Code	Title of the Course	Credits	Credit Split Lecture/Lab/ Seminar/Project	Level
M3020007	Cloud Security	3	2-1-0-0	300
M3020010	Computer Networks and Security	3	2-1-0-0	300
M3020011	Cryptography	3	2-1-0-0	300
M3020012	Cyber Analytics	3	2-1-0-0	300
M3020013	Malware Analysis and Reverse Engineering	3	2-1-0-0	300
M3020014	Ethical Hacking and Penetration Testing	3	2-1-0-0	300
M3020015	Digital Forensics	3	2-1-0-0	300
M3020016	Database Security	3	2-1-0-0	300
M3020018	Hardware Security	3	2-1-0-0	300
M3020020	Mobile Application Security	3	2-1-0-0	300
M3020021	Systems Security and Risk Analysis	3	2-1-0-0	300
M3020022	Information Security Management System	3	2-1-0-0	300

Program Electives for Machine Intelligence (Minimum 15 Credits Required)

Course Code	Title of the Course	Credits	Credit Split Lecture/Lab/ Seminar/Project	Level
M3020000	Stochastic Processes and Models	3	2-1-0-0	300
M3020001	Robotics	3	2-1-0-0	300
M3020005	Data and Intelligence	3	3-0-0-0	300
M3020023	Data Analytics	3	2-1-0-0	300
M3020024	Digital Image and Video Processing	3	2-1-0-0	300
M3020025	Deep Learning	3	2-1-0-0	300
M3020026	Reinforcement Learning	3	2-1-0-0	300
M3020027	Computer Vision	3	2-1-0-0	300
M3020028	Soft Computing	3	2-1-0-0	300

M3020029	Natural Language Processing	3	2-1-0-0	300
M3020030	Speech Processing	3	2-1-0-0	300
M3020031	Cognitive Computing	3	2-1-0-0	300
M3020032	Big Data Technologies	3	2-1-0-0	300
M3020040	Optimization Techniques	3	2-1-0-0	300

Open Electives offered by SoCSE				
Course Code M. Tech/M. Sc	**Title of the Course**	**Credits**	**Credit Split Lecture/Lab/ Seminar/Project**	**Level**
M1010000/ M1020000	Technical Communication	2	1-1-0-0	100
M3020037	Operating Systems	3	2-1-0-0	300
M3010038/ M3020038	Blockchain Technology	3	2-1-0-0	300
M3010039/ M3020039	Augmented and Virtual Reality	3	2-1-0-0	300
M3020041	Computer Architecture	3	2-1-0-0	300
M3010042/ M3020042	Quantum Computing	3	2-1-0-0	300
M3020043	Web Technology	3	2-1-0-0	300
M3020044	OOPS and JAVA	3	2-1-0-0	300
M3020045	Object Oriented Software Engineering	3	2-1-0-0	300
M3010046/ M3020046	Cloud and Edge Computing	3	2-1-0-0	300
	Approved SWAYAM Courses in AI/Cyber Security/Connected Systems and Intelligence	1-6		300
M4010003/ M4020003	Project/Thesis in AI/Cyber Security Engineering/Connected Systems and Intelligence	3-9	0-0-0-(3-9)	400

Theory Courses

PREPARATORY MATHEMATICS

Course Code	Course Name	Credit	Year of Introduction
M0000000	Preparatory Mathematics	0	2023

Prerequisites: Nil

Course Objectives:

1. To equip students with the necessary mathematics background for the postgraduate level Mathematics and Computer Science courses.
2. To serve as a refresher course for Mathematics.
3. To help the students develop the ability to solve problems using the learned concepts.

Course Outcomes: After completion of this course, the students will be able to,

CO1: Gain enough mathematical maturity to do the postgraduate level computer science courses**.**

CO2: Analyze and evaluate critically the appropriate mathematical techniques required for solving various problems.

CO3: Apply mathematical techniques to solve various problems.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	3	0		
CO2	3	3	3	2		
CO3	3	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:

Module	Content
1	Basic Properties of the integers, divisibility and primality, LCM, GCD, real numbers, properties of real numbers, Complex numbers, algebra of complex

	numbers
2	Sets, Set Operations, Functions, Sequences and Summations, Counting, Permutation, Combination.
3	Statistical population and sample, Measures of central tendency, Measures of dispersion, Skewness, Kurtosis.
4	Functions, limits, continuity, derivatives, Product, quotient, and chain rules.

Text Books

1. K. Rosen, *Discrete Mathematics and its Applications*, 7th ed., McGraw-Hill Education, 2017.
2. G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry*, 9th ed. India: Pearson Education, 2010.
3. D. Freedman, R. Purves, and R. Pisani, *Statistics*, *Viva Books*, 4th ed., 2011.
4. T. Koshy, *Elementary Number Theory with Applications*, Academic Press, Elsevier, 2002.

TECHNICAL COMMUNICATION

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M1010000/ M1020000	**Technical Communication**	**1-1-0-0**	**2023**

Prerequisites: Basic English, Grammar rules.

Course Objectives:

1. Get the fundamental knowledge of technical communication.
2. Write technical documents in proper format and structure.
3. Communicate effectively in a professional context, using appropriate rhetorical approaches.
4. Adapt content and rhetorical strategies according to the audience and purpose of each document.
5. Create and deliver technical briefings tailored to specific audiences, purposes, and media.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the nature, objective, and importance of Technical Communication.
C02: Do the technical write-ups.
CO3: Boost their confidence in public speaking.
C04: Do presentations in front of a diverse audience.
CO5: Become efficient communicators by learning the voice-dynamics.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3		1	2	1	3
CO2		2	1	3	1	3
CO3				3		3
CO4				2	3	2
CO5				2	2	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Fundamentals of Technical Communication:** Features of technical communication, The distinction between General and Technical Communication, Language as a tool of Communication, Dynamics of Communication: Definition and process, Kinesics, Proxemics, Paralinguistic features, Importance of Interpersonal and Intercultural Communication in today's organization, The flow of Communication: Downward; upward, Lateral or Horizontal, Barriers to Communication, Code and Content, Stimulus and Response, Encoding process, Decoding process, Professional Personality Attributes
2	**Forms of Technical Writing** Synopsis writing, Technical Report, Thesis/ Project writing, Technical research Paper writing, Seminar and Conference paper writing, Expert Technical Lecture, 7 Cs of effective business writing: concreteness, completeness, clarity, conciseness, courtesy, correctness, consideration, C.V./Resume writing, Technical Proposal, Email writing, Agenda of meeting, Minutes of meeting
3	**Voice Dynamics and Oral Communication** Pronunciation Etiquette; Syllables; Vowel sounds; Consonant sounds; Tone: Rising tone; Falling Tone; Flow in Speaking, Speaking with a purpose, Speech and personality, Professional Personality Attributes: Empathy; Considerateness; Leadership; Competence. Public speaking, Overcoming Stage Fear: Confident speaking; Audience Analysis and retention of audience interest, Presentation strategies, Interview skills, Negotiation skills Critical and Creative thinking in communication.
4	**Technical Presentation: Case Studies Using Learnt Strategies and Techniques** Presentation Skills for Technical Paper/Project Reports/ Professional Reports based on proper Stress and Intonation Mechanics, Comprehension Skills based on Reading and Listening Practicals on a model AudioVisual Usage, Role Play, Group Discussion, Extempore, Mock Interview, Conducting meetings and minutes of meeting.

Text Books

1. M. Raman and S. Sharma, *Technical Communication – Principles and Practices*, Oxford Univ. Press, 2007.
2. R.C. Sharma and K. Mohan, *Business Correspondence and Report Writing*, McGraw-Hill, 2001.
3. L. U. B. Pandey, *Practical Communication: Process and Practice*, India: A.I.T.B.S. Publications, 2014.
4. T. A. Sherman *et al.*, *Modern Technical Writing*, Apprentice Hall, 2015.
5. S.D. Sharma, *A Text Book of Scientific and Technical Writing*, Vikas Publication, 2008.
6. M. Murphy, *Skills for Effective Business Communication*, Harvard University, 2014.
7. P. Mehra, *Business Communication for Managers*, Pearson Publication, 2011.

MATHEMATICS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M2010000/ M2020000	**Mathematics**	**3-0-0-0**	**2024**

Prerequisites: Nil

Course Objectives:

1. To provide students with a good understanding of the concepts of mathematics.
2. To help the students develop the ability to solve problems using the learned concepts.
3. To connect the concepts to other domains, such as machine learning and pattern recognition, within and without mathematics.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the mathematical foundations of the theory, problem, and state-of-the- art solutions.

CO2: Analyze and evaluate critically the building and integration of mathematical foundations.

CO3: Design and demonstrate mathematical foundations through team research projects and project report presentations.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Probability Theory - sample space - events - Algebra of sets- Notion and Axioms of probability-Equally likely events - Conditional probability- independent events. Bayes' theorem.
2	Axiomatic definition of Probability - Probability spaces- Random variables- PMF and PDF - Discrete and Continuous distributions. Joint, probability mass function, Marginal distribution function, Joint density function. Popular distributions- binomial, Bernoulli, Poisson, exponential, Gaussian.
3	Fundamental concepts in statistics- Measures of location and variability- Population, sample, parameters. Sampling and Testing of Hypothesis: Introduction to testing of hypothesis - Tests of significance for large samples – t, F and Chi-square tests; ANOVA - one-way and two-way classifications. Correlation and Regression.
4	Scalar, Vectors, Vector addition and scalar multiplication, i, j, k notation, inner product, lines and hyperplanes, Vector spaces, Bases, Dimension, Linear transformations - The matrix representation – Change of basis – Rank and Nullity – Row and Column space of a matrix -System of linear equations. Inner product spaces – Cauchy Schwarz inequality- Gram Schmidt Orthogonalization – Normed linear spaces.

Text Books

1. H.P. Hsu, *Theory and Problems of Probability, Random Variables, and Random Processes*, McGraw-Hill, 2014.
2. S. M. Ross, *Introduction to Probability Models, 11th ed.*, Academic Press, 2014.
3. S. Lipschutz, *Schaum's Outline of Theory and Problems of Linear Algebra*, New York: McGraw-Hill, 1968.
4. G. Strang, *Linear Algebra and its Applications*, 4th ed. India: Cengage Learning, 2005.
5. C. D. Meyer, *Matrix Analysis and Applied Linear Algebra*, Siam, 2000.
6. P. J. Olver and C. Shakiban, *Applied Linear Algebra*, Prentice Hall, 2006.
7. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, International Edition, Wiley, 1988.
8. R. V. Hogg, J. W. McKean, and Allen T. Craig, *Introduction to Mathematical Statistics, 7th ed*. Asia: Pearson Education, 2014.

References

1. W. Feller, *An Introduction to Probability Theory and its Applications*, John Wiley and

Sons, 2008.
2. D. S. Bernstein, *Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory*, Princeton University Press, 2005.

PYTHON PROGRAMMING LAB

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M2010001/ M2020001	Python Programming Lab	0-2-0-0	2024

Prerequisites: Nil

Course Objectives:

1. To help students learn problem-solving techniques.
2. To help students understand the fundamental concepts of programming using the Python. programming language and introduce the basic concepts of Object-Oriented programming in Python.
3. To introduce students to database concepts and simple data science tools.
4. To help students build practical skills for solving problems computationally.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Explain the basic concepts of computational problem solving, procedural and object-oriented programming paradigms, and database programming.

CO2: Use algorithms and flowcharts to lay out the procedure to solve a problem**.**

CO3: Explain the basics of Python, such as variables, data types, control structures, functions, and files, and apply Python knowledge to solve computational problems.

CO4: Explain coding and analyzing data with Python using tools like Pandas, NumPy, and Matplotlib and understand the basics of cybersecurity data analytics.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3					
CO2	3					1
CO3	3					
CO4	3			2		1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:

Module	Content
1	Computational Problem Solving. Algorithms and Flowcharts, Introduction to Computer Programming. Programming Paradigms and Programming Languages. Introduction to Object Oriented Programming. Introduction to Database Programming and Scripting. Software Development Process. Programming Code of Ethics. Introduction to Python. Real-world Applications of Python. Features of Python Programming Language. Implementations of Python. Python Career Opportunities.
2	Python Data Types, Variables, Basic Input-Output Operations, Basic Operators. Boolean Values, Conditional Execution, Loops, Lists and List Processing, Logical and Bitwise Operations. Functions, Tuples, Dictionaries, and Data Processing. Modules, Packages, String and List Methods, and Exceptions.
3	The Object-Oriented Approach: Classes, Methods, Objects, and Exception Handling. A brief introduction to OO Design. File Handling in Python. Introduction to Data Science. Tools for Data Science (GitHub, Jupyter Notebooks). Database Concepts and SQL. SQL using Python.
4	Data Handling using NumPy and Pandas. Data Visualization in Python. Simple projects. Case studies.

Lab Exercises

Module 1

1. Problems on number systems and data encoding.
2. Writing simple algorithms and flowcharts.
3. Writing advanced algorithms and flowcharts, installing and running Python.
4. Writing simple programs (e.g. Drake equation) to familiarize with variables, keywords, operators, expressions, data types and operator precedence. The print() function, type conversion, formatting numbers and strings.

Module 2

5. Conditional statements, writing simple scripts, using comments for program

readability.

6. Loops, nested loops, break and continue statements (e.g. Prime number, Fibonacci series, Factorial, Armstrong number, Palindrome)
7. Built-in data structures and their applications - Lists, Tuples, Sets and Dictionaries, Range function, Functions such as zip() and enumerate().
8. More coding exercises using lists (e.g. Merging sorted lists), tuples, sets, dictionaries.

Module 3

9. Defining and calling functions: Passing arguments and returning values (e.g. Pascal's triangle.), scope, local functions, Lambda functions, function redefinition, standard library modules.
10. File and exception handling.
11. Coding exercises to practice Object Oriented Programming.

Module 4

12. Data Handling using NumPy and Pandas.
13. Python and SQL
14. Data Visualization in Python

Text Books

1. C. Dierbach, *Introduction to Computer Science Using Python: A Computational Problem-Solving Focus*, Wiley, 2017.
2. A. N. Kamthane and A. A. Kamthane, *Programming and Problem Solving with Python*, McGraw-Hill Education, 2018.
3. S. F. Lott, *Object Oriented Python*, Packt Publishing, 2014.
4. W. McKinney, *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython*, O'Reilly, 2012.

References

1. R. Thareja, *Python Programming Using Problem Solving Approach*, Oxford Higher Education, 2017.
2. B. N. Miller and D. L. Ranum, *Problem Solving with Algorithms and Data Structures Using Python*, Franklin, Beedle and Associates, 2011.
3. D. D. Riley and K. A. Hunt, *Computational Thinking for the Modern Problem Solver*, CRC Press, 2014.
4. J. VanderPlas, *Python Data Science Handbook: Essential Tools for Working with Data*, O'Reilly, 2016.
5. F. Nelli, *Python Data Analytics: With Pandas, NumPy, and Matplotlib*, 2nd ed., Apress, 2018.

DIGITAL ACCESS FOR COMMUNITY EMPOWERMENT I

Course Code	Course Name	Credit	Year of Introduction
M4010000/ M4020000	Digital Access for Community Empowerment I	3	2023

Prerequisites: Nil

Course Objectives:

1. Orient students to identify real-life problems beyond the classrooms through community engagement.
2. Exposing the students to human problems for which digital solutions are thought through to the ideational level and beyond.
3. Familiarize students with the interface between society and technological/digital solutions.
4. Enabling them to understand social innovation and define digital solutions.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Develop the ability to identify societal problems that can be transformed into digital solutions by fostering effective teamwork and communication skills.

CO2: Enhance creative thinking and problem-solving by employing brainstorming, ideation, and lateral thinking techniques within a multidisciplinary group.

CO3: Cultivate self-awareness and empathy, essential for collaboratively identifying and addressing community issues within a supportive learning environment.

Program Learning Outcomes:

PLO 1 Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and specialization to the solution of complex engineering problems.

PLO 2 Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using the first principles of mathematics, natural, and engineering sciences.

PLO 3 Design/development of solutions: Design solutions for complex engineering problems and design system components processes to meet the specifications with consideration for public health and safety and cultural, societal, and environmental considerations.

PLO 4 Conduct investigations of complex problems: Use research-based knowledge, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PLO 5 Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling for complex engineering activities with an understanding of the limitations.

PLO 6 The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PLO 7 Environment and sustainability: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.

PLO 8 Ethics: Apply ethical principles and commit to professional ethics, responsibilities, and norms of the engineering practice.

PLO 9 Individual and team work: Function effectively as an individual, member, or leader in teams and multidisciplinary settings.

PLO 10 Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports and documentation. Make effective presentations, and give and receive clear instructions.

PLO 11 Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's work as a member and leader in a team. Manage projects in multidisciplinary environments.

PLO 12 Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping of course outcomes with program learning outcomes:

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CO1	2	3	1	3	2	3	3	3	3	3	2	3
CO2	2	3	2	3	2	2	3	2	3	2	3	3
CO3	1	2	1	3	3	1	3	1	2	1	2	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	**Content**
Design Thinking and Innovation- 1 Credit	Icebreaker Activity to Build Group Cohesion, Overview of Design Thinking and Its Relevance to Community Problem-Solving, Understanding the Importance of Empathy in Identifying Community Problems, Empathy Building Exercises, Techniques for Problem Framing and Defining Community Issues, Brainstorming and Ideation Methods Creating an Affinity Diagram or Problem Prioritization Exercise, Rapid Prototyping - Turning Ideas into Actionable Concepts, Preparing and Polishing Pitch Presentations
Community Empowerment/Visits- 2 Credit	Classroom Interaction: community, society, sustainability, technology, development and discourse on development, various top down and bottom-up approaches, democracy, political and administrative processes and divisions in India with focus on Kerala's context. Methods of approaching a community, Participatory Rural Appraisal, Rapid Rural Appraisal and other methods to identify issues in brief. Instructions on analysis of data and report writing. Ethical engagement with the community for development I: 5-day outbound program to various identified communities where students get exposed to societal problems and explore ways to use digital technologies to find solutions.

DIGITAL ACCESS FOR COMMUNITY EMPOWERMENT II

Course Code	Course Name	Credit	Year of Introduction
M4010001/ M4020001	Digital Access for Community Empowerment II	2	2023

Prerequisites: Successful completion of DACE - I

Course Objectives:

1. To provide digital solutions to communities based on the problem identified in DACE I.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Explore various innovation strategies and tools to develop and implement sustainable solutions to social problems.

CO2: Develop skills in assessing and measuring the impact of innovative solutions for social problems.

CO3: Demonstrate various phases of project management and explore diverse business models and revenue-generating strategies.

CO4: Engage with various stakeholders such as governments, corporations, NGOs, and communities to create effective alliances for social change.

CO5: Cultivate an entrepreneurial mindset and a strong sense of purpose in addressing social problems.

Program Learning Outcomes:

PLO 1 Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and specialization to the solution of complex engineering problems.

PLO 2 Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using the first principles of mathematics, natural, and engineering sciences.

PLO 3 Design/development of solutions: Design solutions for complex engineering problems and design system components processes to meet the specifications with consideration for public health and safety and cultural, societal, and environmental considerations.

PLO 4 Conduct investigations of complex problems: Use research-based knowledge, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PLO 5 Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling for complex engineering activities with an understanding of the limitations.

PLO 6 The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PLO 7 Environment and sustainability: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.

PLO 8 Ethics: Apply ethical principles and commit to professional ethics, responsibilities, and norms of the engineering practice.

PLO 9 Individual and team work: Function effectively as an individual, member, or leader in teams and multidisciplinary settings.

PLO 10 Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports and documentation. Make effective presentations, and give and receive clear instructions.

PLO 11 Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's work as a member and leader in a team. Manage projects in multidisciplinary environments.

PLO 12 Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping of course outcomes with program learning outcomes:

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CO1	3	3	3	3	2	3	3	2	3	1	2	3
CO2	2	3	3	2	1	3	3	2	3	2	1	2
CO3	3	1	1	2	2	3	3	3	3	3	3	2
CO$	2	1	1	2	1	2	3	3	3	3	3	2
CO5	3	3	3	3	3	3	3	3	3	3	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	**Content**
Digital Transformations of Societal Problems/ Social Innovation - 1 Credit	DACE I Recap: Refreshing the problems identified in DACE I, Revisiting Design Thinking and Innovation, Understand the problem in a deeper context, segments, gaps, and beneficiaries, Ethical considerations. Project Planning: Action Plan - Defining project objectives, deliverables, and success criteria, feasibility study - operational, legal, economic, technical, social, Budgeting, Cost table, Social marketing, SWOT analysis, Identifying (already done in DACE - I) project stakeholders and their roles, Introduction to project management tools, working with project scheduling (e.g., Gantt charts, Kanban boards) Technology: Selecting appropriate digital tools/platforms/services, ensuring accessibility inclusivity, and ethical considerations, Developing prototypes, testing, implementation and feedback collection Implementation: Deploying solution in the community identified, Monitoring and evaluating performance, Engaging community and stakeholders, addressing challenges and feedback, social impact and ethical implications analysis. Social entrepreneurship, Sustainability and scaling in social ventures, Business models and funding strategies
Personal Development and	Dissertation/Report, Presentations to peers and mentors, Demonstration of working prototypes or digital solutions, Reflection on the development process and lessons learned, Implementation and Monitoring Reports, Marketing the

Scientific Communication (PDSC) - 1 Credit	product.

STOCHASTIC PROCESSES AND MODELS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010000/ M3020000	Stochastic Processes and Models	2-1-0-0	2024

Prerequisites: M2010000/M2020000

Course Objectives:

1. To give students a good understanding of the concepts of information-theoretic methods, stochastic processes, and models.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without stochastic processes and models.

Course Outcomes: After completion of this course, the students will be able to,

CO1: Understand the mathematical foundations of the theory, problem, and state-of-the-art solutions of modern stochastic models.

CO2: Analyze and critically evaluate the building and integration of stochastic models, algorithms, and systems.

CO3: Design and demonstrate a stochastic model through team research projects and project report presentations.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus	
Module	**Content**
1	Concepts of multiple random variables. Bayesian belief networks (BBN): Representation, Independence and conditional independence, Partial independence and other structure. Exact inference in BBN: Variable elimination, Pearl's algorithm, Junction tree, Recursive decomposition, Using additional structure.
2	Approximate inference: Monte Carlo approximations, Loopy belief propagation, Variational methods. Learning of BBNs: learning parameters, learning structure, Bayesian averaging, EM (learning with hidden variables and missing values), structural EM.
3	Dynamic belief networks: Particle filtering. Markov random fields (Markov networks): Representation (potentials), Independence and conditional independence, Trees, Boltzman machines, Conditional Markov random fields.
4	Inference in Markov networks. Learning Markov networks: Iterative proportional fitting, Cluster variational methods, Other approximations. Relational graphical models.

Text Books

1. D. Koller and N. Friedman, *Probabilistic Graphical Models: Principles and Techniques*, MIT Press, 2009.
2. D. Barber, *Bayesian Reasoning and Machine Learning*, Cambridge University Press, 2012.
3. D. J. C. Mackay, *Information Theory, Inference, and Learning Algorithms*, UK: Cambridge University Press, 2003
4. J. Pearl, *Probabilistic Reasoning in Intelligent Systems*, Morgan Kaufman, 1997.

ROBOTICS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010001/ M3020001	**Robotics**	**2-1-0-0**	**2024**

Prerequisites: Prior knowledge of undergraduate level Mathematics, Programming

Course Objectives:

1. To impart a comprehensive and in-depth understanding of Robotics, technologies and applications to students by introducing and researching cutting-edge topics, technologies, applications and implementations.
2. To expose the students to frontier areas of Robotics while providing sufficient foundations for further study and research.

Course Outcomes: After completion of this course, the students would be able to:

CO1: Understand the foundations of robotics, concepts, and issues related to mechanics,

planning and control by completing homework, quizzes, and examinations.

CO2: Prepare students for an industrial automation environment by completing robotics projects.

CO3: Expose students to current literature in robotics.

CO4: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in robotics.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**
CO1	3	2	1	2		
CO2	3	2	2	2		
CO3	2	2	2	2		
CO4	2	2	2	3	3	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:

Module	**Content**
1	Introduction to the subject, automation, Industrial robots, Serial, parallel robots, configuration space, rigid body motion, kinematics, Inverse and forward kinematics, dynamics, trajectory planning, Applications. Configuration space: degrees of freedom (dof), robot joints, Grubler, s formula, Open and close chains, configuration space and its representation. Configuration and velocity constraints, taskspace and workspace
2	Rigid body motion: rigid body motion in plane, mathematical description of position and orientation, rotation and angular velocities, changing the coordinate frames, representations of rotation, homogenous transformation matrix, rotating and translating a vector or frame, twists, wrenches. Forward Kinematics: DH parameters, examples of DH parameters, product of exponential formulas,

3	Velocity, kinematics and statics: Jacobian, space jacobian, body jacobian, singularity analysis, manipulability, Inverse kinematics: Analytical and numerical inverse kinematics, kinematics of closed chains (parallel robots), Stewart-Gaugh platform. Manipulator dynamics: Acceleration of rigid body, mass distribution, Newton's equation, Example of close form dynamic equations, Lagrangian formulation of manipulator dynamics.
4	Trajectory generation: Point to point trajectory, polynomial via point trajectory, time scaling, Manipulator-mechanism design: basing design on task requirements, kinematic configuration, redundant and closed-chain structures, Actuation schemes, gears, shafts, links, Actuators, pneumatic cylinders, motors, position sensing, force sensing

Text Books

1. J. J. Craig,*Introduction to Robotics: Mechanics and Control*, 3rded., Pearson, 2004.
2. K. M. Lynch and F. C. Park, *Modern Robotics: Mechanics*, *Planning*, *and Control*, Cambridge University Press, 2017.
3. D. Fox and S. Thrun,*Probabilistic Robotics*, MIT Press, 2005.
4. S. K. Saha,*Introduction to Robotics*, McGraw-Hill Education,2008.

AI AND MACHINE LEARNING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010002/ M3020002	**AI and Machine Learning**	**3-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To impart algorithmic skills for designing AI and machine learning techniques and solutions.
2. To equip the students to identify and analyse problems solvable with AI/machine learning algorithms/techniques.
3. To impart solution design capability with AI/machine learning techniques.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Algorithm design/analysis capability in AI/Machine Learning.

CO2: Problem identification and analysis skills on application domains requiring AI/machine learning techniques.

CO3: Solution design capability with AI/machine learning techniques.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		2
CO2	2	3	3	2		2
CO3	2	3	3	2		2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Artificial Intelligence - Turing Test, Rule/Logic based AI and Machine Learning Based AI, Importance of search in AI - uninformed and informed search, local search - gradient descent, modelling the brain - Perceptron, Back Propagation Algorithm, Narrow and General AI.
2	Machine Learning Paradigms: Supervised, Unsupervised and reinforcement Learning. Generalization performance, Bias-Variance tradeoffs, Feature Engineering - relevance, feature extraction - PCA. Supervised Learning: - Classification - Bayesian, Decision Tree and Random Forests, Ensemble Methods - Boosting and Bootstrap Aggregation, Regression - linear, logistic.
3	Unsupervised Learning: Density Estimation - Maximum Likelihood and Parzen Windows, Clustering - Partition Based, Subspace Clustering, Incremental Clustering, Spectral Clustering. Sequence Modelling - Hidden Markov Models.
4	Statistical Learning theory - Empirical Risk Minimization, and Structural Risk Minimisation: VC Dimension. Kernel Machines - Support Vector Machines, Support Vector Clustering, Support Vector Regression, Scalable Kernel Machines, Deep Kernel Machines - Deep Kernels and Multi Kernel Learning

Lab Exercises

Module 1:
Experiments on Google AI Experiments platform, Implementation of Perceptron

Module 2:
Implementation of PCA, Nave Bayes Classifier, Logistic Regression

Module 3:
Implementation of ML Estimation, K-Means and HMM

Module 4:
Experiments with SVM Libraries - SVM and Deep SVM

Text Books

1. S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 4th ed., Pearson, 2020.

2. S. Shalev-Shwartz and S. Ben-David, *Understanding Machine Learning: From Theory to Algorithms*, Cambridge University Press, 2014.
3. I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, MIT Press, 2016.

References

1. S. Haykin, *Neural Networks and Learning Machines*, 3rd ed., Pearson, 2009.
2. G. Bonaccorso, *Mastering Machine Learning Algorithms*, Packt Publishing, 2018.

ADVANCED DATA STRUCTURES AND ALGORITHMS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010003/ M3020003	Advanced Data Structures and Algorithms	2-1-0-0	2024

Prerequisites: Students should possess the fundamental programming skills in Computer Programming Languages such as Python.

Course Objective:

1. Understand fundamental data structures and algorithms and the tradeoffs between various implementations of these abstractions.

Course Outcomes: After completion of this course, the students will be able to,

CO1: Understand advanced data structures and their applications conceptually.

CO2: Implement various application algorithms and develop an insight into NP-completeness, randomization, approximation, and parameterized complexity.

CO3: Design, prove the correctness, and analyse new algorithms.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3					
CO2	3	2		1		
CO3	3	2		1		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Various Algorithm Design Strategies. Revising Asymptotic Complexity Analysis, Sorting, Searching and Divide and Conquer Algorithm strategy.
2	Trees: Balanced Binary Search Trees (AVL trees). Amortized Complexity and Splay Trees. Graphs: Weighted graphs, Basic Graph Algorithms (BFS, DFS and

	applications), Strongly Connected Components.
3	Single-Source Shortest Paths and Minimum Spanning Trees: implementation through heaps, Greedy Algorithm design. All Pairs Shortest Paths and other Dynamic Programming examples.
4	Overview of P, NP Problems, NP-Completeness and a brief introduction to Randomization, Approximation and Parameterized Complexity.

Lab Exercises

Solving various problems using appropriate data structures. Use of recursion. Solving problems with Greedy, Divide and Conquer, and Dynamic programming techniques. Solving other interesting problems where data structures need to be used in an intelligent way.

Text Books

1. T.H. Cormen *et al.*, *Introduction to Algorithms*, MIT Press, 2009.
2. B. N. Miller and D. L. Ranum, *Problem Solving with Algorithms and Data Structures Using Python*, Franklin, Beedle and Associates, 2011.

References

1. Y. Langsam *et al.*, *Data Structures using C*, Asia: Pearson Education, 2004.
2. A. Drozdek, *Data Structures and Algorithms in JAVA*, 2nd ed., Brooks/Cole, 2002.
3. J. Kleinberg and E. Tardos, *Algorithm Design*, Pearson Education, 2006.
4. S. Dasgupta *et al.*, *Algorithms*, New York: McGraw-Hill Higher Education, 2008.

ADVANCED DISTRIBUTED SYSTEMS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010004	**Advanced Distributed Systems**	**3-0-0-0**	**2023**

Prerequisites: Prior Knowledge of operating systems, computer networks, distributed systems, DBMS, Graph Theory.

Course Objectives:

1. To understand the basic principles of distributed systems, core problems, and solutions.
2. To introduce communication technologies used in distributed platforms, viz., computer networks and other inter-process communications.
3. To explore real-life examples of distributed systems and how core problems related to distributed systems are solved in those example domains.
4. To give hands-on experience in working with and implementing distributed systems.

Course Outcomes: After completion of this course, the students will be able to:

C01: Understand the fundamental problems of distributed systems and different solution algorithms.

C02: Apply the knowledge of distributed systems while developing distributed software solutions.

C03: Implement and configure the various state-of-the-art distributed systems solutions.

C04: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in Distributed Systems.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) .
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3			1		
CO2	3	3	3	1		
CO3	3	3	3	3	1	1
CO4	1	3	2	3	2	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:

Module	Content
1	Basics of Computer Networks Concept of layering: OSI and TCP/IP Protocol Stacks, Basics of packet, circuit and virtual circuit switching. Data link layer: framing, error detection, Medium Access Control, Ethernet bridging. Routing protocols, Fragmentation and IP addressing, IPv4, CIDR notation, Basics of IP support protocols (ARP, DHCP, ICMP), Network Address Translation (NAT). Transport layer: flow control and congestion control, UDP, TCP, sockets, Application layer protocols: DNS, SMTP, HTTP, FTP, Email, Introduction to Wireless Network.
2	Distributed Systems Fundamentals I Introduction: Distributed computing Issues and Solutions, Examples of distributed systems. Architecture: Types of distributed Architecture Concepts: Process-Threads, Client-Server, Remote Procedure Call (RPC), Remote Method Invocation, Virtualization, Inter-Process Communication.
3	Distributed Systems Fundamentals II Synchronization: Clock Synchronization, Mutual Exclusion, Leader Election. Consistency and Replication. Fault Tolerance. Security: secure channels, access control.
4	Distributed Systems' Examples *Cloud:* Introduction to Cloud Computing, Cloud Computing Platforms, Parallel Programming in the Cloud, Distributed Storage Systems, Virtualization (Multicore Operating Systems). *Distributed Database Management Systems*: Introduction, Architecture, Design, Query Processing, Concurrency Control, Reliability Protocols. Distributed File Systems, Peer-to-Peer Computing (Bit Torrent), Distributed Network (TOR), Distributed Version/Source Control System (Git)

Lab Exercises

Module 1:

Client-Server implementation (preferably using cloud-based virtual machines)

Module 2:

Message Queue implementation to communicate among multiple processes

Module 3:

Semaphore-based Mutual Exclusion Implementation

Module 4:

TOR implementation, Git Implementation, Distributed Data Processing with Apache Hadoop/Spark

Text Books

1. A. S. Tanenbaum and M. V. Steen, *Distributed Systems*, *Principles and Paradigms*, 2nd ed., CreateSpace Independent Publishing, 2016.
2. S. Ghosh, *Distributed Systems*, *An Algorithmic Approach*, 2nd ed., Chapman and Hall/CRC, 2020.
3. H. Attiya and J. Welch, *Distributed Computing: Fundamentals*, *Simulations*, *and Advanced Topics*, 2nd ed., Wiley, 2006.
4. G. F. Coulouris *et al.*, *Distributed Systems: Concepts and Design*, 5th ed., Pearson, 2011.
5. A. D. Kshemkalyani and M. Singhal, *Distributed Computing*, 1st ed., Cambridge University Press, 2011.
6. W. Stevens, B. Fenner, and A. M. Rudoff, *Unix Network Programming*, *Volume 1: The Sockets Networking API*, 3rd ed. India: Pearson Education, 2015.
7. W. Stevens, *Unix Network Programming*, *Volume 2: Interprocess Communications*, 2nded. India: Pearson Education, 2015.
8. A. S. Tanenbaum, *Computer Networks*, 5th ed. India: Pearson Education, 2013.
9. B. A. Forouzan, *Data communication and Networking*, 5th ed. India: McGraw-Hill, 2012.
10. J. F. Kurose and K. W. Ross, *Computer Networking: A Top-Down Approach*, 6th ed., Pearson Education, 2017.

DATA AND INTELLIGENCE

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010005/ M3020005	Data and Intelligence	3-0-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To impart skills needed to identify and understand data problems.
2. To equip with analytical thinking on problems solvable with data intelligence.
3. To impart solution design capability with data intelligence.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand and develop techniques in data intelligence.

CO2: Problem identification and analysis skills on data intelligence problems.
CO3: Solution design capability with data intelligence.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		2
CO2	2	3	3	2		2
CO3	2	3	3	2		2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:

Module	Content
1	Data Intelligence and Decision Making, Collaborative Intelligence - Humans and AI. Data Architecture, Data Profiling and Storage, Data Quality and Integration, ETL process.
2	Data Analytics Thinking, Exploratory Analysis, Multidimensional Analysis, OLAP, Data Visualization, Data Modelling, Overfitting and Underfitting.
3	Decision Analytic Thinking - Applications of Clustering, Classification and Association Mining. Big Data Environments and Knowledge Extraction. Enterprise Data Management - Collibra case study.
4	Responsible Data Intelligence - Digital Personal Data Protection Bill 2023, Intelligence in CRM - Telenor case study, Healthcare Intelligence - Videa Health Case study, Retail Intelligence - Vispera case study, Manufacturing Intelligence - Dow Chemicals case study.

Lab/Assignment

A case study presentation and discussion (by a group of three)

Text Books

1. F. Provost and T. Fawcett, *Data Science for Business*, Shroff Publishers and Distributors, 2014.
2. D. T. Larose and C. D. Larose, *Data Mining and Predictive Analytics*, John Wiley and Sons, 2016.

References

1. T. Erl *et al*., *Big Data Fundamentals: Concepts, Drivers and Techniques*, India: Pearson Education, 2016.

2. S. Stephens-Davidowitz, *Everybody Lies: Big Data, New Data, and What the Internet Can Tell Us About Who We Really Are*, Harper Luxe, 2017.

DATA STRUCTURES AND ALGORITHMS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020006	**Data Structures and Algorithms**	**2-1-0-0**	**2024**

Prerequisites: Nil

Course Objectives:

1. To impart the basic concepts of data structures and algorithms.
2. To understand concepts about searching and sorting techniques.
3. To understand basic concepts about stacks, queues, lists, trees, and graphs.
4. To enable writing algorithms and doing a step-by-step approach to solving problems with the help of fundamental data structures.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Analyze an algorithm and find its efficiency.

CO2: Apply the concepts of Stack, Queue and Linked List in problem solving.

CO3: Obtain the skill to use recursion for problem solving.

CO4: Practice algorithm design and implementation to solve searching and sorting problems.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	1	1	1	1
CO2	3	2	3	1	1	1
CO3	3	1	3	1	1	1
CO4	3	2	3	1	1	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus	
Module	**Content**
1	Introduction to ADT and Algorithms: Data types, Data structures, Abstract data types, Algorithms, Algorithm analysis, Best case, worst case and average case complexities, Big-O notation, Analysis of Python List and Dictionary operations. Introduction to complexity classes.
2	Stacks: Introduction to stack, the stack abstract data type, basic operations, Algorithm analysis and implementation of stack in Python, expression representation using prefix and postfix notations, Evaluation of expression using stack. Queues: Introduction to queues, the queue ADT, basic operations, Algorithm and computational problems related to queue. Linked List: The unordered list ADT, linked list operations, doubly linked list, applications.
3	Recursion: The laws of recursion, format of a recursive function, applications of recursion such as Fibonacci series, Towers of Hanoi. Searching: Sequential and binary search, hashing. Sorting: Selection, bubble, insertion, quick, merge, heap sorts.
4	Trees: Vocabulary, Definitions, Tree operations, Implementation of tree, Binary trees, Balanced binary tree, Complete binary tree, binary search tree, balanced binary search tree, tree traversals. Heap: Introduction to binary heap, max heap, min heap, representation.

Lab Exercises

Module 1:

Computation of complexities of various algorithms.

Module 2:

Implementation stack, queue, linked list.

Module 3:

Solving problems using recursion and implementation of all the sorting and searching algorithms.

Module 4:

Implementation of tree, balanced tree, BST and heap structure.

Text Books

1. T. H. Cormen *et al.*, *Introduction to Algorithms*, MIT Press, 2009.
2. B. N. Miller and D. L. Ranum, *Problem Solving with Algorithms and Data Structures Using Python*, Franklin, Beedle and Associates, 2011.

References

1. Y. Langsam *et al.*, *Data Structures using C*, Asia: Pearson Education, 2004.
2. A. Drozdek, *Data Structures and Algorithms in JAVA*, 2nd ed., Brooks/Cole, 2002.
3. J. Kleinberg and E. Tardos, *Algorithm Design*, Pearson Education, 2006.

4. S. Dasgupta *et al.*, *Algorithms*, McGraw-Hill Higher Education, 2008.

CLOUD SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010007/ M3020007	Cloud Security	2-1-0-0	2024

Prerequisites: Cloud Computing

Course Objectives:

1. Understand the principles and challenges of cloud computing security, including risk assessment, legal considerations.
2. Learn about the Key strategies and best practices for securing the cloud environment.
3. Gain practical skills in securing cloud environments using Amazon Web Services (AWS), including monitoring, encryption, key management, threat detection, and compliance management.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Develop a comprehensive understanding of cloud computing security principles, risk assessment methodologies, and legal considerations.

CO2: Analyze and evaluate cloud architecture security and Cloud data security.

CO3: Acquire practical skills in implementing security measures within cloud environments, specifically utilizing Amazon Web Services (AWS) tools and services.

C04: Demonstrate proficiency in monitoring, auditing, and responding to security incidents within AWS, employing best practices to mitigate risks and enhance data protection.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	1	2		
CO2	3	2	1	2		
CO3	3	3	2	2	1	1
CO4	3	3	2	2	1	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus:	
Module	**Content**
1	Cloud Computing Security Concerns, Risk issues and Legal Aspects: Virtualization, Provisioning, Storage, Operation, Security and Networking – Risk Tolerance – Legal and Regulatory Issues. Key Strategies and Best Practices.
2	Cloud Architecture security – Security Requirements, Security Patterns and Architectural elements, Cloud Security Architecture Cloud Data security – Overview – Data Encryption – Sensitive Data Categorization – Cloud Data Storage – Cloud Lock in
3	Amazon AWS Monitoring & Auditing: AWS Monitoring Introduction, Cloud watch metrics – Cloud watch Logs, Live Tail, Agents -Cloud watch Alarms, Even Bridge – Cloud Trail – AWS Config
4	AWS Security – Introduction, Encryption, KMS, Multi-Region Keys, S3 Replication with encryption, Encrypted AMI Sharing process, SSM Parameter Store, AWS secrets Manager, AWS certificate Manager, Web Application Firewall, Shield – DDoS protection, Amazon Guard Duty, Amazon Inspector, Amazon Macie

Text Books

1. J.R. Winkler, *Securing the Cloud: Cloud Computer Security Techniques and Tactics*, 1st ed., Elsevier, 2011.
2. T. Mather, S. Kumaraswamy, and S. Latif, *Cloud Security and Privacy*, 1st ed., O'Reilly, 2009.

References

1. J. R. Vacca, *Cloud Computing Security Foundations and Challenges*, CRC Press, 2017.

DATABASE SYSTEMS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020008	**Database Systems**	**2-1-0-0**	**2024**

Prerequisites: Nil

Course Objectives:

1. To provide students with a good understanding of fundamental principles of Database Management Systems (DBMS) with a particular focus on relational databases.
2. To help the students develop the ability to manage the data efficiently by identifying suitable structures to maintain organizations' data assets and develop systems that utilize database technologies.

Course Outcomes: After completion of this course, the students will be able to,

CO1: Summarize the basic concepts and applications of Database Management System.

CO2: Design Entity – Relationship diagram and convert into the corresponding logical schema.

CO3: Write SQL queries based on the given requirements and get practical knowledge on data modeling , data manipulation and data retrieval.

CO4: Summarize the architecture and features of distributed databases and get the knowledge on distributed databases and understanding on handling unstructured data.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	2	2	1	1	1	1
CO2	2	2	3	1	1	2
CO3	2	3	2	1	1	1
CO4	2	3	2	1	1	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Database Management Systems: Data, Information, Database, File Server Model, Client Server Model, Components of DBMS, DBMS Features, Transaction and ACID properties, Data Abstraction and data independence.
2	Data Modeling: Logical and Physical Data Models, E-R Modeling A detailed study, Record Based Models, Relational Model - overview, Relational Concepts, Tables, Keys, Constraints, Data Integrity and Constraints, Integrity Rules, Database Objects, Schema and Non-schema, Database Normalization, Codds Rules, Functional dependency.

3	Introduction to SQL: Introduction to SQL, SQL Features, SQL Operators, SQL Datatypes, SQL Parsing, Types of SQL Commands, Advanced Study of Structured Query Language, Querying Data from the database, Queries, Correlated Sub-queries, Joins, Hierarchical Queries, Bind Variables, Cursors, Views, Functions, Stored Procedures and Triggers.
4	Distributed Databases: Architectures for parallel databases, Parallel query evaluation; Parallelizing individual operations, Distributed database concepts, Data fragmentation, Replication, and allocation techniques for distributed database design; Query processing in distributed databases; Concurrency Control and Recovery in distributed databases. NoSQL- The Emergence and relevance of NoSQL, Types of NoSQL Databases, MongoDB, Cassandra, HBASE, Neo4j use and deployment, Application, Challenges NoSQL approach, Key-Value store and Document Data Models, Column-Family Store and graph database.

Text Books and References

1. R. Elmasri and S. B. Navathe, *Fundamentals of Database Systems*, Pearson, 2000.
2. A. Silberschatz et al., *Database System Concepts*, 4th ed., McGraw-Hill, 2002.
3. S. Ceri and G. Pelagatti, *Distributed Databases: Principles and Systems*, Universities Press, 2000.
4. A. Meier and M. Kaufmann, *SQL and NoSQL Databases: Models*, *Languages*, *Consistency Options and Architectures for Big Data Management*, Springer, 2019.
5. P. J. Sadalage and M. Fowler, *NoSQL Distilled: A Brief Guide to the Emerging World of Polyglot Persistence*, *Addison Wesley Professional*, *2012*.
6. S. Acharya, *Demystifying NoSQL*, India: Wiley, 2020.

INTRODUCTION TO CYBER SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010009/ M3020009	**Introduction to Cyber Security**	**3-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To introduce the fundamental aspects of cyber security.
2. To introduce the basic security problems related to data, internet, cloud, and IoT networks.
3. To introduce the basics of various security mechanisms.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundational concepts of data security, including threats, security elements, potential losses, and methods to implement adequate security measures.

CO2: Develop the ability to recognize and address online security risks, including safe web browsing, secure communication, social media safety, and email security.

CO3: Acquire the skills to safeguard mobile devices, comprehend cloud security threats, privacy issues, network connections, and effectively secure home networks.
CO4: Gain basic knowledge in cryptographic methods, data backup strategies, disaster recovery planning, and securing Internet of Things (IoT) devices for a comprehensive approach to data protection.
CO5: Gain proficiency in safeguarding digital information through an in-depth exploration of data security concepts and applications.

Program Learning Outcomes:
PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		1
CO2	3	3	3	2	2	1
CO3	2	3	3	2	2	3
CO4		2	2	1	2	
CO5		1	2		1	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Introduction to Data Security** Foundations of Data Security: Introduction to Data Security and its Importance, Data as Digital Building Blocks, Common Threats to Data and Potential Losses Essential Security Elements: Confidentiality, Authenticity, Integrity, Availability, Non-repudiation Implementing Data Security: Strategies for Security Implementation Securing Operating Systems: Importance of OS Security, Guidelines for Windows and Linux OS Security, Introduction to Kali Linux OS Understanding Malware and Antivirus: Introduction to Malicious Software (Malware), Types of Malware and Symptoms of Infection, Antivirus Software: Functionality and Selection. Data Privacy: Concepts, Evolution of Data Privacy Laws in India, Key aspects of Digital Personal Data Protection Act 2023, Challenges and Opportunities in Implementing Data Privacy in India.
2	**Internet Security and Online Safety**

	Web Browser and Online Safety: Securing Web Browsers (e.g., Chrome, Mozilla), Browser Features: Benefits and Risks, Identifying Secure Websites Communication and Social Networking: Instant Messaging: Security Concerns, Child Online Safety: Key Considerations, Security on Social Networking Platforms, Risks of Social Networking and Geotagging Safe Social Media Usage: Safety Measures for Facebook and Twitter Email Security: Email Security Threats: Attachment, Phishing, Hoaxes, Addressing Nigerian Scams and Spam, Guidelines for Securing Email Communication
3	**Mobile Security and Cloud Protection** Mobile Device Security: Mobile OS Security, Common Mobile Threats, Mobile Security Guidelines Mobile Phone and Bluetooth Security: Security Checklists for Devices and Bluetooth Cloud Security: Cloud Threats and Privacy Issues, Selecting a Cloud Service Provider Securing Network Connections: Networking Basics, Wireless Network Setup, Wireless Security Measures, Home Network Safety: Threats to Home Networks and Countermeasures, Network Safety Checklist
4	**Encryption, Data Backup, and IoT Security** Cryptography Essentials: Encryption and Decryption, Symmetric and Asymmetric Cryptography, Hashing Techniques, Digital Signature and Digital Certificates Data Backup and Recovery: Causes of Data Loss, Importance of Data Backup, Types of Backup and Online Benefits, Disaster Recovery Strategies Securing IoT Devices: IoT Security Considerations and Challenges

Text Books

1. C. J. Brooks and C. Grow, *Cybersecurity Essentials*, 2nd ed., Pearson, 2020.
2. W. Stallings, *Network Security Essentials: Applications and Standards*, 6th ed., Pearson, 2021.
3. I. Chlamtac *et al.*, *Mobile Computing and Wireless Communications: Applications, Networks, Platforms, Architectures, and Security*, 2nd ed., Pearson, 2017.
4. W. Stallings, *Cryptography and Network Security: Principles and Practice*, 7th ed., Pearson, 2020.

References

1. A. Conklin *et al.*, *Principles of Computer Security*, 5th ed., McGraw-Hill Education, 2018.
2. M. H. Au and R. Choo, *Mobile Security and Privacy: Advances, Challenges and Future Research Directions*, CRC Press, 2016.
3. M. E. Whitman and H. J. Mattord, *Principles of Information Security*, 6th ed., Cengage Learning, 2020.

COMPUTER NETWORKS AND SECURITY

Course Code	Course Name	Credit Split	Year of

		Lecture/Lab/Seminar/Project	Introduction
M3010010/ M3020010	**Computer Networks and Security**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To introduce the fundamental aspects of computer networks.
2. To enable the students to understand various cyber-attacks targeted on computer networks.
3. To enable the students to develop various security mechanisms for computer networks.
4. To enable the students to simulate various network attacks.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Summarize principles of Networks.
CO2: Describe the layered protocol model.
CO3: Discriminate between various protocols.
CO4: Appraise security threats and resolve them effectively.
CO5: Analyse the challenges in different network architectures.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Network Basics: The Network Edge, The Network Core, Access Networks, Delay, Loss and Throughput, Protocol Layers and Their Service Models, Application Layer: RPC, P2P, HTTP, FTP, DNS, DHCP, Electronic Mail, WLAN, Socket, Programming with TCP and UDP
2	Transport Layer: Services, TCP, UDP, Network Layer: Functions, design issues, Internet Protocol (IP), IPV4 and IPv6, Routers, Routing algorithms, Congestion Control Algorithms

3	Data Link Layer: Design issues, framing methods, Error Detection and Correction, PPP, Sliding Window Protocols, Multiple Access Protocols, Address Resolution, Protocol (ARP), Ethernet, Link Layer Switches, Spanning Tree Protocol, VLAN
4	Security Attacks, Security Services, Security Mechanisms, Key Management and Distribution, User Authentication Protocols, SSL, TLS, Wireless Network Sec urity, Electronic Mail Security, Vulnerability Analysis, Attacks in sensor and IoT networks, Endpoint Security, familiarization of Network simulators - NS2/NS3 or Cooja/Contiki and simulation of attacks and analyze network perfor mance.

Text Books

1. J. Kurose and K. Ross, *Computer Networking: A Top-Down Approach*, 7th ed., Pearson, 2016.
2. A. S. Tanenbaum, *Computer Networks*, 5th ed., Pearson, 2013.
3. W. Stallings, *Cryptography and Network Security Principles and Practice*, Prentice Hall, 1998.
4. V. Tsiatsis *et al*., *Internet of Things: Technologies and Applications for a New Age of Intelligence*, Elsevier Academic press, 2018.
5. Z. Mahmood, *Connected Vehicles in the Internet of Things: Concepts, Technologies and Frameworks for IoT*, Springer, 2020.
6. I. F. Akyildiz and M. Can Vuran, *Wireless Sensor Networks*, Wiley, 2010.

References

1. L. L. Peterson and B. S. Davie, *Computer Networks: A Systems Approach*, Morgan Kaufmann, 2011.
2. S. Keshav, *An Engineering Approach to Computer Networking*, Pearson Education, 2000.
3. S. S. Shinde, *Computer Network*, New Age International, 2009.
4. P. Raj and A. C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, 1st ed., Auerbach Publications, 2017.
5. A. McEwen, *Designing the Internet of Things*, Wiley, 2013.

CRYPTOGRAPHY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010011/ M3020011	**Cryptography**	**2-1-0-0**	**2023**

Prerequisites: A basic understanding of algebra, linear algebra, modular arithmetic, probability

Course Objectives:

1. Learn modern cryptographic algorithms, their implementations in contemporary computing platforms, and security analysis.
2. Analyze countermeasures to thwart implementation-level attacks on cryptographic operations in hardware and software.
3. Identify appropriate cryptographic techniques for real-world applications.

Course Outcomes: After completion of this course, the students will be able to:
CO1: Understand the foundations of modern cryptography and its limitations.
CO2: Analyze and evaluate critically various cryptographic schemes and protocols.
CO3: Apply appropriate cryptographic techniques to solve real-world problems in information security.

Program Learning Outcomes:
PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	1	2
CO2	3	3	3	2	1	2
CO3	3	3	3	2	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Basic Properties of the integers, Divisibility and primality, Congruence, Residue classes, Euler's phi function, Fermat's little theorem, Classical cryptosystems
2	Block Ciphers, DES, Triple-DES, AES, Block Cipher Modes, Stream Ciphers, RC4
3	Public-Key Cryptography, Diffie Hellman Key Exchange, RSA, Rabin, ElGamal, ECC, Lattice Cryptography
4	Hash Functions, SHA-1, SHA3, MAC, HMAC, Digital Signatures, RSA, El Gamal, DSA, ECDSA

Text Books

1. W. Stallings, *Cryptography and Network Security: Principles and Practice*, Pearson, 1998
2. N. Koblitz, *A Course in Number Theory and Cryptography*, 2nd ed., Springer, 1994
3. J.P. Aumasson, *Serious Cryptography: A Practical Introduction to Modern Encryption*, No Starch Press, 2017
4. D. R. Stinson, Cryptography*: Theory and Practice*, Chapman and Hall/CRC, 2018

References

1. R. Anderson, *Security Engineering: A Guide to Building Dependable Distributed Systems*, Wiley, 2020
2. T. R. Shemanske, *A Beginner's Guide, Modern Cryptography and Elliptic Curves*,

American Mathematical Society, 2017

CYBER ANALYTICS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010012/ M3020012	Cyber Analytics	2-1-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To Introduce various supervises, unsupervised and reinforcement learning algorithms.
2. To enable the students to apply ML techniques to analyze cyber data.
3. To enable the students to perform cyber threat detection, risk estimation, vulnerability detection, and cyber-attack detection.
4. To make the students design ML-based cyber security solutions.

Course Outcomes: After completion of this course, the students will be able to,

CO1: Demonstrate a comprehensive understanding of the concepts and importance of cybersecurity analytics in modern cyber defense.

CO2: Apply various data collection and preprocessing techniques to extract valuable insights from cybersecurity data.

CO3: Utilize data analysis techniques and machine learning algorithms for effective threat detection and categorization.

CO4: Employ artificial intelligence approaches, including deep learning, natural language processing, and generative models, for analyzing complex cybersecurity challenges.

CO5: Utilize a comprehensive data engineering and machine learning tool/platform to explore advanced techniques in cybersecurity analytics, including deep learning and GPT.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2	2	2
CO3	2	3	3	2	1	1
CO4	2	2	2	1	2	3
CO5	1	2	3	1	2	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))	
Syllabus	
Module	**Content**
1	**Cyber Threat Intelligence and Data Collection** Understanding Cyber Threat Intelligence and its Significance, Effective Data Collection for Cybersecurity Insights, Data Preprocessing Techniques for Enhanced Analysis, Exploratory Data Analysis for Identifying Threat Indicators, Leveraging Machine Learning in Cybersecurity: Concepts and Techniques Use Case: Network Intrusion Detection using Machine Learning
2	**Advanced Threat Detection and Profiling** Advanced Techniques for Threat Detection and Categorization, Clustering and Classification Methods for Effective Analysis, Feature Engineering and Selection for Improved Detection, Profiling User and Entity Behavior for Insider Threat Detection, Real-time Intrusion Detection Systems (IDS) and Intrusion Prevention Systems (IPS) Use Case: Identifying Suspicious Insider Activities using Behavioral Analysis
3	**Machine Learning and AI for Threat Analysis** Harnessing Deep Learning for Intrusion Detection, Leveraging Natural Language Processing for Threat Analysis, Synthetic Data Generation using Generative Adversarial Networks (GANs), Explainable AI Models for Transparent Cybersecurity Analysis, Utilizing Machine Learning in Security Information and Event Management (SIEM) Use Case: Detecting Zero-Day Attacks with Deep Learning Techniques
4	**Incident Response and Cyber Big Data Analytics** Effective Incident Response Strategies: Analytics-driven Incident Handling, Incorporating Analytics into Incident Response Workflow, Monitoring Key Performance Indicators (KPIs) for Cyber Defense Use Cases: ● Detecting and Responding to Advanced Threats with Analytics ● Analyzing Insider Threats and Unauthorized Data Exfiltration Cyber Big Data Analytics: Role of Cyber Big Data in Identifying Emerging Threat Patterns, Scalable Storage and Processing Solutions for Large-scale Security Data Use Case: Predictive Analysis of Cyber Threats using Big Data Techniques
Text Books 1. T. Thomas *et al*., *Machine Learning Approaches in Cybersecurity Analytics*, Springer, 2020. 2. K. Harbott, *Cybersecurity Analytics: The Evolution of Threat and Risk Management*, Wiley, 2015. 3. M. Panella, R. Setola, and E. Bertino, *Cybersecurity Analytics and Decision Support in Smart Grids*, Springer, 2021. 4. R. Chandel and P. Sharma, *Cybersecurity Analytics: A Hands-On Approach*, Apress, 2020. 5. I. Santos, C. Laorden, and X. Ugarte-Pedrero, *Data Science for Cybersecurity*, Springer, 2018.	

6. O. Savas and Y. Karaca, *Big Data Analytics for Cybersecurity*, CRC Press, 2018.

References

1. H. Xiong, S. Shekhar, and W. B. Croft, *Applied Data Analytics: Principles and Applications*, CRC Press, 2018.
2. S. Chen, J. Yan, and D. Z. Du, *Big Data Analytics for Cyber-Physical Systems: Machine Learning for the Internet of Things*, CRC Press, 2019.
3. E. D. Knapp and R. Samani, *Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure*, Syngress, 2013.

MALWARE ANALYSIS AND REVERSE ENGINEERING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010013/ M3020013	Malware Analysis and Reverse Engineering	2-1-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To provide students with a knowledge of various malware types and families.
2. To help the students apply tools and techniques to detect malware.
3. To provide the students with an understanding of the need for protecting computer systems against malware attacks.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the fundamentals of malware analysis, including various types of malware and their families across different operating systems.

CO2: Acquire proficiency in static analysis and reverse engineering techniques for detecting and analyzing obfuscated and packed malware.

CO3: Demonstrate dynamic analysis skills to investigate malware behavior and evasion techniques.

CO4: Explore advanced topics such as IoT malware analysis and using machine learning and deep learning for automated malware detection.

CO5: Develop an awareness of adversarial evasion techniques in malware detection mechanisms.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6

CO1	1	2	2			
CO2	1	3			3	
CO3	1	2	2			
CO4		3			1	
CO5	1		3	1		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Introduction to Malware and Operating Systems** Understanding Android Malware: Source Code, Security Assessment Tools; Types and Families of Android Malware, Reverse Engineering Android Applications, Windows Operating System and Malware Types, Reverse Engineering Windows Applications, Security Assessment Tools for Windows, Types of Linux and IoT Malware and Families, Linux Operating System Overview, Reverse Engineering Linux OS and IoT Firmware, Security Assessment Tools for Linux and IoT.
2	**Static Analysis and Reverse Engineering** Static Analysis of Android Malware, Detection of Obfuscated and Packed Android Malware, Dalvik Opcode Analysis, Static Analysis Tools for Android Malware, Static Analysis of Windows Malware, Reverse Engineering Windows Malware, Detection of Obfuscated and Packed Windows Malware, Static Analysis Tools for Windows Malware, Static Analysis of Linux and IoT Malware, Reverse Engineering Linux and IoT Malware, Detection of Obfuscated and Packed Linux and IoT Malware, Static Analysis Tools for Linux and IoT Malware, IoT Implant Toolkit for Malware Implantation.
3	**Dynamic Analysis and Evading Malware** Dynamic Analysis of Android Malware, Investigating Android Malware Obfuscation, Dynamic Analysis Tools for Android Malware, Android Malware Evasion and Current Trends, Dynamic Analysis of Windows Malware, Process Monitoring for Dynamic Analysis of Windows Malware, Windows Registry Monitoring, Investigating Windows Malware Obfuscation, Dynamic Analysis Tools for Windows Malware, Dynamic Analysis of Linux and IoT Malware, Examining Memory Snapshots for Linux Malware, Investigating Security of Linux Kernel Against Malware Attacks, Detecting IoT Malware Using Network Traffic Analysis.
4	**Machine Learning and Deep Learning in Malware Detection** Machine Learning for Malware Detection: Static and Dynamic Features, Deep Learning for Automated Malware Analysis, Introduction to Adversarial Malware Evasion, Adversarial Evasion in Various OS Malware Detection Mechanisms.

Text Books

1. A. Kleymenov and A. Thabet, *Mastering Malware Analysis: The Complete Malware Analyst's Guide to Combating Malicious Software, APT, Cybercrime, and IoT Attacks*, Packt Publication, 2019.
2. K. A. Monappa, *Learning Malware Analysis: Explore the Concepts, Tools, and*

Techniques to Analyze and Investigate Windows Malware, Packt Publication, 2018.
3. A. D. Joseph *et al.*, *Adversarial Machine Learning*, Cambridge University Press, 2019.
4. T. Thomas *et al.*, *Machine Learning Approaches in Cybersecurity Analytics*, Springer, 2020.
5. K. Dunham, *Android Malware and Analysis*, 1st ed., Auerbach Publications, 2014.
6. M. Sikorski and A. Honig, *Practical Malware Analysis: The Hands-On Guide to Dissecting Malicious Software*, 1st ed., No Starch Press, 2012.

References

1. M. H. Ligh et al., *The Art of Memory Forensics: Detecting Malware and Threats in Windows, Linux, and Mac Memory*, 1st ed., Wiley, 2014.
2. C. Chio and D. Freeman, *Machine Learning and Security*, O'Reilly, 2018.

ETHICAL HACKING AND PENETRATION TESTING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010014/ M3020014	Ethical Hacking and Penetration Testing	2-1-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To help the students apply tools and techniques to explore cyber security breaches.
2. To provide students with a knowledge of the need for protecting the cyber assets from an adversary.
3. To provide students with a knowledge of employing machine learning techniques for vulnerability assessment.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the fundamental principles and legal aspects of ethical hacking and penetration testing.

CO2: Identify various information security threats, vulnerabilities, and their assessment techniques.

CO3: Apply password cracking, social engineering, and authentication mechanisms to enhance security.

CO4: Analyze and counter network-level attacks, web application vulnerabilities, and insider threats.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3		3		3	
CO2	3	2			1	
CO3	3	3		3		1
CO4			2		2	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Ethical Hacking Fundamentals and Information Security Threats** Understanding Ethical Hacking: Principles, Importance, and Legal Aspects, Basics of Cybersecurity: Threats, Attacks, and Defense Mechanisms, Information Security Laws, Standards, and Regulatory Compliance, Footprinting and Reconnaissance: Gathering Information for Assessments, Network Scanning and Enumeration: Identifying Targets and Services, Vulnerability Assessment and Analysis: Identifying Weaknesses, Developing Comprehensive Vulnerability Assessment Reports
2	**Password Cracking and Social Engineering Techniques** Password Cracking Techniques: Brute Force Attack, Dictionary or Word List Attack and Rainbow Table Attack, Password Cracking Tools and Countermeasures; Strengthening Authentication: Multi-Factor Authentication (MFA), Social Engineering Concepts and Techniques, Countermeasures to Social Engineering and Identity Theft, Insider Threats and Countermeasures Hands-on Password Cracking and Social Engineering Simulations
3	**Network and Web Application Attacks** Network Level Attacks: DoS, DDoS, Session Hijacking, and Mitigation, Hacking Web Applications: Common Vulnerabilities and Attack Surfaces, OWASP Top 10: Understanding and Mitigating Web App Threats, Countermeasures to Web App Attacks: Security Best Practices, Network Intrusion Detection and Prevention Systems (IDS/IPS), Firewalls and Network Infra Devices: Concepts and Configurations, Practical Penetration Testing: Network and Web Application Targets
4	**Wireless, Mobile, and Cloud Security Assessment** Wireless Network Security: Threats, Attacks, and Mitigation, Hacking Wireless Networks: Techniques and Countermeasures, Mobile Device Security: Vulnerabilities and Exploits, Assessing Mobile Apps: Identifying Security Flaws, Cloud Computing Security: Risks, Benefits, and Best Practices, IoT and OT Security: Attacks and Countermeasures Hands-on Wireless Hacking, Mobile Exploitation, and Cloud Assessment
	Text Books 1. M. Walker, *Certified Ethical Hacker All-in-One Exam Guide*, 4th ed., McGraw-Hill Education, 2020. 2. J. Erickson, *Hacking: The Art of Exploitation*, 2nd ed., No Starch Press,

	2021. 3. W. Stallings, *Network Security Essentials: Applications and Standards*, 7th ed., Pearson, 2021. 4. P. L. Wylie, *The Pentester Blue Print*, Wiley Publication, 2021. **References** 1. P. Kim, *The Hacker Playbook 2: Practical Guide to Penetration Testing*, Createspace Independent Publishing, 2015 2. M. T. Simpson, *Hands-On Ethical Hacking and Network Defense*, 2nd ed., Cengage Learning, 2012. 3. M. Meucci and A. Muller, *Owasp Testing Guide v. 4.0*, Open Web Application Security Project, 2014. 4. D. Kennedy *et al.*, *Metasploit: The Penetration Tester's Guide*, 4th ed., No Starch Press, 2018.

DIGITAL FORENSICS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010015/ M3020015	**Digital Forensics**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. Familiarize students with cybercrimes and cyber security.
2. Understand various techniques of cyber-attacks and defenses.
3. Perform digital forensic investigations.

Course Outcomes: After completion of this course, the students will be able to:

CO1 Understand the foundational concepts of digital forensics, including the investigation process and roles of forensic investigators.

CO2 Analyze different types of storage media and demonstrate proficiency in data acquisition and duplication.

CO3 Conduct a thorough analysis of operating systems, including memory forensics and file system examination.

CO4 Apply network forensics techniques to capture, analyze, and interpret network traffic.

CO5 Develop the skills to collaborate with legal professionals, prepare comprehensive reports, and adhere to ethical considerations in digital investigations.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the

School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2			
CO2	3	3	3	1	3	
CO3	3	3	3		3	
CO4					3	3
CO5			2	3	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Foundations of Digital Forensics** Fundamentals of Computer Forensics, Digital Evidence and Forensic Readiness, Roles and Responsibilities of a Forensic Investigator, Digital Forensics Investigation Process, Importance of Digital Forensics, Investigative Phases: Pre-investigation, Investigation, Post-investigation; Chain of Custody and Digital Evidence Handling, Steps of a Digital Forensic Investigation: Identification, Collection, Analysis, Reporting; Technology and Law: Digital Evidence in the Courtroom, Legal and Ethical Considerations in Digital Investigations, Collaboration with Law Enforcement and Legal Professionals, Report Preparation and Effective Communication.
2	**Storage Media Analysis** Characteristics of Different Disk Drive Types, Logical Structure of Disk Drives, Booting Process of Windows, Linux, and Mac Operating Systems; File Systems of Windows, Linux, and Mac Operating Systems; File System Examination Techniques, Data Acquisition and Duplication Fundamentals, Data Acquisition Formats and Methodologies.
3	**Operating System Forensics** Volatile and Non-Volatile Information, Windows Memory forensic, Registry Analysis, Analysis of Cache, Cookie, and History Recorded in Web Browsers Windows Files and Metadata analysis. Hibernation File Analysis, Crash Dump Analysis, File System Analysis. Linux and Mac Forensics: Volatile and Non-Volatile Data in Linux, Analyze Filesystem Images Using Sleuth Kit, Memory Forensics, Mac Forensics.
4	**Network and Mobile Forensics** Fundamentals of Network Forensics, Understanding Protocols Using Wireshark, Packet Capturing with Wireshark, tshark, and tcpdump, Packet Filtering and Data Extraction from PCAP Files, Analysis of Network Logs: Apache, IIS, and System Logs, Event Correlation: Concepts and Types, Identifying Indicators of Compromise (IoCs) from Network Logs, Investigating Network Traffic and Identifying Network-Based Attacks, Intrusion Detection and Identification of Network-Based Attacks.

	Mobile Forensics: Data Extraction Techniques, Analysis of Mobile Data - Call Logs, Messages, emails, Images, Videos, and App Data; Mobile App and Social Media Forensic.

Text Books

1. B. Nelson *et al*., *Guide to Computer Forensics and Investigations*, 6th ed., 2020.
2. J. Sammons, *The Basics of Digital Forensics: The Primer for Getting Started in Digita l Forensics*, Elsevier, 2014.
3. A. M. Marshall, *Digital Forensics: Digital Evidence in Criminal Investigation*, John – Wiley and Sons, 2008.
4. N. Reddy, *Practical Cyber Forensics: An Incident-Based Approach to Forensic Investigations*, 1st ed. New York: Apress, 2019.
5. L. E. Daniel and P. R. Johnson, *Digital Forensics for Legal Professionals: Understanding Digital Evidence from the Warrant to the Courtroom*, Syngress, 2012.

References

1. T. J. Holt *et al*., *Cybercrime and Digital Forensics: An Introduction*, 2nd ed., Routledge, 2017.
2. S. Widup and J. Sammons, *Computer Forensics and Digital Investigation with EnCase Forensic*, Syngress, 2014.
3. M. H. Ligh *et al*., *The Art of Memory Forensics: Detecting Malware and Threats in Windows, Linux, and Mac Memory*, Wiley, 2014.
4. EC-Council, *Computer Forensics: Investigating Network Intrusions and Cyber Crime*, EC Council Press Series: Computer Forensics, 2016.

DATABASE SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010016/ M3020016	**Database Security**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To teach different types of databases.
2. To teach the security aspects of databases
3. To perform data auditing.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Discriminate between different Types of Databases.

CO2: Develop and design Entity Relationship Models.

CO3: Summarize concepts related to applications of SQL.

CO4: Identify differential attributes of Structured Data, Unstructured Data and Semi-Structured Data.

CO5: Apply principles of Database Security for efficient Data auditing.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		
C04					2	1
C05					2	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Different Types of Databases, Entity Relationship Models, Relational Models, Relational Algebra, Calculus, ACID Properties, Relational Databases, Concurrency Control, Process of Database Design, Dependencies and Normalization for Relational Databases, Object-oriented/Object-Relational Models, Threats to the Database, Principles of Database Security, Levels of Database Security, Database Security Issues.
2	Introduction to SQL, SQL Features, SQL Operators, SQL Datatypes, SQL Parsing, Types of SQL Commands, Advanced Study of Structured Query Language, Querying Data from the database, Correlated Sub-queries, Joins, Hierarchical Queries, Bind Variables, Cursors, Functions, Stored Procedures, MySQL, Basics of New SQL Databases, SQL Injection and Mitigation.
3	Structured Data, Unstructured Data, Semi-Structured Data, Limitations of Traditional RDBMSs, SQL and Structured Data, SQL and Semi-Structured Data, SQL and Unstructured Data, The Emergence of NoSQL, NoSQL Database features, Types of NoSQL Databases, Search Engine Databases, Basics of MongoDB and Neo4j, Data Auditing, Statistical Database Security, Semantic Integrity Control, Privilege Analysis, Virtual Private Database (VPD), Data Redaction, Sensitive Data Protection.
4	Authentication and Authorization in DBMS, Properties and Basic Principles of Access Control Mechanisms, Views for Access Control, Classical Database Access Control: Discretionary Access Control, Role-Based Access Control and Mandatory Access Control; Access Control in Open Environments such as Attribute Based Encryption and Identity Based Encryption, Access Control in SQL, Network Data Encryption, Strong Authentication, Private Data Aggregation, Search in Encrypted Data : Searchable Encryption Overview, Selected Schemes on Searchable Encryption.

Text Books

1. A. Silberschatz *et al*., *Database System Concepts*, 6th ed., McGraw-Hill, 2011.
2. A. Meier and M. Kaufmann, *SQL and NoSQL Databases: Models*, *Languages*, *Consistency Options and Architectures for Big Data Management*, Springer, 2019.
3. G. Harrison, *Next Generation Databases: NoSQL*, *NewSQL*, *and Big Data*, Apress, 2015.
4. R. Elmasri and S. B. Navathe, *Fundamentals of Database Systems*, 6th ed., Pearson Education, 2011.
5. R. B. Vatan, *Implementing Database Security and Auditing*, Digital Press, 1st ed., 2005.

References

1. C. J. Date *et al*., *An Introduction to Database Systems*, 8th ed., Pearson Education, 2006.
2. R. Elmasri and S. Navathe, *Fundamentals of Database Systems*, Pearson, 2000.
3. G. K. Gupta, *Database Management Systems*, McGraw-Hill, 2011.
4. J. Hellerstein and M. Stonebraker, *Readings in Database Systems (The Red Book)*, 4th ed., MIT Press, 2005.
5. J. L. Harrington, *Object Oriented Database Design Clearly Explained*, Harcourt, 2000.
6. R. Ramakrishnan, *Database Management Systems*, 4th ed., McGraw-Hill, 2015.
7. R. Ramakrishan and J. Gehrke, *Database Management Systems*, 3rd ed. McGraw-Hill, 2002.
8. S. Ceri and G. Pelagatti, *Distributed Databases: Principles and Systems*, Universities Press, 2000.
9. V. Atluri and P. Samarati, *Security of Data and Transaction Processing*, Springer, 2000.

HARDWARE SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010018/ M3020018	Hardware Security	2-1-0-0	2023

Prerequisites: Prior knowledge of computer networks, cryptography, sensor networks and basics of computer hardware.

Course Objectives:

1. Provide knowledge of state-of-the-art security methods and devices.
2. Familiarize the range of hardware-level attack techniques and countermeasures.
3. Make students aware of potential hardware vulnerabilities and provide them with the knowledge and skills to build trustworthy hardware.

Course Outcomes: After completion of this course, the students will be able to:

C01: Describe the vulnerabilities in the current digital system design flow and the physical attacks on these systems.

C02: Demonstrate proficiencies in understanding hardware security issues.

C03: Apply the tools and skills to build secure and trusted hardware.

C04: Discuss the recent trends in hardware security and apply their knowledge in research and development.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written).
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	2	1		2		
CO2	2	1	1	1		
CO3	2	2	1	2	1	
C04		2	2	2	3	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Hardware Security threats, Vulnerabilities, and Attacks. Challenges in Securing Hardware, Threats to Hardware. Hardware Security Vulnerability Assessment. Hardware-Assisted Computer Security: ARM Trust Zone, Intel SGX. Hardware Root of Trust, Trusted Platform Module (TPMs), TPM Cryptographic Hardware, Hardware Accelerators, Cryptographic Coprocessors. Implementing Security in Reprogrammable Hardware. FPGA Basics, Applications and Uses, FPGA Based Security Solutions.
2	Modern IC Design and Manufacturing Practices and Their Implications: Hardware Intellectual Property (IP) Piracy and IC Piracy, Design Techniques to Prevent IP and IC Piracy, Physically Unclonable Functions (PUFs), PUF Implementations and using PUFs to prevent Hardware Piracy, Model Building Attacks on PUFs (Case Study: SVM Modeling of Arbiter PUFs, Genetic Programming based Modeling of Ring Oscillator PUF). JTAG Protection.
3	Side-channel Attacks (SCA) on Cryptographic Hardware: Current-measurement based Side-channel Attacks, power, electromagnetic SCA. Design Techniques to Prevent Side-channel Attacks, Improved Side-channel Attack Algorithms and Cache Attacks. Fault-tolerance of Cryptographic Hardware, Fault Attacks. Hardware Trojan based SCA.
4	Hardware Trojans: Hardware Trojan Nomenclature and Operating Modes, Countermeasures-Design and Manufacturing Techniques to Prevent/Detect Hardware Trojans, Logic Testing and Side-channel Analysis based Techniques for Trojan Detection. Case study: Hardware security issues and solutions in vehicles, hardware security of fog end-devices for the internet of things.

Text Books

1. D. Mukhopadhyay and R. S. Chakraborty, *Hardware Security: Design, Threats, and Safeguards*, Chapman and Hall/CRC, 2014.
2. Y. Jin, *Introduction to Hardware Security*, Electronics, *MDPI*, 2015.
3. S. Sidhu *et al.*, *Hardware Security in IoT Devices with Emphasis on Hardware Trojans*,

Journal of Sensor and Actuator Networks, 2019.
4. I. Butun *et al*., *Hardware Security of Fog End-Devices for the Internet of Things*, Sensors, 2020.
5. P. Prinetto and G. Roascio, *Hardware Security, Vulnerabilities, and Attacks: A Comprehensive Taxonomy*, ITASEC, 2020.

IOT NETWORKS AND ENDPOINT SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010019	IoT Networks and Endpoint Security	2-1-0-0	2023

Prerequisites: Prior knowledge of distributed systems, computer networks, cryptography, sensor networks and basics of connected systems.

Course Objectives:

1. To impart a comprehensive and in-depth understanding of network security, IoT Networks, endpoint security, and various security mechanisms.
2. To expose the students to frontier areas of IoT security while providing sufficient foundations for further study and research.

Course Outcomes: After completion of this course, the students will be able to:

C01: Understand network security threats, security services, and countermeasures.

C02: Understand vulnerability analysis and risk mitigation strategies and prepare a sample Vulnerability Assessment Report.

C03: Expose students to current literature in IoT networks and endpoint security and understand various security challenges and issues.

C04: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in the related areas.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	1	3		
CO2	3	2	2	2	2	
CO3	2	2	2	2	2	
C04	2	2	2	3	3	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content

1	Overview of TCP/IP, TCP/IP networks, Network Vulnerabilities, Zero-day vulnerabilities, Malwares, Threat and Risk Assessment, Network Vulnerability Assessment, Vulnerability Naming Schemes, Information Infrastructure Defense, Reverse Engineering and Code Obfuscation. Network Access Control. Firewalls. DMZ Network. Router Security. Enterprise Wireless Network Security Protocols. Security in 5G and 6G. Endpoint Devices, Security of Endpoint Devices, Endpoint Device Security Challenges. Case Studies: Cyber Attacks on Critical Infrastructure.
2	IoT Architecture, Resource Management, Interoperability in IoT, IoT Communication Protocols, Network and Transport Layer Challenges, IoT Threats and Security Challenges, Attacks on Different Layers and Categorization of IoT Attacks, IoT Gateway Security, IoT Routing Attacks, Secure Data Aggregation Mechanisms, *Security Analytics and Threat Prediction*. IoT Endpoint Devices, Threats to IoT Endpoints, General Attacks on IoT Endpoint Devices, IoT Endpoint Security Mechanisms, Security of AIOT Devices. Endpoint Security Best Practices. Case Studies.
3	Security Frameworks for IoT networks, Intrusion Detection and Prevention, Lightweight Cryptography, Key Management and Authentication, Privacy Enhancing and Anonymization Techniques, Trust and Identity Management, Access Control, IoT Simulators to simulate IoT Networks and Attacks on IoT networks, IoT Operating Systems and Security, IoT Forensics. IoT Security Standards.
4	Case Studies: Internet of Vehicles (IoV), Unmanned Aerial Vehicle (UAV) Networks, Industrial IoT Networks. Future Research Direction/Opportunity in the IoT Networks and Endpoint Security.

Text Books

1. C. H. Gebotys, *Security in Embedded Devices*, Springer, 2010.
2. C. H. John, Wu, and J. David Irwin, *Introduction to Computer Networks and Cybersecurity*, CRC Press, 2013.
3. E. A. Lee and S. A. Seshia, *Introduction to Embedded Systems, A Cyber-Physical Systems Approach*, 2nd ed., MIT Press, 2017.
4. F. Hu, *Security and Privacy in Internet of Things (IoTs): Models, Algorithms, and Implementations*, CRC Press, 2020.
5. K. Namuduri *et al.*, *UAV Networks and Communications*, Cambridge University Press, 2017.
6. N. Gupta *et al.*, *Internet of Vehicles and its Applications in Autonomous Driving*, Springer, 2021.
7. R. Buyya and A. V. Dastjerdi, *Internet of Things: Principles and Paradigms*, Elsevier, 2016.
8. R. Buyya and S. N. Srirama, *Fog and Edge Computing: Principles and Paradigms*, Wiley, 2019.
9. W. Stallings, *Cryptography and Network Security: Principles and Practice*, Pearson education, 2013.
10. Z. Mahmood, *Connected Vehicles in the Internet of Things: Concepts, Technologies and Frameworks for the IoV*, Springer, 2020.

MOBILE APPLICATION SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010020/ M3020020	Mobile Application Security	2-1-0-0	2023

Prerequisites: Nil.

Course Objectives:

1. To impart a comprehensive and in-depth understanding of mobile application security, mobile OS security, and various security mechanisms.
2. To expose the students to frontier areas of mobile security while providing sufficient foundations for further study and research.

Course Outcomes: After completion of this course, the students will be able to:

C01: Understand the fundamental concepts of mobile application security, the importance of securing smartphone devices, and the various types of mobile applications.

C02: Grasp the architecture and components of Android OS, including activities, services, content providers, broadcast receivers, fragments, and intents.

C03: Analyze Android security models, app sandboxing, permissions, and data encryption techniques.

C04: Develop secure Android applications using best practices, including app signing, secure communication, and root protection mechanisms.

C05: Acquire hands-on skills in mobile application vulnerability identification, analysis, and mitigation techniques, including malware analysis, static and dynamic analysis, and runtime manipulation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	1	3		
CO2	3	2	2	2	2	
CO3	2	2	2	2	2	
C04	2	2	2	3	3	1
C05		1	2	3	2	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content

1	**Introduction to Mobile Application Security and Android Basics** Importance of Smartphone Security, Types and Categories of Mobile Applications, History of Android and its Evolution, Features and Architecture of Android OS, Components of Android: Activity, Service, Content Provider, Broadcast Receiver, Fragment, Intent, Resources.
2	**Android Security and Development Environment** Android Security Models: App Sandboxing, App Signing, App Permissions; Data Encryption and Secure Coding Practices, Securing Android Devices: Best Practices and Configuration, Certificate/SSL Pinning for Secure Communication, Android Software Development Kit (SDK) Tools, Android Emulator and Debugging with Android Debug Bridge (adb), Using Android Studio for Application Development.
3	**Mobile Application Vulnerabilities and Analysis** Common Mobile Vulnerabilities and Avoidance Techniques, Identifying Vulnerable Features in Android Applications, Decompiling Android Applications: Smali Files and Java Code Recovery, Risk Analysis and Classification of Android Applications, Tools for Mobile Malware Analysis, Android Malware Analysis Approaches: Static, Dynamic, Network, Hybrid Analysis; Bypassing Root Detection and Certificate/SSL Pinning, Application Patching and Runtime Manipulation using Frida and Objection, Introduction to OWASP Top 10 Mobile Security Risks.
4	**iOS and Windows Phone Security** iOS Security Model and Architecture, Introduction to Jailbreaking and its Implications, Xcode and iOS Application Development Environment, File System and Device Interaction in iOS, Decompiling iOS Applications and Reverse Engineering, Intercepting Network Traffic for Analysis, Security Model of Windows Phone OS, Comparative Analysis of Mobile Security across Platforms.

Text Books

1. M. Swamynathan and J. Mannino, *Mobile Security and Privacy: A Hands-On Guide*, O'Reilly, 2019.
2. H. Dwivedi, *Mobile Application Security*, Packt Publishing, 2019.
3. Tim Speed *et al.*, *Mobile Security: How to Secure, Privatize, and Recover Your Devices*, Apress, 2019.
4. V. K. Velu, *Mobile Application Penetration Testing*, Packt Publishing, 2020.
5. N. Elenkov, *Android Security Internals: An In-Depth Guide to Android's Security Architecture*, 1st ed., No Starch Press, 2014.
6. D. Thiel, *iOS Application Security: The Definitive Guide for Hackers and Developers*, 1st ed., O'Reilly, 2016.
7. N. Bergman *et al.*, *Hacking Exposed Mobile: Security Secrets and Solutions, 2nd ed.*, McGraw-Hill Education, 2020.

References

1. A. Hoog and K. Strzempka, *Android Forensics: Investigation, Analysis, and Mobile Security for Google Android*, 1st ed., Elsevier, 2011.
2. C. Miller *et al.*, *iOS Hacker's Handbook*, 1st ed., Wiley, 2012.
3. D. Chell *et al.*, *The Mobile Application Hacker's Handbook*, 1st ed., Wiley, 2015.

SYSTEMS SECURITY AND RISK ANALYSIS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010021/ M3020021	Systems Security and Risk Analysis	2-1-0-0	2023

Prerequisites: Prior Knowledge of operating systems, computer networks, web technology, DBMS, security fundamentals, mathematics.

Course Objectives:

1. To impart a comprehensive and in-depth understanding of systems security and risk analysis.
2. To enable the students to study an organization, model security, measure risk, and design security strategy.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Perform threat analysis of an IT organization.

CO2: Perform risk analysis of an IT organization.

CO3: Find comprehensive defense strategies for the organization.

CO4: Respond in case of security emergency scenarios.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	1	1
CO2	2	3	3	2	2	1
CO3	3	3	3	3	2	2
C04	1	1	1	3	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Discussion of fundamental Network and Systems security issues: Various Attacks on - Network Protocols, Systems, Web Infrastructure
2	Phases of YACRAF Risk Analysis: Phase 0: Scope and delimitations Phase 1: Business Analysis Phase 2: System Definition and Decomposition

3	Phase 3: Threat Analysis Phase 4: Attack and Resilience Analysis Phase 5: Risk Assessment and Recommendations
4	Main Assignment: Think like a CISO!

Text Books

1. T. UcedaVelez and M. Morana, *PASTA: Risk Centric Threat Modeling: Process for Attack Simulation and Threat Analysis*,John Wiley and Sons, 2015.
2. J. Freund and J. Jones, *Measuring and Managing Information Risk: A FAIR Approach*, Butterworth-Heinemann., 2014.
3. W. Du, *Computer Security: A Hands-on Approach*, CreateSpace Independent Publishing, 2017.

References

1. A. Hoffman, *Web Application Security*, O'Reilly, 2020.
2. P. Ackerman, *Industrial Cybersecurity: Efficiently Secure Critical Infrastructure Systems*, Packt Publishing, 2017.
3. W. Stallings, *Cryptography and Network Security: Principles and Practice*, Prentice Hall, 2017.
4. M. Ekstedt, Z. Afzal, P. Mukherjee et al., *Yet Another Cybersecurity Risk Assessment Framework*, International Journal of Information Security, Springer, 2023.

INFORMATION SECURITY MANAGEMENT SYSTEM

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010022/ M3020022	**Information Security Management Systems**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To impart an in-depth understanding of information security management systems.
2. To prepare students for managing all the aspects of security of any large organization.

Course Outcomes: After completion of this course, the students would be able to:

CO1: Manage the security of an organization.

CO2: Prepare a complete risk treatment plan.

CO3: Prepare security policies, procedures, guidelines.

CO4: Audit security and check compliance.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	3	3	1	2
CO2	3	3	3	2	2	2
CO3	1	3	3	3	3	3
CO4	2	1	1	2	1	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Information Security: Fundamentals of Information Security and Risk Management, Introduction to ISMS, Introduction to Information Security Standards
2	Information Security Management Systems: Identification of Information Security Requirements, Application of Risk Assessment Techniques, Risk Treatment and Security Control Identification, Statement of Applicability. Practical: Assessing the risk for an IT organization, Preparation of the risk treatment plan.
3	Information Security Policies: Selection of Protective Measures, Preparation of Documented Information (ISMS Manual, Information Security Policies, Information Security Procedures, Information Security Guidelines, Forms and Records) Practical: Preparation of the security policy and guidelines for an IT organization.
4	Implementation Techniques and Measuring Effectiveness: Asset Management, Information Security Incident Management, Business Continuity Management, Measuring Effectiveness of ISMS, Internal Audit and Compliance Checking. Practical: Preparation of security audit report for an IT organization.

Text Books

1. A. Calder and S. Watkins, *ISO 27001: 2013 - A Pocket Guide*, IT Governance Publishing, 2017.
2. D. Alexander and A. Finch, *Information Security Management Principles*, BCS, The Chartered Institute for IT, 2020.

3. W. Siler, *Information Security Management Systems: A Novel Framework and Software as a Tool for Compliance with Information Security Standard*, CRC Press, 2013.
4. A. Nair, G. M. R., *Mastering Information Security Compliance Management*, Packt Publication, 2023.
5. K. C. Laudon and J. P. Laudon, *Management Information System*, Pearson Education, 2022.
6. S. Nadkarni, *Fundamentals of Information Security*, BPB Publications, 2020.

References

1. H. F. Tipton and M. Krause, *Information Security Management Handbook*, Auerbach Publications, 2019.
2. P. H. Gregory, *CISM Certified Information Security Manager All-in-One Exam Guide*, McGraw-Hill Education, 2018.
3. A. Kohnke and D. Shoemaker, *The Complete Guide to Cybersecurity Risks and Controls*, Apress, 2017.
4. D. Kosutic, *ISO 27001 -Risk Management in Plain English*, Advisera, 2015.
5. *ISO*, *ISO/IEC 27001:2022 - Information Security Management System - Requirements*, *ISO*, 2013.

DATA ANALYTICS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010023/ M3020023	**Data Analytics**	**2-1-0-0**	**2023**

Prerequisites: Basic knowledge in Machine learning, statistics and Python

Course Objectives:

1. To provide students with a good understanding of the concepts of data analytics.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without data analytics.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the data analytics techniques and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of data analytics.

CO3: Design and demonstrate data analytics through team research projects and project report presentations.

Program Learning Outcomes:

PLO1 Develop strong fundamental disciplinary knowledge.

PLO2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO3 Apply for a scholarship to conduct independent and innovative research.

PLO4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO5 Practice ethical standards of professional conduct and research.
PLO6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course out comes with program learning out comes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	1	2
CO2	3	3	3	2	1	2
CO3	2	1	1	2	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Data science fundamentals, Nature of Data and its characteristics, Total information awareness, Bonferroni's Principle, Rhine's paradox, Recap of Statistical and Inferential Analysis, Data preprocessing, Data wrangling, Data exploration, Dealing with missing data – single and multiple data imputation, Entropy based techniques.
2	Sampling distributions; Point estimation - estimators, minimum variance unbiased estimation, maximum likelihood estimation, method of moments, consistency; Interval estimation; Testing of hypotheses - tests and critical regions, likelihood ratio tests; Linear regression.
3	Monte Carlo and MCMC simulations; Correcting inconsistent data – Deduplication, Entity resolution, Pairwise Matching; Fellegi-Sunter Model, Advanced processing- Regression, Correlation, Covariance analysis, Aggregation, Sampling.
4	Dimensionality Reduction; Feature extraction and feature selection; Graph data analysis, Stream processing and online analytics, Dealing with infinite length, concept drift, concept/feature evolution, Visual analytics, Current trends and research.

Text Books

1. J. Leskovec, A. Rajaraman and J. Ullman, *Mining of Massive Datasets*, Cambridge University Press, 2014.
2. S. Ozdemir, *Principles of Data Science*, 2nd ed., Packt Publishing, 2018.
3. S. Lau, J. Gonzalez, and D. Nolan, *Principles and Techniques of Data Science*, UC Berkeley.
4. J. S. Saltz and J. M. Stanton, *An Introduction to Data Science*, Sage Publications, 2017.

References

1. R. V. Hogg, J. W. McKean and A. Craig, *Introduction to Mathematical Statistics*, 6th ed., India: Pearson Education, 2006.
2. D. Cielen, A. D.B. Meysman, and M. Ali, *Introducing Data Science: Big Data, Machine Learning, and More, Using Python Tools*, Simon and Schuster, 2016.

3. G. Grolemund and H. Wickham, *R for Data Science*, O'Reilly, 2017.
4. N. Zumel and J. Mount, *Practical Data Science with R*, Simon and Schuster, 2014.

DIGITAL IMAGE AND VIDEO PROCESSING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010024/ M3020024	Digital Image and Video Processing	2-1-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To provide students with a good understanding of the concepts of image and video processing tasks.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without image and video processing.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of modern image/video signal processing theory, problems, and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of image/video signal processing algorithms and systems.

CO3: Design and demonstrate a working image/video signal processing system through a team research project, project report, and presentation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content

1	Introduction to Image Processing Systems, Image Acquisition, Sampling and Quantization, Pixel Relationships, Color Fundamentals and Modules, File Formats, Image Enhancement and Restoration, Spatial Domain Gray Level Transformations, Histogram Processing, Spatial Filtering, Smoothing and Sharpening.
2	Frequency Domain: Filtering in Frequency Domain, DFT, FFT, DCT, Smoothing and Sharpening Filters, Homomorphic Filtering. Noise Models: Spatial and Frequency Properties of Noise, Important Noise Probability Density Functions, Periodic Noise, Estimation of Noise Parameters, Constrained and Unconstrained.
3	Restoration Models, Image Deblurring Algorithms. Morphological Image Processing: Erosion and Dilation, Opening and closing, Hit or miss transformation, basic morphological algorithms, gray scale morphology. Image Segmentation and Feature Analysis, Detection of Discontinuities, Edge Operators, Edge Linking and Boundary Detection, Thresholding, Region based Segmentation: Region Growing, Region Splitting and Merging. Representation and description: boundary and regional descriptors, Image Compression: classification of lossy and lossless image compression schemes.
4	Video Formation, Perception and Representation: Video Capture and Display, Analog Video Raster, Digital Video, Fourier Analysis of Video Signals and Frequency Response of the Human Visual System. Video Sampling: Basics of the Lattice Theory, Sampling of Video Signals Over Lattices, Filtering Operations in Cameras and Display Devices. Video Sampling Rate Conversion, Different Video Modeling. Video Object Tracking and segmentation. Object recognition, pattern and pattern classes, recognition based on decision- theoretic methods, structural methods, case studies –image analysis, image coding.

Text Books

1. R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, Upper Saddle River, N.J: Prentice Hall, 2008.
2. A. K. Jain, *Fundamentals of Digital Image Processing*, USA: Prentice Hall, 1989.
3. J. W. Woods, *Multidimensional Signal, Image, and Video Processing and Coding*, 2nd ed. USA: Academic Press, 2011.
4. Y. Wang *et al.*, *Video Processing and Communications*, Signal Proc. Series, Prentice Hall, 2002.

References

1. W. K. Pratt, *Digital Image Processing: PIKS Scientific Inside*, USA: Wiley-Inter Science, 2007.
2. S. E. Umbaugh, *Digital Image Processing and Analysis: Human and Computer Vision Applications with CVIP Tools, 2nd ed. USA:* CRC Press, 2010.
3. A. M. Tekalp, *Digital Video Processing, 2nd ed.* USA: Prentice Hall Press, 2015.
4. A. C. Bovik, *Handbook of Image and Video Processing (Communications, Networking and Multimedia)*, USA: Academic Press, 2005.

DEEP LEARNING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction

M3010025/ M3020025	Deep Learning	2-1-0-0	2023

Prerequisites: M3010002/M3020002

Course Objectives:

1. To provide students with a good understanding of the concepts of the deep learning.
2. To help the students develop the ability to solve problems using the learned concepts.
3. To connect the concepts to other domains.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of modern deep learning theory, problem, and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of deep learning algorithms and systems.

CO3: Design and demonstrate a working deep learning system through a team research project and project report presentation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	1	2
CO2	3	3	3	2	1	2
CO3	2	1	1	2	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Deep Feed forward Networks, Regularization for Deep Learning
2	Optimization for Training Deep Models. Convolutional Neural Networks, Sequence Modeling - Recurrent and Recursive Nets
3	Practical Methodology, Autoencoders, Representation Learning
4	Deep Generative Models, Applications of Deep Learning

Text Books

1. J. Patterson and A. Gibson, *Deep learning: A Practitioner's Approach*, O'Reilly, 2017.
2. I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, MIT Press, 2016.
3. M. A. Nielsen, *Neural Networks and Deep Learning*, Determination Press, 2015.

References

1. L. Deng and D. Yu, *Deep Learning: Methods and Applications*, Now Publishers, 2013.
2. D. Koller and N. Friedman, *Probabilistic Graphical Models*, MIT Press, 2009.

REINFORCEMENT LEARNING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010026/ M3020026	Reinforcement Learning	2-1-0-0	2023

Prerequisites: M2010000/M2020000

Course Objectives:

1. To provide students with a good understanding of the concepts of the reinforcement learning.
2. To help the students develop the ability to solve problems using the learned concepts.
3. To connect the concepts to other domains.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of modern reinforcement learning theory, problem, and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of reinforcement learning algorithms and systems.

CO3: Design and demonstrate a working deep learning system through a team research project and project report presentation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	1	2
CO2	3	3	3	2	1	2
CO3	2	1	1	2	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium)3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Reinforcement Learning, Markov Processes Markov Reward Processes (MRPs) Markov Decision Processes (MDPs), MDP Policies, Policy Evaluation, Policy Improvement, Policy Iteration, Value operators.
2	Model-free learning - Q-learning, SARSA, Scaling up: RL with function approximation, RL with function approximation.
3	Imitation learning in large spaces, Policy search, Exploration/Exploitation, Meta-Learning, Batch Reinforcement Learning, Bandit problems and online learning.
4	Solution methods: dynamic programming, Monte Carlo learning, Temporal difference learning, Eligibility traces, Value function approximation, Models and planning.

Text Books

1. R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*, MIT Press, 1998.
2. C. Szepesvari, *Algorithms for Reinforcement Learning*, Morgan and Claypool Publishers, 2010.

References

1. K. P. Murphy, Machine *Learning: A Probabilistic Perspective*, MIT Press, 2012.
2. M. L. Puterman, *Markov Decision Processes: Discrete Stochastic Dynamic Programming*, *1st ed. USA:* John Wiley and Sons, 1994.

COMPUTER VISION

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010027/ M3020027	**Computer Vision**	**2-1-0-0**	**2023**

Prerequisites: M2010000/M2020000

Course Objectives:

1. To provide students with a good understanding of computer vision concepts.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without computer vision.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of modern computer vision theory, problems, and state-of-the-art solutions.

CO2: Analyse and evaluate critically the building and integration of computer vision algorithms and systems.

CO3: Design and demonstrate a working computer vision system through a team research project, project report, and presentation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	The Four Rs of Computer Vision, Geometry of Image Formation and Sensing, Single/Two View Geometry, Camera Calibration, Vanishing Points, Planar Scenes and Homography, Interest Point Detection, Robust Correspondence Estimation
2	Feature Extraction: Edges - Canny, LoG, DoG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT.
3	Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection
4	Motion Analysis: Background Subtraction and Modelling, Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo; Motion parameter estimation.

Text Books

1. R. Szeliski, *Computer Vision: Algorithms and Applications*, London: Springer, 2011.
2. D. A. Forsyth and J. Ponce, *Computer Vision: A Modern Approach*, Pearson Education, 2003.
3. R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, 2nd ed., Cambridge University Press, 2004.

References

1. S. J. D. Prince, *Computer Vision: Models, Learning, and Inference*, 1st ed. USA: Cambridge University Press, 2012.
2. E. R. Davies, *Computer Vision: Principles, Algorithms, Applications, Learning*, 5th ed. USA: Academic Press, 2017.

SOFT COMPUTING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010028/ M3020028	Soft Computing	2-1-0-0	2023

Prerequisites: Nil

Course Objectives:

1. To impart algorithmic skills needed for designing soft computing techniques and solutions.
2. To equip the students to identify and analyze problems solvable with soft computing techniques.
3. To impart solution design capability with soft computing techniques.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Algorithm design/analysis capability in Soft Computing.

CO2: Problem identification and analysis skills on application domains requiring soft computing techniques.

CO3: Solution design capability with soft computing techniques.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in a variety of formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and write articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	1	1	2
CO2	3	2	3	1	1	2
CO3	3	3	3	2	1	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content

1	Difference between Soft and Hard computing, Overview of different components of soft computing techniques - Fuzzy Logic, Rough Logic, ANNs, Genetic Algorithms, Swarm Intelligence
2	Introduction to Fuzzy logic, Fuzzy membership functions, Operations on Fuzzy sets, Fuzzy relations, Fuzzy propositions, Fuzzy implications, Fuzzy inferences, Defuzzification, Fuzzy logic controller.
3	Genetic algorithms basic concepts, encoding, fitness function, Parent Selection - Roulette wheel, Rank, Tournament, Mutation and Crossover operators, Convergence of GA, Applications of GA, Case studies.
4	Swarm Intelligence - agent systems, social agents, Particle Swarm Optimisation - path planning applications, Ant Colony Optimisation - solving traveling salesman problem with ACO, introduction to Artificial Immune Systems

Text Books

1. R. Rajasekaran *et al.*, *Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications*, India: Prentice Hall, 2011.
2. T. Ross, *Fuzzy Logic with Engineering Applications*, McGraw-Hill, 1997.
3. A. Slowik, *Swarm Intelligence Algorithms*, CRC press, 2020.

References

1. D. E. Goldberg, *Genetic Algorithms in Search, Optimisation, and Machine Learning*, Addison-Wesley, 1989.
2. E. Bonabeau *et al.*, *Swarm Intelligence: From Natural to Artificial Systems*, Oxford University Press, 1999.
3. L. Polkowski and P. Verlag, *Rough Sets: Mathematical Foundations*, Heidelberg, 2002.

NATURAL LANGUAGE PROCESSING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010029/ M3020029	**Natural Language Processing**	**2-1-0-0**	**2024**

Prerequisites: Prior knowledge of Python, Probability and Statistics and Machine Learning

Course Objectives:

1. To introduce the fundamental concepts of Natural Language Processing.
2. To impart the principles, concepts, and theory behind Language Modeling from an algorithmic point of view.
3. To get insights into the conceptual and application levels of Natural Language Processing.

Course Outcomes: After completion of this course, the students will be able to:

C01: Understand the fundamental concepts, historical development, linguistic essentials, and text preprocessing techniques in Natural Language Processing.

C02: Apply various text representation techniques for extracting features from text data.

C03: Explore deep learning models and Transformer-based architectures to tackle complex NLP tasks, such as sentiment analysis and language generation.

C04: Develop practical skills in building Natural Language Processing applications while considering its ethical implications.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	3	1	1	1
CO2	3	3	3	1	1	1
CO3	3	3	3	1	1	1
CO4	3	3	3	1	1	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Natural Language Processing: Definition, Scope and Applications. Essential Linguistics: Syntax, Semantics and Pragmatics, Morphology, Corpus, Token, Lexicon, Stop Words, Multilingualism, Script Diversity. Classical NLP Paradigms and Methods: Semantic Analysis, Syntactic Analysis. Constituency Grammar, Dependency Grammar, Context Free Grammar, Regular Expressions, Finite-State Automata, Morphological Parsing and analysis, Dependency Parsing, Tokenization, Stemming, Lemmatization, Stop word removal, Parts-of-Speech (POS) Tagging, Named Entity Recognition, Hidden Markov Model (HMM) - Viterbi algorithm and Conditional Random Fields(CRF), Maximum Entropy models.
2	Language Modeling: Defining language models, distributional semantics, probabilistic n-gram language models, smoothing, interpolation, entropy, perplexity. Text Representation Techniques: Word Embedding - Word2Vec, GloVe, Fastext. Document Embedding- Bag of Words (BoW), Count Vectors, TF-IDF. Topic Modeling, LDA. Word Sense Disambiguation(WSD), Information Retrieval, Sentiment Analysis, Topic Modeling- LDA.
3	NLP using Deep Learning: RNN, CNN, LSTM, Multilingual Seq2seq Deep Neural Network, Encode-decoder Model, Attention, Self Attention, Transformer Models - BERT, GPT, XLNet, GAN, Generative AI and LLM. Ethics and Bias in NLP.

4	Applications and Case Studies: Machine Translation - Rule-Based Machine Translation (RBMT), Statistical Machine Translation (SMT), Hybrid Machine Translation, Neural Machine Translation (NMT), Machine learning of cross-lingual mappings, learning representations using cross-lingual supervision, Challenges in using NLP with multilingual resources. Text summarization, Text Classification, Question Answering.

Text Books

1. Daniel Jurafsky and James H. Martin, *Speech & Language Processing*, Pearson Education India, 2000.
2. S. Vajjala et al., *Practical Natural Language Processing: A Comprehensive Guide to Building Real-World NLP Systems*, O'Reilly, 2020.
3. Palash Goyal et al., *Deep Learning for Natural Language Processing*, APress, Springer, 2018.
4. Matthew S. Liao, *Ethics of Artificial Intelligence*. Oxford University Press, 2020.

SPEECH PROCESSING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010030/ M3020030	**Speech Processing**	**2-1-0-0**	**2023**

Prerequisites: M2010000/M2020000

Course Objectives:

1. To give students a good understanding of speech processing tasks.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without speech.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of modern speech processing theory, problems, and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of speech signal processing algorithms and systems.

CO3: Design and demonstrate a working speech signal processing system through a team research project, project report, and presentation.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and write articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	The human vocal and auditory systems. Characteristics of speech signals: phonemes, prosody, IPA notation. Lossless tube model of speech production. Time and frequency domain representations of speech; window characteristics and time/frequency resolution tradeoffs. Properties of digital filters: mean log response, resonance gain and bandwidth relations, bandwidth expansion transformation, all-pass filter characteristics.
2	Autocorrelation and covariance linear prediction of speech; optimality criteria in time and frequency domains; alternate LPC parametrisation. Speech coding: PCM, ADPCM, CELP. Speech synthesis: language processing, prosody, diphone and formant synthesis; time domain pitch and speech modification.
3	Speech recognition: hidden Markov models and associated recognition and training algorithms. Language modelling. Large vocabulary recognition. Acoustic preprocessing for speech recognition.
4	Speech Processing: Spectral and non-spectral analysis techniques, Model- based coding techniques, Noise reduction and echo cancellation, Synthetic and coded speech quality assessment. Selection of recognition unit, Model-based recognition, Language modeling, Speaker Identification, Text analysis and text-to-speech synthesis.

Text Books

1. L. Rabiner and R. Schafer, *Theory and Applications of Digital Speech Processing*, 1st ed. USA: Prentice Hall Press, 2010.
2. B. Gold et al., *Speech and Audio Signal Processing: Processing and Perception of Speech and Music*, 2nd ed. USA: Wiley-Inderscience, 2011.

References

1. D. O'Shaughnessy, *Speech Communication: Human and Machine*, Addison-Wesley, 1987.
2. T. Ogunfunmi *et al.*, *Speech and Audio Processing for Coding, Enhancement and Recognition*, Springer, 2014.
3. J. Benesty *et al.*, *Springer Handbook of Speech Processing*, Berlin: Springer, 2008.

COGNITIVE COMPUTING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010031/M3020031	**Cognitive Computing**	**2-1-0-0**	**2023**

Prerequisites: 10th class biology and chemistry, basic background in simple differential equations and probability theory, interest in neuroscience and cognitive science.

Course Objectives:

1. To provide students with a basic understanding of the concepts of neuroscience, cognitive science, and cognitive computing.
2. To help them understand how to connect the concepts of cognitive science and neuroscience to the computing domain.
3. To inform students of current research trends in cognitive computing and artificial emotional intelligence.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the various cognitive and emotional processes in the brain/mind and how this knowledge can be applied in the computing domain.

CO2: Analyze and evaluate critically the building of cognitive and affective computing models and systems.

CO3: Think about research ideas in cognitive science and computing and pursue them.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	1		1		1
CO2	3	2	1	1	1	1
CO3	2	2	2		1	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Basic neuroscience: Neurons, Dendrites and Axons, Synapses, Synaptic and Action Potentials, Action Potential generation and propagation, Brain organization, anatomy and functions, Synaptic integration and plasticity, the Concept of a Basic Circuit, Abstractions of Cortical Basic Circuits, Neocortical Brain Organization. Neuron models - McCulloch-Pitts, Integrate-and-Fire, Hodgkin-Huxley.
2	Cognitive psychology of decision making, neural basis, Scientific theories and measures of Consciousness, Cognitive models of memory, Mental Imagery, Understanding a problem, a cybernetic view of cognition consciousness and free will. Hierarchical temporal memories, Brain Simulations, Eye Tracking and

	other modalities for data acquisition. Scope of Realization of Cognition in Artificial Intelligence.
3	Brain Computer Interface: Types – Synchronous and Asynchronous, Invasive-Partially Invasive - Non-Invasive BCI, Structure of BCI System, BCI Monitoring Hardware-EEG, EEG Pre-processing Techniques, Analysis -time, spatial and frequency domains, fMRI, neuro imaging tools, Brain Response useful for Building BCIs, BCI applications. Emotions and Machines; Theories, models and neural basis of emotions, computational models for synthetic emotion simulation and dynamics, application of artificial emotional intelligence in healthcare, video surveillance.
4	Introduction to Brain networks, graph models for complex systems, graph theory and brain, connectivity at microscale. Clinical applications of brain network analysis, network visualization, case studies. Demonstration and tools for computing different connectivity measures and their visualizations.

References

1. E. Kandel *et al*., *Principles of Neural Science*, McGraw-Hill Professional, 2012.
2. E. Bruce Goldstein, *Cognitive Psychology: Connecting Mind*, *Research*, *and Everyday Experience*, 4th ed., Cengage Learning, 2014
3. Rao, R. P. N., *Brain Computer Interfacing: An Introduction*, Cambridge University Press, 2013.
4. N. Panigrahi and S. P. Mohanty, *Brain Computer Interface EEG Signal Processing*, CRC Press, 2022
5. A. Ortony, G. L. Clore, and A Collins, *The Cognitive Structure of Emotions*, Cambridge University Press, 2011
6. J. Friedenberg and G. Silverman, *Cognitive Science: An Introduction to the Study of Mind*, Sage Publications, 2021.
7. M. Gazzaniga, *Cognitive Neuroscience: The Biology of the Mind*, W. W. Norton, 2018.

BIG DATA TECHNOLOGIES

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010032/ M3020032	**Big Data Technologies**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To introduce various technologies related to big data analysis.
2. To enable the students to design big data analysis systems using machine learning.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the concept of bigdata.
CO2: Analyze and process bigdata using Apache Spark.
CO3: Perform mining in data stream.
CO4: Design bigdata analysis system using machine learning with spark.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	1	2	1
CO2	3	2	1	1	1	1
CO3	3	3	1	1	1	2
CO4	3	3	2	1	2	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Big Data Technology, Hadoop, HDFS and MapReduce, Hadoop Environment -PIG, Hive, Messaging systems, Distributed SQL Query Engines, No SQL Database.
2	Introduction to Apache Spark, Spark Cluster ASpark Core, High level architecture, Spark Context, RDD, Lazy Operation, Caching methods, Spark SQL
3	Machine learning with spark, Spark Machine Learning libraries, Spark ML and Applications, Graph Processing with Spark
4	Mining data stream, Examples of data stream applications, Sampling in data streams, filtering streams, counting distinct elements in stream, Querying on Windows.

Text Books

1. C. Eaton and D. deroos et al., *Understanding Big Data*, McGraw-Hill, 2017.
2. S. Chellappan and S. Acharya, *Big Data and Analytics*, 2nd ed., Wiley, 2019.
3. N. Marz and J. Warren, *Big Data: Principles and Best Practices of Scalable Real-Time Data Systems*, Manning Publishers, 2015.

References

1. J. Aven, *Data Analytics with Spark Using Python*, Addison-Wesley Professional, 2018.
2. M. Guller, *Big Data Analytics with Spark*, Apress, 2015.

SOFTWARE DEFINED NETWORKING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010033	**Software Defined Networking**	**2-1-0-0**	**2023**

Prerequisites: Basic knowledge in computer networks, operating systems, distributed

systems, machine learning and Python Programming.

Course Objectives:

1. To instill a thorough understanding of SDN fundamentals, technologies, and applications by introducing and investigating cutting-edge topics, technologies, applications, and implementations.
2. To expose students to cutting-edge research in SDN and NFS while providing a sufficient foundation for further study and research.

Course Outcomes: After completion of this course, the students will be able to:

C01: Analyze the evolution of SDNs, express the various components of SDN and their uses, explain the use of SDN in the current networking scenario, and develop various applications.
C02: Describe Network Functions Virtualization and investigate emerging SDN models and security aspects of SDN and NFV.
C03: Complete paper reviews, oral presentations, and a final course project.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written).
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	1		1		
CO2	2	2	1	2		
CO3	1	2	1	2	1	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Networking Basics - Switching, Addressing, Routing, The history of SDN, SDN Architecture, Data, Control, and Management Planes, Distributed Control Planes, Centralized Control Planes, Hardware Lookup, Forwarding Rules, Dynamic Forwarding Tables, Autonomous Switches and Routers, Network Automation and Virtualization, SDN Network Updates, SDN Scalability, SDN Applications.
2	OpenFlow: Switch-Controller Interaction, Flow Table, Packet Matching, Actions and Packet Forwarding, Extensions and Limitations, Mininet: A simulation environment for SDN; White-box Switching, Open Sourcing SDN, Open Networking Foundation, OpenDaylight, ONOS, OpenStack, OpenSwitch; Programming Languages, Verification Techniques, Debugging Tools for SDN, Virtual appliances on SDN, Virtualization and SDN.
3	Emerging SDN Models: Protocol Models: NETCONF, BGP, MPLS; Controller

	Models; Application Models: Proactive, Declarative, External; SDN in Datacenters: Multitenancy, Failure Recovery; SDN in Internet eXchange Points (IXPs); SDN-Powered Mobile Edge Computing, IoT–SDN. Network Function Virtualization (NFV): Introduction to Network Functions, SDN vs. NFV, NFV Reference Architecture, OPNFV, Inline Network Functions, Service Creation and Chaining, NFV Orchestration, Network Slicing, Developing Virtual Network Functions, Deploying Virtualized Network Functions.
4	Security Threats and Vulnerabilities Introduced by NFV and SDN, Threat Detection and Mitigation through SDN and NFV;, Authentication, Authorization, and Access Control (AAA), Anomaly Detection and Prevention Mechanisms, Intrusion Detection and Prevention Systems, Security of applying SDN to Wireless and Mobile Networks, Security of applying NFV and SDN to IoT and Cloud/Edge Computing, Security of SDN API, Security Architecture for SDN, Security of SDN Data Plane, Control Plane and Application Plane, Security of Routing in SDN, Security of Network Slicing, Security as a Service for SDN, Machine and Deep Learning for SDN Security, Secure SDN with Blockchain.

Text Books

1. P. Goransson and C. Black, *Software Defined Networks: A Comprehensive Approach*, Morgan Kaufmann Publications, 2017.
2. N. Thomas and K. Gray, *SDN - Software Defined Networks*, O'Reilly, 2013.
3. K. Gray and T. D. Nadeau, *Network Function Virtualization*, *Morgan Kaufmann*, 2016.
4. S. Zhu *et al.*, *Guide to Security in SDN and NFV: Challenges*, *Opportunities*, *and Applications*, Springer, 2017.
5. D. Huang et al., *Software-Defined Networking and Security from Theory to Practice*, CRC Press, 2021.
6. J. Gooley *et al.*, *Cisco Software-Defined Wide Area Networks: Designing*, *Deploying and Securing Your Next Generation WAN with Cisco SD-WAN*, Cisco Press, 2020.

SOCIAL NETWORK ANALYTICS AND SECURITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010034	**Social Network Analytics and Security**	**2-1-0-0**	**2023**

Prerequisites: Prior knowledge of Computer Networks, Natural Language Processing, DBMS, Graph Theory and Machine Learning

Course Objectives:

1. To impart a comprehensive and in-depth understanding of social networks, research challenges, and social media analytics to M. Tech students by researching and providing insights into cutting-edge topics, technologies, applications, and implementations.
2. To expose the students to the frontier areas of social networks and provide sufficient foundations for further study and research.

Course Outcomes: After completion of this course, the students will be able to:

C01: Summarize social network concepts and security issues and apply basic principles behind network analysis algorithms to develop practical skills in network analysis.

C02: Summarize human cognition and social networks and analyse the techniques used for behaviour analysis in social networks.
C03: Apply mechanisms on how big data technologies, machine and deep learning algorithms are employed in social networks.
C04: Understand how social technologies impact society and vice versa and examine the ethical and legal implications of leveraging social media data.
C05: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in the related areas.

Program Learning Outcomes:
PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written).
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	1	1	1		
CO2	2	2	2	2	2	1
CO3	2	2	1	2		
C04	1	2	2	2	2	2
C05	2	2	2	2	2	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Online Social Networks- Introduction, Types of networks, Properties of nodes and networks, Social Network Analysis: Graph Structure of Social Networks, Centrality Measures- Degree, Closeness, Betweenness, Eigenvector centrality, Idea of small worlds, Networks and Groups- Identifying actors, Activating and mobilizing ties, understanding how people form communities. System Architectures of OSN- Client Server, P2P.
2	Privacy and Security in Social Networks: Security Threats- Malware attacks, Sybil attacks, Phishing in OSN, Fake Profiles, Social Engineering Attacks, Information Leakage, Dark Web and Social Media. Social Network Analysis and its applications – Influence Maximization-How Information is being created and distributed, Information diffusion among people in a network, How Online Social Networks are formed and evolve over time, Visualizing complex relationships, Identifying powerful and influential participants, Community Detection, Link Prediction. Big Data Analytics and Deep Learning for Social Network Security.
3	Data extraction from Online social media, APIs, Modeling and Visualizing Social Network graphs - Tools- Gephi, Graphviz, and NodeXL. Dataset Collection for

	Social Media Analytics – Visualizing data using Ne04j. Challenges in collecting social media data. esearch in Social Networks: Design of novel algorithms for analyzing social networks, Improving the performance of information sharing in social networks. Rumor Detection, Semantic Analysis, Online Sentiment Analysis-opinion mining, feature based sentiment analysis, Trust, credibility, and reputations in social systems. Emerging Areas in OSN: Decentralized Social Networks- When Blockchain meets social networks, Mobile Social Networks, Social Internet of Things (SIoT), Internet of Behavior (IoB) and Social Networks, Cognitive and AI in Social Network Security.
4	Human Cognition and Social Networks: Human Social Networks and ego networks, Analysis of ego networks in online social networks, Applying structural knowledge to Online Social Networking services. User Behavior Analysis in Social Networks: Psychology of social media users, Personality theories and User Behavior Prediction – Five Factor Theory- TPB-MBTI, Relationships between Personality and Interactions in social networks, Cognitive Psychology and Social Network Usage.

Text Books

1. M. Cross, *Social Media Security - Leveraging Social Networking While Mitigating Risk*, 1st ed., Newnes, 2013.
2. P. Kazienko *et al.*, *Applications of Social Media and Social Network Analysis*, Springer, 2015.
3. S. Wasserman and K. Faust, *Social Network Analysis: Methods and Applications*, New York: Cambridge University Press, 1994.
4. P. Federico *et al.*, *Sentiment Analysis in Social Networks*, 1st ed., Elsevier, 2016.
5. V. Arnaboldi et al., *Online Social Networks: Human Cognitive Constraints in Facebook and Twitter Personal Graphs*, 1st ed., Elsevier, 2015
6. D. Hansen *et al.*, *Analyzing Social Media Networks with NodeXL: Insights from a Connected World*, Morgan Kaufmann, 2010.
7. R. Missaoui *et al.*, *Social Network Analysis - Community Detection and Evolution*, Springer, 2014.
8. R. Missaoui *et al.*, T*rends in Social Network Analysis - Information Propagation*, *User BehaviorModeling*, *Forecasting*, *and Vulnerability Assessment*, Springer, 2017.

WIRELESS SENSOR NETWORKS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010035	**Wireless Sensor Networks**	**2-1-0-0**	**2023**

Prerequisites: Prior knowledge of operating systems, computer networks, distributed systems, DBMS, Graph Theory.

Course Objectives:

1. To understand the fundamentals of wireless sensor networks and their application to real-world scenarios.

2. To investigate the protocols at various layers and their differences with traditional protocols.
3. To understand the issues about sensor networks and the challenges involved in managing a sensor network.
4. To introduce students to cutting-edge areas of wireless sensor networks while providing foundations for further study and research.

Course Outcomes: After completion of this course, the students will be able to:
CO1: Understand the basis of sensor networks, sensor node hardware and software, architecture and placement strategies of sensors, analyze routing and congestion algorithms.
CO2: Explore and implement solutions to real- world problems using sensor networks.
CO3: Expose students to current literature in wireless sensor networks and related areas.
CO4: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in Wireless Sensor Networks.

Program Learning Outcomes:
PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written).
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	1	1		
CO2	3	2	2	2		
CO3	2	2	2	2		
C04	2	2	2	3	2	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Introduction to Wireless Sensor Networks: Motivations, Application domains of sensor networks, Design Challenges. Operational and Computational Models, Performance metrics, Network Architecture: Traditional Layered Stack, Cross-Layer Designs, Sensor Network Architecture. Single-Node Architecture. Sensor node hardware: mica2, micaZ, telosB, cricket, Imote2, tmote, btnode; Sensor Node Software (Operating System): tiny0S, MANTIS, Contiki, and Ret0S. Introduction to Simulation tools- TOSSIM, OPNET, NS2, NS3, Description of the NS-3 core module and simulation examples and projects.
2	Middleware for WSN, Protocol Stack in WSN, Medium Access Control in WSN, MAC Protocols, Node Discovery Protocols, Network Clustering, Introduction to Markov Chain: Discrete time Markov Chain

	definition, Properties, Classification and Analysis; MAC Protocol Analysis; Programming in WSNs, Programming Tools: C, nesC. Challenges and Limitations of Programming WSNs.
3	Robust Route Setup, Routing Protocols for WSN, Coping with energy constraints, Clustering in WSNs, QoS Management, Topology Management. Network Bootstrapping: Sensor deployment mechanisms, Issues of Coverage. Localization Schemes. Fault Tolerance. Mobile WSN, Synchronization, Congestion and Flow Control; Sensor Data Storage, Retrieval, Processing. Sensor Fusion and Aggregation: Sensor Fusion Paradigms, Probabilistic, Dempster-Shafer Based, Centralized and Distributed Kalman filter, Q-digest. Compressive Sensing and Data Gathering in WSN.
4	Underwater Acoustic Sensor Networks: Issues and Challenges, Simulation Tools, Application Areas. Body Area Sensor Networks. IoT-Enabled Sensor Networks. Sensor Cloud. Sensor Networks and Edge Computing. Security, Trust and Privacy. Key Management. Real Life Deployment of WSN and Underwater Sensor Networks.

Text Books

1. A. Prayati, *Problem Solving for Wireless Sensor Networks*, London: Springer, 2008.
2. A. Kurniawan, *Practical Contiki-NG: Programming for Wireless Sensor Networks*, Apress, 2018.
3. A. Forster, *Introduction to Wireless Sensor Networks*, Wiley, 2016.
4. A. Hac, *Wireless Sensor Network Designs*, John Wiley and Sons, 2003.
5. E. H. Callaway *et al*., *Wireless Sensor Networks: Architectures and Protocols*, CRC Press, 2003.
6. H. Karl and A. Willig, *Protocols and Architectures for Wireless Sensor Networks*, Wiley-Interscience, 2007.
7. H. M. A. Fahmy, *Wireless Sensor Networks: Concepts*, *Applications*, *Experimentation and Analysis*, Springer, 2021.
8. I. M. M. El Emary and S. Ramakrishnan, *Wireless Sensor Networks: From Theory to Applications*, CRC Press, 2016.
9. J. Zheng and A. Jamalipour, *Wireless Sensor Networks: A Networking Perspective*, Wiley-IEEE Press, 2009.
10. K. Sohraby and T. Znati, *Wireless Sensor Networks: Technology*, *Protocols*, *and Applications*, John Wiley and Sons, 2007.
11. M. Conti, *Secure Wireless Sensor Networks: Threats and Solutions*, New York: Springer, 2015.
12. M. Matin, *Wireless Sensor Networks - Technology and Protocols*, InTech, 2012.
13. S. Yang, *Wireless Sensor Networks: Principles*, *Design and Applications*, London: Springer, 2013.
14. W. Dargie and C. Poellabauer, *Fundamentals of Wireless Sensor Networks: Theory and Practice*, Wiley, 2010.

CONNECTED ENVIRONMENTS AND ENABLING TECHNOLOGIES

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010036	Connected Environments and Enabling Technologies	2-1-0-0	2023

Prerequisites: Prior knowledge of Computer Networks, Distributed Computing, DBMS, Programming in Python

Course Objectives:

1. To learn the current state of the art in the IoT domain and learn details regarding several necessary principles required for future connected systems.
2. To expose the students to the different application areas of IoT along with providing sufficient foundations for further study and research.
3. To improve the critical reading, presentation, and research skills.

Course Outcomes: After completion of this course, the students will be able to:

C01: Understand the various building blocks of IoT and its characteristics and application areas.

CO2: Explore the relationship between IoT, cloud computing, and big data and apply basic principles to develop practical skills in IoT and related fields.

C03: Complete written paper reviews, an oral paper presentation, and a final course project.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written).

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills and write articles for scholarly journals.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	1		1		
CO2	2	2	1	2		1
CO3	2	2	1	2		1

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Demystifying the IoT Paradigm, IoT Network Architecture and Design, IoT Sensors and Devices, IoT Edge Gateways, IoT Access Technologies, IP as the IoT Network Layer, IoT Standards and Protocols, Machine to Machine Communications, RFID, 5G, Software-defined Networking (SDN), Network Functions Virtualization (NFV), Semantic Technologies, Discovery Services, Industrial IoT, Internet of Medical Things, Semantic Web of Things and Cognitive IoT

2	Microcontrollers, Single Board Computers (SBCs) and boards based on Arduino and Raspberry PI, Data Transmission and Service Access Protocols such as MQTT, COAP, etc., IoT Graphical user interface: Web servers, HTML, PHP, Scripting languages: - Python, Bash, IoT application development for Android and iOS phones, Embedded Linux and Applications, Cotiki OS, Cooja Simulator, IoT Database management: MySQL, MongoDB
3	IoT programming languages for Edge devices, gateways and cloud applications, System on Chip (SoC) Technologies and Tools including NVIDIA® Jetson, REST Application programming interfaces (APIs) for Device and Cloud Services, Intelligent IoT Devices and Applications through AI Processing, IoT Data Analytics Platforms, IoT Data Virtualization Platforms, IoT Data Visualization Platform, IoT Edge Data Analytics, IoT-Cloud Integration through AWS IoT for the Edge, Lambda@Edge, etc.
4	IoT-enabled Applications: Smart Home, Smart Building, Smart City, Smart Health, Smart Transportation, Environmental Monitoring, Smart Industry, Smart Grid, Smart Farming, Public Safety, Case Studies.

Text Books

1. A. McEwen and H. Cassimally, *Designing the Internet of Things*, Wiley, 2013.
2. D. Parker, *Arduino Programming*, New Begin, 2020.
3. D. Hanes *et al*., *IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things*, Cisco Press, 2017.
4. D. S. Dawoud and P. Dawoud, *Microcontroller and Smart Home Networks*, River Publishers, 2020.
5. H. Fairhead, *Raspberry Pi IoT in C*, I/O Press, 2020.
6. J.P. Vasseur and A. Dunkels, *Interconnecting Smart Objects with IP: The Next Internet*, Morgan Kuffmann, 2010.
7. M. Lin and Q. Lin, *Internet of Things Ecosystem*, 2021.
8. O. Vermesan and P. Friess, *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*, River Publishers, 2013.
9. P. Raj and A. C. Raman, *The Internet of Things Enabling Technologies, Platforms, and Use Cases*, Taylor and Francis, 2017.
10. Q. Tang and F. Du, *Internet of Things Security: Principles and Practice*, Springer, 2021.
11. R. Singh *et al*., *Internet of Things with Raspberry Pi and Arduino*, CRC Press, 2019.
12. T. Lynn *et al*., *The Cloud-to-Thing Continuum: Opportunities and Challenges in Cloud, Fog and Edge Computing*, Palgrave Macmillan, 2020.
13. A. Bahga and V. K. Madisetti, *Internet of Things: A Hands-on-Approach*, New Delhi: Orient Blackswan, 2015.
14. Z. Shelby and C. Bormann, *6LoWPAN: The Wireless Embedded Internet*, Wiley, 2009.

OPERATING SYSTEMS

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020037	**Operating Systems**	**2-1-0-0**	**2023**
Prerequisites: Nil			

Course Objectives:

1. To help students understand the necessity and fundamental concepts of an Operating System.
2. To explore all the essential building blocks in an Operating System.
3. To build practical skills for developing application programming in an Operating System.
4. Explore the different types of Operating Systems in different domains and analyse the security aspects.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Analyze various concepts and building blocks associated with Operating Systems.

CO2: Apply the concepts, building blocks, principles, and best practices to the software development.

CO3: Illustrate security aspects in the Operating System through its predefined features.

CO4: Design application programming with multi-processing concepts.

CO5: Analyze different types of Operating Systems available and develop applications.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3			2	
CO2	2	3	3		3	3
CO3		3			3	3
C04	2	3	3		3	3
C05	3	3	3		3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	**Introduction**: Basic OS functions, evaluation of OS, different types of OS, computer system operation, I/O structure, system protection, OS services,

	Processor and user modes, kernels, system calls and system programs. **Process Management:** Concept of processes, I/O and CPU bound process, process hierarchy, co-operating processes, inter-process communication. **Process scheduling:** Scheduling criteria, preemptive and non-preemptive scheduling, scheduling algorithms, multiprocessor scheduling. **Threads:** Overview, benefits of threads, user and kernel threads. **Process Synchronization:** Background, concurrent processes, critical section problem, classical problems of synchronization, semaphores.
2	**Deadlocks:** Characterization, detection, prevention, avoidance, recovery. **Memory Management:** Background, logical vs. physical address, swapping, paging, segmentation. **Virtual Memory:** Background, demand paging, page replacement algorithms, thrashing. **Disk Management:** Disk structure, disk scheduling, boot block and bad blocks. Characteristics of Embedded Systems, Embedded Linux, and Application specific OS. Basic services of NACH Operating System, Principles of protection, domain of protection, access matrix, access control, language-based protection, program threats, system and network threats, user authentication, implementing security defenses, firewalling, exercises - man-in-the middle attacks.
3	**File Systems:** File concept, access methods, file system structure, allocation methods, free-space management, directory structure, efficiency and performance. **I/O Management:** I/O hardware, polling, interrupts, DMA, application I/O interface, performance. **Protection and Security:** Goals of protection, security problem, authentication, program threats, system threats, threat monitoring, encryption.
4	**FreeRTOS:** architecture, distribution, management of heap memory, task, queue, software timer, interrupt, resource management, memory management, task notification, low power support, porting.

Text Books

1. W. Stallings, *Operating System: Internals and Design Principles*, 8th ed., Prentice Hall, 2014.
2. A. Silberschatz *et al.*, *Operating System Concepts*, 9th ed., John Wiley and Sons, 2012.
3. M. J. Bach, *The Design of the Unix Operating System*, People's Posts and Telecommunications Publishing House, 2003.
4. L. Qing and C. Yao, *Real-time Concepts for Embedded Systems*, CRC press, 2003.
5. R. Barry, *Mastering the FreeRTOS™ Real Time Kernel -A Hands-On Tutorial Guide*, Real Time Engineers, 2016.

6. W. Mauerer, *Professional Linux® Kernel Architecture*, O'Reilly, 2010.

References

1. E. Siever *et al.*, *Linux in a Nutshell*, O'Reilly Media, 2005.
2. D. P. Bovet and M. Cesati, *Understanding the Linux Kernel*, O'Reilly, 2005.
3. F. Mayer *et al.*, *SELinux by Example: Using Security Enhanced Linux*, Pearson Education, 2006.

BLOCKCHAIN TECHNOLOGY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010038/ M3020038	**Blockchain Technology**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To provide students with a deeper understanding of the concepts of blockchain technology with due focus on decentralized computing and distributed systems.
2. To help the students develop the ability to address real-world problems using the learned concepts of smart contracts and Dapps.
3. To connect the learned concepts with other business domains having opportunities for disruptive innovation with blockchain.
4. To make students aware of the existing challenges of blockchain and focus on contributing revolutionary solutions of the same.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Apply the science of blockchain technology in modelling better solutions for distributed computing.

CO2: Analyze the variants of blockchain/DLT and their adoption in respective domains.

CO3: Visualize the use of blockchain technology and its potential disruptions in multiple business domains in the coming era.

Program Learning Outcomes:

PLO 1 Develop strong fundamental knowledge about the underlying concepts of blockchain technology.

PLO 2 Demonstrate in-depth understanding of different blockchain types, architectures and distributed consensus methods.

PLO 3 Critically compare and evaluate the need of Blockchain/DLT in industry.

PLO 4 Alert the problems and challenges in deploying blockchain based Dapps and Smart Contracts with a deeper understanding of the multiple tradeoffs in the proposed product.

PLO 5 Demonstrates the disruptive potential of blockchain technology in revolutionizing the existing business models.

PLO 6 Acquire research skills to propose better algorithms/solutions for the existing challenges and contribute to the upcoming blockchain protocols.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	3	2	2	2	3
CO2	2	3	3	3	3	2
CO3	2	3	3	3	3	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Fundamentals of Blockchain technology: Centralized Vs Decentralized Computing, Concept of Distributed Ledger. Cryptographic principles - Encryption Techniques, Block Ciphers, Hash Functions (SHA), Digital Signatures, Public-Key Cryptography (RSA, ECDSA), Merkle Trees, DAG, PKI. Distributed Systems - Basic principle, design, architecture, Inter-process communication, peer-to-peer networks. Features of Blockchain. Blockchain vs Database, Blockchain vs Internet.
2	Blockchain network: Byzantine Generals Problem, Consensus Approach - PoW, PoS, pBFT. Working of Bitcoin network - Nodes, Forks, Mining, Wallets, UTXO Model. Challenges of Blockchain Technology. Blockchain Architectures: Public, Private, Hybrid. Potential Threats. - 51% attack, Sybil and Eclipse attacks.
3	Programmable Blockchains - Smart Contracts, Dapps. Introduction to Ethereum - Architecture, EVM. Token Standards - Fungible and Non-fungible (ERC). Hyperledger Umbrella Projects. Corda DLT. Why or Why Not Blockchain. Next Generation Blockchains - Cardano, Algorand, Polkadot. Application of Blockchain - Banking, Supply chain, Governance
4	Advanced Concepts - ZKPs, Sharding and sidechains, Layer-2 Protocols solving Blockchain Trilemma. Decentralized Finance (DeFi), Decentralized Autonomous Organizations (DAO). SegWit. BIP and EIP.

Lab Experiments

Experiments will be done with Ethreum and Hyperledger Fabric

Text Books

1. I. Bashir, *Mastering Blockchain: A Deep Dive into Distributed Ledgers*, *Consensus Protocols*, *Smart Contracts*, *DApps*, *Cryptocurrencies*, *Ethereum*, *and More*, 3rd ed., Packt Publishing, 2020
2. D. Tapscott and A. Tapscott, *Blockchain Revolution: How the Technology Behind Bitcoin and Other Cryptocurrencies is Changing the World*, Portfolio Penguin, 2018.
3. A. M. Antonopoulos and G. Wood, *Mastering Ethereum: Building Smart Contracts and*

DApps, O´Reilly 2018.

References

1. S. Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System*, 2009.
2. A. Lewis, *The Basics of Bitcoins and Blockchains:An Introduction to Cryptocurrencies and the Technology that Powers Them (Cryptography, Crypto Trading, Digital Assets, NFT)*, Mango Media, 2018.

AUGMENTED AND VIRTUAL REALITY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010039/ M3020039	**Augmented and Virtual Reality**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To provide students with an understanding of concepts and frameworks of immersive technologies.
2. To help students get familiarized with the hardware and software of AR/VR systems.
3. To help the students develop immersive technology applications.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Apply the concepts of immersive technologies to manage large-scale virtual environments in real-time.

CO2: Employ the AR/VR concepts to identify the research gaps.

CO3: Develop AR/VR systems for application in varied areas.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	1			3		1
CO2		3	3			1
CO3		3	3	3	3	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))	
Syllabus	
Module	**Content**
1	**Familiarization with Immersive Technologies** Human perception and cognition: Human auditory system, Human visual system, Visual perception, Visual rendering; Motion in real and virtual worlds; 3D Computer graphics: virtual world space, virtual observer positioning, 3D clipping, 3D modeling, illumination and reflection models, shading algorithms; Tracking: 2D orientation, 3D orientation, characteristics, types of trackers, SLAM; Sound in immersive environments: evolution, sound design basics, natural vs. real sound; Milgram's Reality-virtuality Continuum; Ethics, scientific concerns, social consequences, health and safety issues.
2	**Augmented Reality** History and evolution of AR; Components for visualizing AR: sensors, processor, display devices; Software components in AR: environmental acquisition, sensor integration, application engine, rendering software; Types of AR experiences: Marker based, marker-less, projection based; Augmented Reality Markup Languages (ARML): Types; Augmented reality content: Content creation, tools; User interface; Computer vision algorithms for AR: Marker tracking, infrared tracking, feature tracking, incremental tracking, localization and mapping, outdoor tracking; Interaction in real world: Manipulation, Navigation, Communication; Types of AR interaction: Browsing, 3D, tangible; Tangible AR; Collaborative AR; Mobile AR: technologies, promises and constraints; Existing challenges; Styles of augmented reality applications: magic books, magic mirrors, magic windows and doors, magic lens, navigation assistance, non-referential augmentation, objective view augmented reality ; Familiarization with Microsoft HoloLens, ARCore.
3	**Virtual Reality** Key elements of VR experience; History and evolution of VR; Virtual reality systems: tracking, Aural display, haptic display, vestibular display, visual displays-stationary, head based, hand-held; Rendering the virtual world- Aural representation, haptic representation, rendering systems- visual, aural, haptic; Interaction with virtual world: Manipulation, Navigation, Communication; Virtual reality experience: immersion, types of virtual world; Designing VR experience; Development tools and framework: software development tool frameworks, X3DStandard; VR software integration, game engines; Existing challenges; Familiarisation with OculusRift and Unity 3D.

4	**Related Technologies, Applications and Potential Research Areas** Related Technologies: Mixed Reality, XR, Comparison of immersive technologies; Areas and industries for immersive technologies: entertainment, education, training, medical, industrial, military; Case-studies: Design and evaluation, Production pipeline: sensing, rendering, mobile, stand alone and high-end computing platforms; Potential research directions: design, prototyping, innovative applications, cloud services, IoT, cyber physical systems.

Text Books

1. G.C. Burdea and P. Coiffet, *Virtual Reality Technology*, 2nd ed., Wiley-IEEE Press, 2003/2006.
2. A. B. Craig, *Understanding Augmented Reality*, *Concepts and Applications*, Morgan Kaufmann, 2013.
3. A. B. Craig and W. R. Sherman, *Understanding Virtual Reality: Interface*, *Application*, *and Design*, 2002.
4. S. M. LaValle, *Virtual Reality*, Cambridge University Press, 2017.
5. J. G. Tromp *et al.*, *Emerging Extended Reality Technologies for Industry 4.0 Early Experiences with Conception*, *Design*, *Implementation*, *Evaluation and Deployment*, Wiley 2020.
6. S. Aukstakalnis, *Practical Augmented Reality: A Guide to the Technologies*, *Applications*, *and Human Factors for AR and VR*, Pearson Education, 2016.

References

1. A. B. Craig *et al.*, *Developing Virtual Reality Applications: Foundations of Effective Design*, Morgan Kaufmann, 2009.
2. T. Jung and M. Cluaudia, *Augmented Reality and Virtual Reality*, *Empowering Human*, *Place and Business*, Springer International Publishing, 2018.
3. D. Schmalstieg and T. Höllerer, *Augmented Reality: Principles and Practice*, Boston: Addison-Wesley, 2016.
4. S. Greengard, *Virtual Reality*, MIT Press, 2019.
5. D. Vroegop, *Microsoft HoloLens Developer's Guide*, Packt Publishing, 2017.
6. M. Lanham, *Learn ARCore-Fundamentals of Google ARCore: Learn to Build Augmented Reality Apps for Android*, *Unity*, *and the Web with Google ARCore 1.0*, Packt Publishing, 2018.
7. S. Ong, *Beginning Windows Mixed Reality Programming: For HoloLens and Mixed Reality Headsets*, Springer, 2021.
8. P. Fuchs, *Virtual Reality Headsets - A Theoretical and Pragmatic Approach*, CRC Press, 2017.

OPTIMIZATION TECHNIQUES

Course Code	Course Name	Credit Split	Year of

		Lecture/Lab/Seminar/Project	Introduction
M3010040/ M3020040	**Optimization Techniques**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To provide students with a good understanding of optimization techniques.
2. To help the students develop the ability to solve problems using the learned concepts.
3. Connect the concepts to other domains, such as machine learning and pattern recognition, within and without optimization techniques.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the optimization techniques problem and state-of-the-art solutions.

CO2: Analyze and evaluate critically the building and integration of optimization techniques.

CO3: Design and demonstrate optimization techniques through team research projects, project reports, and presentations.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research;

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	2	3	2		
CO2	3	3	3	2		
CO3	2	3	3	2		

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Optimization - sequences and limits, derivative matrix, level sets and gradients, Taylor series.
2	Unconstrained optimization - necessary and sufficient conditions for optima, convex sets, convex functions, optima of convex functions, steepest descent, Newton and quasi-Newton methods, conjugate direction methods.
3	Constrained optimization - linear and non-linear constraints, equality and inequality constraints, optimality conditions.
4	Constrained convex optimization, projected gradient methods, penalty methods.

Text Books

1. E. K. P. Chong and S. H. Zak, *An Introduction to Optimisation*, 2nd ed. India: Wiley, 2010.
2. D. G. Luenberger and Y. Ye, *Linear and Nonlinear Programming*, 3rd ed., Springer, 2010.

References

1. S. Sra, S. Nowozin, and S. J. Wright, *Optimization for Machine Learning*, MIT Press, 2012.
2. R. Battiti and M. Brunato, *The LION Way: Machine Learning Plus Intelligent Optimization*, Createspace Independent Publishing, 2014.

COMPUTER ARCHITECTURE

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020041	**Computer Architecture**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To help students understand the fundamentals behind a computer and its architecture.
2. To explore the working principles of a computer's essential building blocks.
3. To understand how these building blocks are assembled to design a so-called computer.
4. To explore a few advanced topics in computer architecture.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Know how different components of a computer system are working.

CO2: Apply the knowledge of computer architecture while modelling systems for security analysis.

CO3: Compare various types of computer architectures and can analyze the design principles.

CO4: Use a computer more confidently with the acquired knowledge of its constituent components.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3		2			
CO2		3	3	2	3	3
CO3	2	3	2	1	2	1
C04	2	2	3	2	3	2

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Computer Fundamentals: Computer types, functional units, Basic concepts. Von Neumann Architecture Instruction Sets: Machine instructions, Memory operations, addressing modes, Instructions sets, Stacks, Subroutines, RISC & CISC architectures.
2	Processing Unit: Components (Registers, ALU, Datapath), Instruction execution, Control signals, Operations of control unit. Computer Arithmetic: Basic operations on signed numbers, Floating point operations.
3	Memory Management: Memory Hierarchy, Semiconductor based memory (Internal Organization, SRAM, DRAM), Read only memory, Cache memories – mapping techniques, performance, locality of reference, Cache hit / miss, Cache coherence problem Input/output: Accessing I/O devices, Bus Operations, I/O Modules, I/O Control mechanisms – Programmed I/O, Interrupt controlled, Direct Memory Access, I/O Interface (Serial, Parallel), I/O interconnection Standards.
4	Pipelining: Pipeline concept, Speedup, Throughput, Hazards in pipeline – structural hazard, data hazard, control hazard: Branch hazard; Dealing with hazards - Register Renaming, Branch Prediction. Advanced Computer Architecture: Parallel Processing - Flynn's classification, Amdahl's law, Characteristics of Multiprocessors, Interconnection Structures, Interprocessor Arbitration, Interprocessor Communication and Synchronization, Cache Coherence, Vector/Array Processing.

Text Books

1. C. Hamacher et al., *Computer Organization*, 6th ed., McGraw-Hill Higher Education, 2011.
2. D. A. Patterson and J. L. Hennessy, *Computer Organization and Design – The Hardware/Software Interface*, 6th ed., Morgan Kaufmann, 2020.
3. W. Stallings, *Computer Organization and Architecture: Designing for Performance*, 8th ed., Pearson, 2009.

4. P. P. Chaudhuri, *Computer Organization and Design*, 3rd ed., PHI Learning, 2008.
5. A. S. Tanenbaum, *Structured Computer Organization*, 6th ed., Pearson, 2012.

References

1. William Stallings, *Computer Organization and Architecture: Designing for Performance*, 7th ed., Prentice-Hall India.
2. C. Hamacher, Z. Vranesic and S. Zaky, *Computer Organization*, 5th ed., McGraw-Hill.
3. C. Hamacher, Z. Vranesic, and S. Zaky, *Computer Organization*, 6th ed., McGraw Hill.
4. M. M. Mano, *Digital Logic and Computer Design*, 4th ed., Pearson Education.

QUANTUM COMPUTING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010042/ M3020042	Quantum Computing	2-1-0-0	2023

Prerequisites: Basic linear algebra

Course Objectives:

1. To provide students with a good understanding of the concepts of quantum computing.
2. To help the students develop the ability to solve problems using the learned concepts.
3. To connect the concepts to other domains.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Understand the foundations of quantum computing and familiarize students with well-known quantum algorithms.

CO2: Analyze and critically evaluate various quantum algorithms.

CO3: Apply quantum computing to solve various problems.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO *6* Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3	1	1	1	2	
CO2	3	3	3	2	2	2
CO3	2	3	3	2	2	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	**Content**
1	Elements of quantum mechanics, Wave-particle duality, Wave functions and probability amplitude, Heisenberg's uncertainty principle, Schrodinger equation, postulates of quantum mechanics, Quantum tunneling
2	Qubits, combining qubits using the tensor product, measuring qubits, Performing operations on qubits, Bra-ket notation, Bloch sphere representation, Qubit rotations, Projective measurements, Qubit modalities.
3	Quantum gates, Quantum circuits, Quantum entanglement, No cloning theorem, Quantum teleportation, Super dense coding, Quantum parallelism, DiVincenzo's criteria for quantum computation
4	Quantum Fourier transform, Deutsch's Algorithm, Deutsch-Jozsa Algorithm, Simon's periodicity algorithm, Grover's search algorithm, Shor's Factoring algorithm.

Text Books

1. M. A. Nielsen and I. L. Chuang. *Quantum Computation and Quantum Information*, Cambridge University Press, 2000.
2. V. Kasirajan, *Fundamentals of Quantum Computing*, *Theory and Practice*, Springer, 2021.
3. M. Nakahara and T. Ohmi, *Quantum Computing*, CRC Press, 2008.
4. M. A. Nielsen and I. L. Chuang. *Quantum Computation and Quantum Information*, Cambridge University Press, 2000.

5. V. Kasirajan, *Fundamentals of Quantum Computing*, *Theory and Practice*, Springer, 2021.
6. M. Nakahara and T. Ohmi, *Quantum Computing*, CRC Press, 2008.
7. M. Mosca, *An Introduction to Quantum Computing*, New York: Oxford University Press, 2007.

References

1. M. L. Bellac, *A Short Introduction to Quantum Information and Quantum Computation*, Cambridge University Press, 2006.
2. P. Kaye et al., *An Introduction to Quantum Computing*, Oxford, 2007.
3. A. Peres, *Quantum Theory: Concepts and Methods*, New York: Springer, 1993.
4. N. D. Mermin, *Quantum Computer Science*, Cambridge University Press, 2007.

WEB TECHNOLOGY

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020043	**Web Technology**	**2-1-0-0**	**2024**

Prerequisites: Nil

Course Objectives:

1. To help students understand the web application fundamentals.
2. To explore the architecture and design principles of web-based applications.
3. To understand the most suitable application stack for a requirement and its implementation.
4. To explore a few related concepts like Microservices, common web application security issues, REST API.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Summarize transmission protocols and web server architecture.
CO2: Utilize CSS to display HTML elements in Webpage.
CO3: Develop web pages using Java Script.
CO4: Summarize various design patterns used in software development.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.
PLO 3 Apply for a scholarship to conduct independent and innovative research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants,

entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	1	1	3	3	1	3
CO2	2	1	3	2	1	2
CO3	2	1	3	3	1	2
CO4	1	1	2	3	2	3

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Design, HTML5 Elements, Attributes and elements, Type of Style sheets: Internal Style Sheet, Inline Style sheet, External Style Sheet, CSS3 Elements and features, CSS frameworks, Content delivery network, Selectors, XML Schema, Presenting XML Using XML Processors: DOM and SAX.
2	Introduction to Java Script, Object in JavaScript, Dynamic HTML with Java Script, JavaScript Object Notation, Data types, Arrays, Decisions and Loops, Functions and scope, JavaScript libraries, JavaScript Frameworks, ECMAScript, TypeScript, Single page applications (SPA), Basics of React Web Framework, Introduction to MERN framework.
3	Creational Design Patterns, Factory Pattern, Abstract Factory Pattern, Prototype pattern, Singleton Pattern, Builder Pattern, Dependency Injection pattern, The Web Services based on technologies such as SOAP, REST, WSDL, Django Framework: Architecture, MTV Architecture Pattern in Django Structure.
4	Data Access with Django and Python, CRUD Operations with DJango, Models, Templates, Controllers, Sample Django MTV Web Application, REST API with Django - Advanced, Cache and Sessions with Django, Data Visualization Techniques for small and large data, Fundamentals of web application architecture (1Tier, 2-Tier, 3-Tier, N Tier and MVC) and components, User interface app components, Structural components, Microservices, Monolithic vs. Microservices.

Text Books

1. J. C. Jackson, *Web Technologies - A Computer Science Perspective*, Pearson Education, 2009.
2. William S Vincent, *Django for Professionals: Production Websites with Python & Django* Paperback, Import - 2019.
3. J. B. Mille, *Internet Technologies and Information Services*, ABC-CLIO, 2014.

OOPS AND JAVA

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020044	OOPS and JAVA	2-1-0-0	2023

Prerequisites: Basic programming concept.

Course Objectives:

1. To introduce object-oriented concepts through Java language.
2. To use object-oriented programming in building simple software tools.

Course Outcomes: After completion of this course, the students would be able to:

CO1: Learn object-oriented programming concepts.

CO2: Use JAVA for software development.

CO3: Capture the idea of multi-threading and network programming.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3			3		
CO2	3	3		2		1
CO3	3					

(Correlation: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High))

Syllabus

Module	Content
1	Object Oriented Paradigm and JAVA overview: Object oriented Concepts: Introduction to OOPS, Abstraction, Encapsulation, Objects and Classes, Constructors Inheritance, Polymorphism, Abstract Classes, Interfaces, Introduction to Java, JVM, Primitive data types, Control Statements, Methods, Classes Introduction to Java Compilers and Lab.
2	JAVA statements: selection statements, iteration statements, jump statements,

	Introduction to classes: Class fundamentals, declaring object reference variable, Introducing methods, constructors, the key word, garbage collection, the finalize (), method. Methods and Classes Overloading methods, using objects as parameters.
3	Java Arrays, Utilities and Packages: Java Arrays, Wrapper Classes, Java IO, Inheritance, Super class, Polymorphism, java Packages, class libraries, Interfaces, Exception Handling, JAVA Strings.
4	Multithreading and JAVA Networking: The Java thread model, the main thread, creating thread, creating multiple thread, using is alive () and join (). Thread priorities, synchronization, Inter thread communications, suspending resuming and stopping thread using multithreading Networking: Networking basics, Java and the Internet Address, TCP/IP client Sockets, URL, URL connection, TCP/IP server Sockets The Applet Class.

Text Books

1. P. Naughton and H. Schildt, *The Complete Reference JAVA 2*, McGraw-Hill, 1999.
2. C. T. Wu, *Introduction to JAVA Programming*, 2nd ed., John Wiley and Sons, 2000.
3. M. T. Somashekara *et al.*, *Object Oriented Programming with JAVA*, PHI Learning, 2017.

References

1. B. Eckel and C. Allison, *Thinking in JAVA*, 2nd ed., Prentice Hall, 2000.
2. C. Horstmann, *Computing Concepts with JAVA 2 Essentials*, 2nd ed. India: Wiley, 2006.
3. H. Schildt, *Java: a Beginner Guide Essential Skills Made Easy*, 4th ed., McGraw- Hill Professional, 2007.

OBJECT ORIENTED SOFTWARE ENGINEERING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3020045	**Object Oriented Software Engineering**	**2-1-0-0**	**2023**

Prerequisites: Nil

Course Objectives:

1. To introduce the fundamental concepts of software engineering and various phases of Software development
2. To introduce various software process models and Object-Oriented Technology.
3. To build an understanding of various SE models, Object Oriented Designs, and Models.
4. To familiarize testing, Maintenance, and Deployment Models of Software Systems.

Course Outcomes: After completion of this course, the students will be able to:

CO1: Identify suitable software development life cycle models to be used for a project.
CO2: Analyze a problem, identify and define the system requirements to solve the problem, and prepare the Software Requirements Specification.
CO3: Translate the Software Requirement Specification to a design using an appropriate software design methodology and prepare a Software Design Description, including Object Oriented Modeling.
CO4: Design software systems based on appropriate technology and programming language by adhering to coding standards, ensuring code quality, and managing resources economically.
CO5: Apply appropriate testing strategy for validating the developed software system.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.
PLO 2 Demonstrate Design skills and software modeling using various process and models, that are of modeling and designing systems with theoretical, architectural, and practical in nature.
PLO 3 Apply scholarship to conduct independent and innovative design patterns and research.
PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.
PLO 5 Practice ethical standards of professional conduct and research.
PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CO1	3					
CO2	3			3		
CO3	3			3		
CO4	3					
CO5	3					

(Correlation: 1: Slight (Low) 2: Moderate (Medium)3: Substantial (High))

Syllabus

Module	Content
1	**Introduction to Software Engineering** History of Software and Software Engineering, Software Crisis and Retrospection, Software Engineering Layers, Software Process, A Generic Process Framework, Software Process Models – Waterfall Model, V-Model, Incremental Model, Spiral Model, Prototyping Model, Rational Unified Process, Iterative Models, Agile Software Development, Software Engineering Ethics.

2	**Requirement Analysis and Specification** Requirement Engineering processes: Requirement elicitation – Functional and non-functional requirements, Requirement Analysis, Object Oriented Modelling, Developing use cases and Use Case Models, Use case Analysis, Interaction Diagrams. Requirement Specification, IEEE Std 830-1998 Software Requirement Specification (SRS) Preparation, Requirement verification, Requirement Traceability Matrix, Requirement change control.
3	**Software Design** Design Principles and Concepts, Design methodologies – Structured System Analysis and Design or Function Oriented Design and Object-Oriented Analysis and Design Domain Model, Design Classes, subsystems and Packages, Software Architectural Styles and Design Patterns, Architectural Design-4+1 view Architecture, Data Model, IEEE Std 1016-2009 Software Design Description (SDD) Template. Case Study: Library Management System – Object Oriented Analysis and Design using UML.
4	**Coding, Testing and Deployment** Introduction to Coding, Selection of Technology/Programming Language, Programming Practices, Coding Standards, Code Verification - Code Review and Static Analysis, Size Measures, Complexity Analysis, Software Verification and Validation, Testing Fundamentals, Software Testing Strategies, Black Box and White Box Testing, Unit Testing, Integration Testing, System Testing, User Acceptance Testing, Testing Process and Test Documentation, Test Case Design Techniques for Black Box and White Box Testing, Software Maintenance. Deployment Diagram

Text Books

1. I. Sommerville, *Software Engineering*, 10th ed., Pearson Education, 2015.
2. R. S. Pressman, *Software Engineering: A Practitioner's Approach*, 8th ed., McGraw-Hill, 2014.
3. G. Booch *et al.*, *The United Modeling Language User Guide*, Addison-Wesley, 2005.
4. B. Bruegge and A. H. Dutoit, *Object-Oriented Software Engineering*, 2nd ed., Pearson Education, 2004.
5. A. Cockburn, *Agile Software Development*, 2nd ed., Pearson Education, 2007.

References

1. R. Mall, *Fundamentals of Software Engineering*, PHI Learning, 2014.
2. P. Jalote, *An Integrated Approach to Software Engineering*, 3rd ed., Narosa Publishing House, 2009.
3. I. Jacobson *et al.*, *The Unified Software Development Process*, Pearson Education, 1999.
4. IEEE Std 830-1998 – *IEEE Recommended Practice for Software Requirements*

Specifications.

5. IEEE Std 1016-2009 – *IEEE Standard for Information Technology – Systems Design – Software Design Descriptions*.

CLOUD AND EDGE COMPUTING

Course Code	Course Name	Credit Split Lecture/Lab/Seminar/Project	Year of Introduction
M3010046/ M3020046	Cloud and Edge Computing	2-1-0-0	2023

Prerequisites: Prior knowledge of operating systems, distributed systems, computer networks, machine and deep learning.

Course Objectives:

1. To impart a comprehensive and in-depth understanding of Cloud and Edge Computing basics, technologies and applications to students by introducing and researching cutting-edge topics, technologies, applications and implementations.
2. To expose the students to frontier areas of Cloud and Edge Computing while providing sufficient foundations for further study and research.

Course Outcomes: After completion of this course, the students would be able to:

CO1: Understand the foundations of distributed algorithms, concepts, and issues related to cloud and edge computing by completing homework, quizzes, and examinations.

CO2: Prepare students for an industrial programming environment by completing cloud and edge computing programming projects.

CO3: Expose students to current literature in cloud and edge computing.

CO4: Complete a term project, including independent research, oral presentation, and programming on the latest advancement in cloud and edge computing.

Program Learning Outcomes:

PLO 1 Develop strong fundamental disciplinary knowledge.

PLO 2 Demonstrate research skills that are of an experimental, computational, or theoretical nature.

PLO 3 Apply for a scholarship to conduct independent and innovative research.

PLO 4 Show communication skills in various formats (oral, written) and to expert and non-expert audiences.

PLO 5 Practice ethical standards of professional conduct and research.

PLO 6 Acquire professional skills such as collaborative skills, ability to write grants, entrepreneurial skills, and writing articles for scholarly journals if it is taught by faculty in the School.

Mapping of course outcomes with program learning outcomes:

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6

CO1	3	2	1	2		
CO2	3	2	2	2		
CO3	2	2	2	2		
CO4	2	2	2	3	3	1

(Correlation: 1: Slight (Low) 2: Moderate (Medium)3: Substantial (High))

Syllabus

Module	**Content**
1	Introduction to Distributed Algorithms, Cloud Computing Architecture and Management, Cloud Deployment Models, Cloud Service Models, Cloud Development Process Flows, Cloud Service Providers, Virtualization, Orchestration and Messaging, Networking in Cloud Computing, Cloud Storage, Containers, Micro services and Serverless Computing, Cloud Challenges.
2	Open-Source Tools for IaaS, PaaS and SaaS, Open-Source Tools for Research such as CloudSim, Aneka, AWS and Google Cloud, Programming Models and Languages for Cloud Computing, Software Defined Compute, Software-Defined Data Centers, Virtual Private Cloud Networking, Hybrid Cloud and Multi-Cloud Environments.
3	Edge/Fog Computing Paradigms, Edge Architecture, Edge computing Applications, Real-Time Data Analytics through Edge Clouds, Edge Computing for 5G/6G, Cognitive Edge Computing, Context-Awareness, Kubernetes Platform for Edge Environments; Cognitive Clouds, Mobile Cloud Computing, Green Cloud Computing. IoT Services on cloud, Components, IoT Core, IoT Examples (AWS IoT), IoT Data Analytics Platform on Cloud Environments, Quantum computing Paradigms and platform.
4	Case studies of Cloud and Edge Computing, Cloud Analytics, AI and ML at the Edge and in the Cloud, Fault Tolerance, Load Balancing, Security, Trust and Privacy in Cloud, Performance and QoS, Future Research Direction/Opportunity in the Cloud and Edge Computing.

Text Books

1. R. Misra and Y. S. Patel, *Cloud and Distributed Computing: Algorithms and Systems*, Wiley, 2020.
2. A. S. Tanenbaum and M. V. Steen, *Distributed Systems: Principles and Paradigms*, 2nd ed., Prentice Hall, 2007.
3. G. Tel, *Introduction to Distributed Algorithms*, 2nd ed., Cambridge University Press, 2000.
4. K. Chandrasekaran, *Essentials of Cloud Computing*, CRC Press, 2015.
5. R. Buyya *et al*., *Mastering Cloud Computing*, McGraw-Hill, 2013.
6. C. Surianarayanan and P. Chelliah, *Essentials of Cloud Computing: A Holistic*

Perspective, 1st ed., Springer, 2019.

7. R. Buyya, S. N. Srirama, *Fog and Edge Computing: Principles and Paradigms*, Wiley, 2019.
8. J. R. Vacca, *Cloud Computing Security: Foundations and Challenges*, CRC Press, 2016.
9. B. Burns *et al*., *Kubernetes: Up and Running: Dive Into the Future of Infrastructure*, O'Reilly, 2019.
10. A. A. A. Donovan and B. W. Kernighan, *The Go Programming Language*, Addison-Wesley, 2015.
11. S. Klabnik, C. Nichols, *The Rust Programming Language*, No Starch Press, 2018.
12. J. S. Chelladhurai, V. Singh, and P. Raj, *Learning Docker*, 2nd ed., Packt Publishing, 2017.
13. A. Kurniawan, *Learning AWS IoT*, Packt Publishing, 2018.
14. E. Krishnasamya *et al*., *Edge Computing: An Overview of Framework and Applications*, PRACE Technical Report, 2020.
15. C. *Bernhardt*, *Quantum Computing for Everyone*, *MIT Press*, *Cambridge*, *2020*.