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Sl. No.	Subject Code	**SEMESTER I**	**L**	**T**	**P**	**C**
1	ECS 5101	Design and Analysis of Algorithms	3	0	2	4
2	ECS 5102	Foundations of Computer Systems	3	0	2	4
3	EMC 5103	Probability and Statistics	3	0	2	4
4	EHS 5104	Technical Writing and Soft Skill/Capstone Project	1	2	2	4
5		DE-1(Elective 1)	3	0	0	3
	TOTAL		**13**	**2**	**8**	**19**

**Capstone Project (Optional) online industry case study

Sl. No.	Subject Code	**SEMESTER II**	**L**	**T**	**P**	**C**
1	ECS 5201	Artificial Intelligence	3	0	2	4
2	EMC 5202	Numerical Linear Algebra and Optimization Techniques	3	0	2	4
3		DE-2(Elective 2)	3	0	0	3
4		DE-3(Elective 3)	3	0	0	3
5		IKS	2	0	0	2
	TOTAL		**14**	**0**	**4**	**16**

Sl. No.		**SEMESTER III**	**L**	**T**	**P**	**C**
1		DE-4(Elective 4)	3	0	0	3
2		DE-5(Elective 5)	3	0	0	3
3		Project I	0	0	34	17
	TOTAL		**6**	**0**	**34**	**23**

Sl. No.		**SEMESTER IV**	**L**	**T**	**P**	**C**
1		DE-6(Elective 6)	3	0	0	3
2		DE-7(Elective 7)	3	0	0	3
3		Project II	0	0	40	20
	TOTAL		**6**	**0**	**40**	**26**

Total credits = 84

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Electives for Executive M.Tech Cloud Computing:

Sl. No.	Subject Code	Elective-I	L	T	P	C
1	ECC 6101	Application development framework	3	0	0	3
2	ECC 6102	Python for cloud computing	3	0	0	3
3	ECC 6103	Advanced Cloud Computing	3	0	0	3

Sl. No.	Subject Code	Elective-II, III	L	T	P	C
1	ECC 6201	Cloud computing Architecture	3	0	0	3
2	ECC 6202	Cloud Security	3	0	0	3
3	ECC 6203	Advanced Edge Computing	3	0	0	3
4	ECC 6204	Parallel Algorithms	3	0	0	3
5	ECC 6205	Data Virtualization and Dashboards	3	0	0	3

Sl. No.	Subject Code	Elective-IV, V	L	T	P	C
1	ECC 6301	Cloud strategy planning and Management	3	0	0	3
2	ECC 6302	Cloud Based DevOps	3	0	0	3
3	ECC 6303	Distributed Systems	3	0	0	3
4	ECC 6304	Machine learning for cloud computing	3	0	0	3

Sl. No.	Subject Code	Elective-VI, VII	L	T	P	C
1	ECC 6401	Meta Learning	3	0	0	3
2	ECC 6402	Service-oriented Architecture and Web Security	3	0	0	3
3	ECC 6403	Reinforcement Learning	3	0	0	3
4	ECC 6404	Data Warehousing	3	0	0	3

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Course number	**ECS 5101**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Design and Analysis of Algorithms**
Learning Mode	Online
Learning Objectives	The objective of this course is to equip students with a solid understanding of data structures and algorithms, enabling them to design, analyze, and implement efficient algorithms to solve complex computational problems. The course covers fundamental topics such as data structures, complexity analysis, sorting and searching techniques, problem-solving strategies, graph algorithms, and advanced topics like string matching, FFT-DFT, and approximation algorithms. By the end of the course, students will have developed the skills to critically analyze algorithm efficiency and apply advanced algorithms in practical scenarios.
Course Description	This course will provide basic understanding of methods to solve problems on computers. It will also provide an overview to analyze those theoretically.
Course Outline	Data structures: linked list, stack, queue, tree, balanced tree, graph; Complexity analysis: Big O, omega, theta notation, solving recurrence relation, master theorem Sorting and searching: Quick sort, merge sort, heap sort; Sorting in linear time; Ordered statistics; Problem solving strategies: recursion, dynamic programming, branch and bound, backtracking, greedy, divide conquer, Graph algorithms: BFS, DFS, Shortest path, MST, Network flow; NP-completeness Advanced topics: string matching, FFT-DFT, basics of approximation and randomized algorithms. Lab Component: Implementation of above topics
Learning Outcome	By the end of this course, students will be able to: Use linked lists, stacks, queues, trees, balanced trees, and graphs. Analyze algorithm complexity and solve recurrence relations. Implement Quick sort, Merge sort, Heap sort, and linear time sorting methods. Apply recursion, dynamic programming, branch and bound, backtracking, greedy, and divide-and-conquer methods. Implement BFS, DFS, shortest path algorithms, MST, and network flow algorithms. Comprehend NP-completeness and its significance.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading:

- Mark Allen Weiss, "Data Structures and Algorithms in C++", Addison Wesley, 2003.
- Adam Drozdek, "Data Structures and Algorithms in C++", Brooks and Cole, 2001.
- Aho, Hopcroft and Ullmann, "Data structures and Algorithm", Addison Welsey, 1984.
- Introduction to Algorithms Book by Charles E. Leiserson, Clifford Stein, Ronald Rivest, and Thomas H. Cormen

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Course Number	**ECS 5102**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Foundations of Computer Systems**
Learning Mode	Online
Learning Objective	The objective of the course is to provide a conceptual and theoretical understanding of computer architecture and operating systems.
Course Description	Foundations of computer systems is a review of two fundamental subjects of computer science viz., computer architecture and operating systems.
Course Outline	**Computer architecture:** Performance measures, Memory Location and Operations, Addressing Modes, Instruction Set, A Simple Machine, Instruction Mnemonics and Syntax, Machine Language Program, Assembly Language Program with examples. Processing Unit Design: Registers, Datapath, CPU instruction cycle, Instructions and Micro-operations in different bus architectures, Interrupt handling, Control Unit Design: Control signals, Hardwired Control unit design, Microprogram Control unit design. Pipelining and parallel processing, Pipeline performance measure, pipeline architecture, pipeline stall (due to instruction dependancy and data dependancy), Methods to reduce pipeline stall. RISC and CISC paradigms, I/O Transfer techniques, Memory organization: hierarchical memory systems, cache memories, virtual memory. **Operating systems:** Process states, PCB, Fork, exec system call, Threads, Process scheduling, Concurrent processes, Monitors, Process Synchronization, Producer Consumer Problem, Critical section, semaphore, Various process synchronization problems. Deadlock, Resource Allocation Graph, Deadlock prevention, Deadlock Avoidance: Banker's Algorithm and Safety Algorithm. Memory management techniques, Allocation techniques, Paging, Page Replacement Algorithms, Numericals. Lab Component: Implementation of above topics
Learning Outcome	This course will revisit two fundamental subjects of computer science viz., computer architecture and operating systems, thereby enabling the students to pursue more advanced problems in computer science based on these topics.
Assessment Method	Quiz / Assignment / ESE

Suggested readings:

1. A. Silberschatz, P. B. Galvin and G. Gagne, Operating System Concepts, 7th Ed, John Wiley and Sons, 2004.
2. M. Singhal and N. Shivratri, Advanced Concepts in Operating Systems, McGraw Hill, 1994.
3. David A Patterson and John L Hennessy, Computer Organisation and Design: The Hardware/Software Interface, Morgan Kaufmann, 1994. ISBN 1-55860-281-X.

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Course Number	**EMC 5103**
Course Credit (L-T-P-C)	L-T-P-C: 3-0-2-4
Course Title	**Probability and Statistics**
Learning Mode	Online
Learning Objective	To understand the basic concepts in Probability Theory and Statistics through practical examples.
Course Description	The course is divided into two parts: In first part, basic concepts of probability theory are introduced. In the second part, different problems in classical statistics are discussed.
Course Outline	Conditional probability, Bayes' rule, Total probability law, Independence of events. Random variables (discrete and continuous), probability mass functions, probability density functions, Expectation, variance, moments, cumulative distribution functions, Function of random variables, Multiple random variables, joint and marginal, conditioning and independence, Markov and Chebyshev inequalities, Different notions of convergence. Weak law of large number, Central limit theorem. Estimation: Properties, Unbiased Estimator, Minimum Variance Unbiased Estimator, Rao-Cramer Inequality and its attainment, Maximum Likelihood Estimator and its invariance property, Efficiency, Mean Square Error. Confidence Interval: Coverage Probability, Confidence level, Sample size determination. Testing of Hypotheses: Null and Alternative Hypotheses, Test Statistic, Error Probabilities, Power Function, Level of Significance, Neyman-Pearson Lemma.
Learning Outcome	Students will become familiar with principal concepts probability theory and statistics. This helps them to handle, mathematically, various practical problems arising in uncertain situations.
Assessment Method	Quiz / Assignment / ESE

Text Books:

1. Ross, S.M.(2008) Introduction to Probability Models, Ninth edition, Academic Press.
2. Statistical Inference (2007), G. Casella and R.L. Berger, Duxbury Advanced Series.

Reference Book:

1. An Introduction to Probability and Statistics, V.K. Rohatgi and A.K.Md. Ehsanes Saleh, John Wiley, 2nd Ed, 2009.

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Course Number	**ECS 5201**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Artificial Intelligence**
Learning Mode	Online
Learning Objectives	● To understand the foundational concepts and motivations behinrtificial Intelligence and intelligent agents. ● To learn and apply uninformed and informed search strategies for problem-solving. ● To explore local search techniques and optimization methods beyond classical search. ● To implement adversarial search techniques and problem reduction strategies. ● To formulate and solve Constraint Satisfaction Problems (CSPs) using advanced techniques.
Course Description	This course aims to provide students with a comprehensive understanding of the fundamental principles and techniques of Artificial Intelligence (AI). It covers the basics of intelligent agents and their environments, various problem-solving methods through search strategies, and techniques beyond classical search. Students will learn about adversarial search, constraint satisfaction problems, knowledge representation, reasoning, planning, and various learning techniques. The course prepares students to design and implement AI solutions for complex real-world problems.
Course Outline	● Introduction and motivation Artificial Intelligence, intelligent agents, nature of environments ● Problem-solving by searching: Example problems, uninformed, informed search strategies ● Uninformed/ blind search techniques: Breadth-first search (BFS), Depth-first search (DFS), Uniform-cost search (UCS) ● Informed search: Heuristic function design and evaluation, A* search ● Beyond classical search: local search techniques and optimization, hill climbing, simulated annealing, beam search ● Adversarial search: Games, optimal decision in games, min-max, alpha-beta pruning, partially observable games ● Problem reduction techniques: And-OR (AO) and AO* ● Constraint Satisfaction Problem (CSP): definition and examples of CSPs, basic techniques: backtracking search, forward checking, arc consistency

	● Knowledge Representation, Reasoning, and Planning: Propositional logic, first-order logic, inference, planning ● Learning Techniques: meta-heuristic (genetic algorithm), Bayesian, decision tree, etc. ● Some advanced techniques of AI and its applications ● Lab component: Implementation of above architectures.
Learning Outcome	By the end of this course, students will be able to: ● Understand the foundational concepts and motivations behind Artificial Intelligence and intelligent agents. ● Apply uninformed and informed search strategies to solve example problems. ● Utilize local search techniques and optimization methods such as hill climbing, simulated annealing, and beam search. ● Implement adversarial search techniques including min-max, alpha-beta pruning, and strategies for partially observable games. Apply problem reduction techniques. ● Formulate and solve Constraint Satisfaction Problems (CSPs) using techniques like backtracking search, forward checking, and arc consistency. ● Represent knowledge using propositional and first-order logic, and perform inference and planning. ● Explore and apply various learning techniques such as genetic algorithms, Bayesian methods, and decision trees.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading

1. Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach. Pearson.
2. Poole, D. L., & Mackworth, A. K. (2010). Artificial Intelligence: foundations of computational agents. Cambridge University Press.
3. Hastie, T., Tibshirani, R., Friedman, J. H., & Friedman, J. H. (2009). The elements of statistical learning: data mining, inference, and prediction (Vol. 2, pp. 1-758). New York: Springer.

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Course Number	**EMC 5202**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Numerical Linear Algebra and Optimization Techniques**
Learning Mode	Online
Learning Objectives	The objective of the course is to train students about the different numerical techniques to solve linear equations, linear least square problems and find eigen values of matrices as well as check the stability of numerical methods. Moreover, students would be able to perform modeling of convex programming problems and employ various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Numerical Linear Algebra and Optimization Techniques, as a basic subject for postgraduate students, provides the knowledge of various numerical techniques to solve linear equations as well as check the stability of numerical methods. Moreover, this course would help the students to models convex optimization problems and learn different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Review of matrix Algebra, Norms and condition numbers of Matrix, Systems of Equations, Gaussian Elimination, LU, PLU and Cholesky Factorization, Iterative Solvers: Jacobi, Gauss Seidel, SOR and their convergence, Gram-Schmidt orthogonalization QR Factorization and Least Squares, Eigenvalues, Power method, Reduction to Hessenberg or Tridiagonal form, Rayleigh quotient, inverse iteration, QR Algorithm without and with shifts, Singular Value Decomposition and Its applications Introduction to nonlinear programming, Convex Sets, Convex Functions and their properties. Unconstrained optimization of functions of several variables: Classical techniques. Numerical methods for unconstrained optimization: One Dimensional Search Methods, Golden Section Search and Fibonacci search, Basic descent methods, Conjugate direction, Newton's and Quasi-Newton methods Constrained optimization of functions of several variables, Lagrange Multiplier method, Karush-Kuhn-Tucker theory, Constraint Qualifications, Convex optimization Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm Practice of algorithms using Software.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand different Matrix factorization method and employ them to solve linear equations and linear least square problems 2. To comprehend the basic computer arithmetic and the concepts of conditioning and stability of a numerical method. 3. Understand the terminology and basic concepts of various kinds of convex optimization problems and solve different solution methods to solve convex Programing problem.
Assessment Method	Quiz / Assignment /ESE

Text Books:

1. Lloyd N. Trefethen, David Bau III: Numerical Linear Algebra, 1st Edition, SIAM, Philadelphia (1997)
2. Edwin K. P. Chong, Stanislaw H. Zak: An Introduction to Optimization, 4th Edition, Wiley India (2017)
3. Gilbert Strang: Lecture Notes for Linear Algebra, Wellesley Cambridge Press, SIAM (2021)

Reference Books:

1. Stephan Boyd and Lieven. Vandenberghe: Convex Optimization, Cambridge University Press (2004)

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Course Number	**ECC 6101**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Application Development Frameworks**
Learning Mode	Online
Learning Objectives	● Ability to build Java-based applications using the Spring framework and integrate them with relational databases and other enterprise systems. ● Understanding of key concepts such as aspect-oriented programming, dependency injection, and object-relational mapping. ● Familiarity with common Java development tools and techniques, including Spring MVC and RESTful web services. ● Ability to evaluate and select appropriate application development frameworks for specific use cases.
Course Description	This course teaches students to build Java-based applications using the Spring framework, integrating with relational databases and enterprise systems. It covers key concepts like aspect-oriented programming, dependency injection, and object-relational mapping, along with common Java development tools and techniques, including Spring MVC and RESTful web services.
Course Outline	**MODULE 1: Introduction to Application Development Frameworks** ● Overview of application development frameworks ● Advantages and disadvantages of using frameworks ● Introduction to the Spring framework ● Configuration and setup of Spring-based applications ● Bean life cycle and dependency injection ● Introduction to aspect-oriented programming **MODULE 2: Database Integration with Spring** ● Data access with Spring and JDBC ● Simplifying JDBC-based data access ● Using object-relational mapping (ORM) with Spring ● Introduction to Hibernate in a Spring environment ● Driving database transactions in a Spring environment **MODULE 3: Web Development with Spring** ● Introduction to web application architecture ● Overview of Spring MVC ● Restful web services with Spring MVC ● Securing web applications with Spring Security ● Rendering multiple content types with Spring

	MODULE 4: Integration with Enterprise Systems ● Introduction to enterprise information connectivity ● Serialization and remoting with Spring ● Introduction to messaging and transactions ● Working with JMS and transactional JMS ● Distributed transaction management
Learning Outcome	By the end of this course, students will be able to: ● Understand the basics of application development frameworks and their importance in building complex software applications. ● Gain hands-on experience in using Spring, one of the most widely used Java-based application development frameworks. ● Develop proficiency in integrating Spring with relational databases, web services, and other enterprise systems. ● Choose and evaluate appropriate frameworks for specific application development needs.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. Rod Johnson et al., "Professional Java Development with the Spring Framework," Wiley Pub, 2005.
2. Mark Fisher, "Spring Integration in Action," Manning Publications, 2011.
3. Craig Walls and Ryan Breidenbach, "Spring in Action," Manning Publications, 2007.
4. Paul Fisher and Solomon Duskis, "Spring Persistence with Hibernate," Apress, 2009.

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Course Number	**ECC 6102**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Python for Cloud Computing**
Learning Mode	Online
Learning Objectives	● To understand the fundamental concepts and components of Python Language. ● To understand how the loops, functions, modules and libraries are handled in Python Language. ● To understand how Object-Oriented Programming adopted in Python. ● To understand the debugging and testing (unit) techniques along with regular expressions. ● To understand how to develop web applications using Python. ● To understand how to automate tasks using Python. ● To understand how to use Python in automating tasks in Cloud Environment (AWS / GCP).
Course Description	This course covers fundamental Python concepts, including loops, functions, modules, libraries, and object-oriented programming. Students will learn debugging, unit testing, regular expressions, web development, task automation, and using Python for cloud automation in AWS and GCP.
Course Outline	**Module 1: Introduction to Python** History & need of Python, Application of Python, Installing Python, Program structure, Interactive Shell, Executable or script files, User Interface or IDE. **Module 2: Python Loops, Functions, Modules and Libraries** Conditional Statements, The Range Function, Built-In Function, Structure of Python Functions (e.g. - map, zip, reduce etc.), User Defined Functions **Module 3: Python Data Structure and OOP** Class and objects, OOPS Concept, Error handling, Python Debugger **Module 4: Cloud application development using Python** Develop a basic application using Django & Flask Framework, Deploy the developed application in the Cloud, connect to the Database, Building API in Python

Learning Outcome	● By the end of this course, students will be able to: ● Code in Python for making decisions and construct loops. ● Utilize in-built and user-defined functions in Python. ● Make use of libraries in Python. ● Design, plan and develop web application using Python modules. ● Use Python and handle cloud resources remotely.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. Gift, N. (2019). Python for DevOps: Learn Ruthlessly Effective Automation. O'Reilly Media.
2. Conway, K., & Smith, B. (2020). Cloud Native Python. O'Reilly Media.
3. Garnaat, M. (2011). Python and AWS Cookbook. O'Reilly Media.
4. Sbarski, P. (2017). Building Serverless Architectures. O'Reilly Media.
5. Murty, J. (2008). Programming Amazon Web Services: S3, EC2, SQS, FPS, and SimpleDB. O'Reilly Media.

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Course Number	**ECC 6103**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Cloud Computing**
Learning Mode	Online
Learning Objectives	This course aims to help the students understand **(a)** how and why cloud systems work and the cloud technologies that manifest these concepts, such as those from Amazon AWS and Microsoft Azure; **(b)** distributed systems concepts like virtualisation, data parallelism, CAP theorem, and performance analysis at scale; **(c)** Big Data programming patterns such as Map-Reduce (Hadoop), Vertex-centric graphs (Giraph), Continuous Dataflows (Storm), and NoSQL storage systems to build Cloud applications; **(d)** Cloud native computing and micro-services
Course Description	This course provides an in-depth understanding of cloud computing, virtualisation, and distributed systems. It covers foundational concepts, advanced techniques, and real-world applications. Students will explore various aspects of cloud infrastructure, virtualisation technologies, distributed algorithms, and cloud-native computing. By the end of the course, students will be equipped with the knowledge and skills to design, implement, and manage cloud-based solutions and distributed systems effectively.
Course Outline	Introduction to Clouds, Virtualization, and Virtual Machines. Network Virtualization and Geo-distributed Clouds. Leader Election in Cloud, Distributed Systems, and Industry Systems. Classical Distributed Algorithms and Industry Systems. Consensus, Paxos, and Recovery in Clouds. Cloud Storage: Key-value Stores/NoSQL Systems and their Use in Industry Systems. Cloud Applications: MapReduce, Spark, and Apache Kafka. Cloud Native Computing and Micro-services.

Learning Outcome	Cloud Computing as a Distributed Systems: Explain and contrast the role of Cloud computing within this space. Cloud Virtualization, Abstractions and Enabling Technologies: Explain virtualisation and their role in elastic computing. Characterise the distinctions between Infrastructure, Platform and Software as a Service (IaaS, PaaS, SaaS) abstractions, and Public and Private Clouds, and analyse their advantages and disadvantages. Programming Patterns for "Big Data" Applications on Cloud: Demonstrate using Map-Reduce, Vertex-Centric and Continuous Dataflow programming models. Application Execution Models on Clouds: Compare synchronous and asynchronous execution patterns. Design and implement Cloud applications that can scale up on a VM and out across multiple VMs. Illustrate the use of NoSQL Cloud storage for information storage. Performance, scalability and consistency on Clouds: Explain the distinctions between Consistency, Availability and Partitioning (CAP theorem), and discuss the types of Cloud applications that exhibit these features.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading

- Distributed and Cloud Computing From Parallel Processing to the Internet of Things; Kai Hwang, Jack Dongarra, Geoffrey Fox Publisher: Morgan Kaufmann, Elsevier, 2013.
- Cloud Computing: Principles and Paradigms; Rajkumar Buyya, James Broberg, and Andrzej M. Goscinski Publisher: Wiley, 2011.
- Distributed Algorithms Nancy Lynch Publisher: Morgan Kaufmann, Elsevier, 1996.
- Cloud Computing Bible Barrie Sosinsky Publisher: Wiley, 2011.
- Cloud Computing: Principles, Systems and Applications, Nikos Antonopoulos, Lee Gillam Publisher: Springer, 2012.

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Course Number	**ECC 6201**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Cloud Computing Architecture**
Learning Mode	Online
Learning Objectives	● Understand the fundamentals of cloud computing architecture and its benefits and challenges. ● Learn about the different types of cloud computing and their applications. ● Develop skills in managing and deploying cloud services. ● Gain knowledge in cloud-based application development. ● Analyze case studies and learn to evaluate if cloud computing is the right fit for specific requirements.
Course Description	This course covers the fundamentals of cloud computing architecture, its benefits, and challenges, as well as the different types and applications of cloud computing.
Course Outline	**MODULE 1 - CLOUD COMPUTING FUNDAMENTALS** ● Cloud Computing definition, private, public and hybrid cloud. ● Cloud types: IaaS, PaaS, SaaS. ● Benefits and challenges of cloud computing, public vs private clouds. ● Role of virtualization in enabling the cloud. ● Business Agility: Benefits and challenges to Cloud architecture. **MODULE 2 - CLOUD APPLICATIONS** ● Technologies and the processes required when deploying web services. ● Deploying a web service from inside and outside a cloud architecture, advantages and disadvantages. **MODULE 3 - MANAGEMENT OF CLOUD SERVICES** ● Reliability, availability and security of services deployed from the cloud. ● Performance and scalability of services. ● Tools and technologies used to manage cloud services deployment. ● Cloud Economics: Cloud Computing infrastructures available for implementing cloud-based services. ● Economics of choosing a Cloud platform for an organization, based on application requirements, economic constraints and business needs (e.g. Amazon, Microsoft and Google, Salesforce.com, Ubuntu and Redhat). **MODULE 4 - APPLICATION DEVELOPMENT** ● Service creation environments to develop cloud-based applications. ● Development environments for service development. ● AWS, Azure, Google App.

	MODULE 5 - CLOUD IT MODEL ● Analysis of Case Studies when deciding to adopt cloud computing architecture. ● How to decide if the cloud is right for your requirements. ● Cloud-based service, applications and development platform deployment so as to improve the total cost of ownership.
Learning Outcome	By the end of this course, students will be able to: ● Understand the fundamental concepts and components of cloud computing architecture. ● Develop skills in deploying and managing cloud services. ● Gain knowledge in cloud-based application development. ● Analyze case studies and evaluate if cloud computing is the right fit for specific requirements. ● Be able to identify and choose the appropriate cloud computing platform for an organization based on application requirements, economic constraints, and business needs.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. "Cloud Computing: Principles and Paradigms" by Rajkumar Buyya, James Broberg, and Andrzej Goscinski.
2. "Cloud Computing: A Practical Approach" by Toby Velte, Anthony Velte, and Robert Elsenpeter.
3. "Cloud Native: Using Containers, Functions, and Data to Build Next-Generation Applications" by Boris Scholl, Trent Swanson, and Peter Jausovec.
4. "Cloud Computing for Dummies" by Judith Hurwitz, Robin Bloor, Marcia Kaufman, and Fern Halper.

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Course Number	**ECC 6202**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Cloud Security**
Learning Mode	Online
Learning Objectives	Understand the fundamental concepts of cloud security Learn about the various security threats and vulnerabilities in the cloud environment Understand the different technologies and techniques for securing cloud infrastructure Learn about legal and compliance issues related to cloud security Understand the best practices for implementing and managing cloud security
Course Description	This course covers fundamental cloud security concepts, including security threats, vulnerabilities, and technologies for protecting cloud infrastructure. Students will explore legal and compliance issues and learn best practices for implementing and managing cloud security effectively.
Course Outline	**MODULE 1 - INTRODUCTION TO CLOUD SECURITY** ● Overview of cloud computing and cloud security ● Cloud deployment models ● Cloud service models ● Cloud security risks and challenges ● Security responsibilities in the cloud ● Cloud security best practices **MODULE 2 - CLOUD SECURITY THREATS AND VULNERABILITIES** ● Types of security threats in the cloud ● Cloud security risks and vulnerabilities ● Threats to cloud infrastructure, applications, and data ● Attacks on cloud-based services ● Virtualization security ● Web application security **MODULE 3 - CLOUD SECURITY TECHNOLOGIES** ● Encryption and key management in the cloud ● Identity and access management in the cloud ● Network security in the cloud ● Virtualization security technologies ● Cloud-based security solutions **MODULE 4 - CLOUD SECURITY MANAGEMENT** ● Security governance in the cloud ● Compliance and regulatory issues in the cloud ● Security incident response in the cloud ● Cloud security monitoring and auditing

	MODULE 5 - CLOUD SECURITY BEST PRACTICES ● Secure configuration of cloud services and infrastructure ● Managing security in the cloud ● Training and awareness for cloud security ● Disaster recovery and business continuity in the cloud.
Learning Outcome	● By the end of this course, students will be able to: ● Understand the concepts and principles of cloud security. ● Identify security threats and vulnerabilities in the cloud environment. ● Analyze and evaluate security requirements for cloud infrastructure. ● Implement security measures to protect cloud infrastructure and applications. ● Manage and monitor cloud security. ● Understand legal and compliance issues related to cloud security.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. "Cloud Computing Security: Foundations and Challenges" by John R. Vacca, Syngress (2016)
2. "Cloud Security Automation: Get to secure faster in the cloud" by Prashant Priyam, Packt Publishing (2018)
3. "Building a Comprehensive IT Security Program: Practical Guidelines and Best Practices" by Jeremy Wittkop, Syngress (2016)

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Course Number	**ECC 6203**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Edge Computing**
Learning Mode	Online
Learning Objectives	Upon successful completion of this course, students will be able to: ● Understand the fundamental concepts and limitations of cloud computing and identify the advantages of edge computing; ● Describe various edge computing architectures and differentiate them from traditional cloud models; ● Comprehend the principles of distributed systems as they apply to edge computing environments; ● Explore the functionalities of edge data centers and lightweight edge clouds; Deploy and manage containerized applications using Docker and Kubernetes in edge computing contexts; ● Implement and evaluate edge storage systems and end-to-end edge pipelines utilising MQTT and Kafka, as well as investigate advanced edge computing technologies for real-world applications.
Course Description	This course delves into the emerging field of edge computing, providing a comprehensive understanding of its architectures, systems, and technologies. Students will explore the limitations of traditional cloud computing and learn about the advantages and applications of edge computing. The course covers key concepts in distributed systems, edge data centers, and lightweight edge clouds and includes hands-on experience with Docker, Kubernetes, and edge storage systems. Additionally, students will gain insights into end-to-end edge pipelines using MQTT and Kafka and examine advanced edge computing technologies. By the end of the course, students will be equipped with the knowledge and skills to design, implement, and manage edge computing solutions.
Course Outline	Cloud Computing Basics.Edge Computing basics. Edge Computing Use-Cases, Benefits. Different Types of Edge. Edge Deployment Modes. Edge Computing in 5G, Multi-access Edge Computing (MEC) and Mobile Edge Computing.
Learning Outcome	● Critically evaluate advanced edge computing architectures, such as hierarchical, mesh, and hybrid models, considering their suitability for specific use cases and environments. ● Analyse emerging technologies and trends in advanced edge computing, such as edge AI, blockchain, and serverless computing, and assess their potential impact. ● Design and implement innovative edge computing solutions that leverage advanced techniques, such as federated learning, edge caching, and dynamic resource allocation. ● Evaluate the performance and scalability of advanced edge computing systems using benchmarking, simulation, and experimentation.

	● Investigate advanced techniques for ensuring security, privacy, and data integrity in edge computing ecosystems, such as secure enclaves, encryption, and access control mechanisms. ● Explore specialised applications of advanced edge computing in domains such as healthcare, smart cities, and autonomous systems, analysing their requirements and challenges.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading

1. Fog and Edge Computing: Principles and Paradigms, Rajkumar Buyya (Editor), Satish Narayana Srirama (Editor), Wiley, 2019.
2. Cloud Computing: Principles and Paradigms, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, Wiley, 2011.
3. Cloud and Distributed Computing: Algorithms and Systems, Rajiv Misra, Yashwant Patel, Wiley 2020.
4. Besides these books, we will provide Journal papers as references.

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Course Number	**ECC 6204**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Parallel Algorithms**
Learning Mode	Online
Learning Objectives	• Understand the fundamental principles of parallel computing and parallel algorithm design. • Learn how to develop efficient parallel algorithms for solving complex computational problems. • Gain proficiency in analyzing the performance and scalability of parallel algorithms. • Explore parallel programming models and architectures used in cloud and distributed computing environments. • Develop practical skills in implementing parallel algorithms on modern parallel platforms, including multi-core processors and cloud computing environments.
Course Description	This course provides a comprehensive introduction to parallel algorithms and their applications in cloud and distributed computing environments. Students will learn the theoretical foundations of parallel computing, including models of parallel computation, algorithm design techniques, and complexity analysis. The course also covers various parallel algorithmic techniques, such as divide-and-conquer, dynamic programming, and greedy methods, applied to problems like sorting, searching, graph algorithms, and numerical computations. Emphasis will be placed on understanding the scalability, efficiency, and communication overhead of parallel algorithms, as well as hands-on experience in implementing parallel algorithms on cloud-based platforms and multi-core systems.
Course Outline	**Module 1: Introduction to Parallel Computing** • Basics of parallel computing and its importance in modern applications. • Models of parallel computation: PRAM (Parallel Random Access Machine) and its variants (EREW, CREW, CRCW). • Parallel programming paradigms: shared memory, distributed memory, and hybrid models. • Overview of parallel architectures: multi-core processors, GPUs, cloud-based parallel computing. • Speedup, efficiency, and Amdahl's Law. **Module 2: Parallel Algorithm Design Techniques** • Parallel divide-and-conquer algorithms: parallel merge sort, quicksort. • Parallel dynamic programming techniques: matrix chain multiplication, longest common subsequence. • Parallel greedy algorithms: minimum spanning tree (Kruskal's and Prim's algorithms), shortest path algorithms. • Parallel search algorithms: parallel BFS, DFS, and search algorithms on trees and graphs. • Parallel prefix computation and parallel reduction.

	Module 3: Parallel Algorithms for Numerical Computation • Parallel algorithms for matrix operations: matrix multiplication, matrix inversion, LU decomposition. • Parallel algorithms for solving linear systems: Gaussian elimination, Jacobi and Gauss-Seidel methods. • Parallel FFT (Fast Fourier Transform) algorithms. • Parallel random number generation and Monte Carlo methods. • Applications of numerical parallel algorithms in scientific computing. **Module 4: Parallel Algorithms in Cloud and Distributed Environments** • Distributed computing and cloud-based parallelism: MapReduce, Hadoop, and Spark frameworks. • Designing parallel algorithms for cloud environments: fault tolerance, load balancing, and data locality. • Communication overhead and synchronization in distributed systems. • Performance analysis: scalability, speedup, and cost models in cloud computing environments. • Case studies: real-world applications of parallel algorithms in cloud computing, including big data processing, machine learning, and scientific simulations.
Learning Outcome	• Ability to design and implement efficient parallel algorithms for a variety of computational problems. • Understanding of parallel programming paradigms and models used in cloud and distributed computing environments. • Proficiency in analyzing the scalability and performance of parallel algorithms. • Practical experience in implementing parallel algorithms on cloud-based platforms and multi-core systems.
Assessment Method	Quiz / Assignment / End Semester Exam (ESE)

TEXTBOOKS:

1. "Introduction to Parallel Algorithms" by Joseph JáJá, Addison-Wesley.
2. "Designing and Building Parallel Programs: Concepts and Tools for Parallel Software Engineering" by Ian Foster, Addison-Wesley.
3. "Parallel Computing: Theory and Practice" by Michael J. Quinn, McGraw-Hill.
4. "Parallel Algorithms and Matrix Computation" by Richard S. Varga, Springer.
5. "MapReduce Design Patterns: Building Effective Algorithms and Analytics for Hadoop and Other Systems" by Donald Miner and Adam Shook, O'Reilly Media.

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Course Number	**ECC 6205**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Data Virtualization and Dashboards**
Learning Mode	Online
Learning Objectives	1. To introduce students to the concept of data virtualization and its applications in the field of big data and blockchain. 2. To provide students with hands-on experience using popular data virtualization tools to create a unified view of data from multiple sources and running queries on the views in optimized manner. 3. To teach students how to design effective dashboards that provide meaningful insights into complex data sets and allows intelligent analytics o data. 4. To explore advanced topics in data virtualization and dashboards, such as real-time data integration, self-service analytics, and integration with big data platforms and blockchain.
Course Description	This course introduces data virtualization concepts and applications in big data and blockchain, offering hands-on experience with popular tools for unified data views and optimized querying. Students will learn to design effective dashboards for intelligent analytics and explore advanced topics, including real-time integration, self-service analytics, and integration with big data platforms and blockchain.
Course Outline	**Module 1: Introduction to Data Virtualization:** • Overview of data virtualization and its benefits, Data Silos, Data Partitioning, performance parameters of data virtualization. • Understanding data integration and how it differs from data virtualization, Centralized vs Peer-2-peer Data Integration, ETL, Mediation and Federated Databases. • Data Transformation, Master Data and Metadata Management in Data Virtualization. • Use cases for data virtualization. • Challenges and limitations of data virtualization. • Introduction to popular data virtualization tools and their architectures. **Module 2: Data Virtualization in Action:** • Building a virtual data layer with a popular data virtualization tool such as Denodo and TIBCO, Redhat JBOSS. • Connecting to various data sources (relational databases, big data systems, cloud applications, web applications, etc.). • Creating views and queries using the selected data virtualization tool, query optimization and caching in data virtualization. • Handling complex data transformations with the selected tool.

	• Managing metadata and security in a virtual environment. **Module 3: Data Visualization and Dashboards** • Introduction to data visualization and dashboard design. • Key principles of effective data visualization. • Overview of popular dashboard tools (e.g. Tableau, Power BI, QlikView), Creating reports in Tableau and Power BI. • Best practices for designing interactive dashboards. • Connecting virtual data sources to dashboards. **Module 4: Advanced Topics in Data Virtualization and Dashboards** • Using data virtualization to support self-service analytics, Experimenting self-service analytics in Denodo and Power BI. • Real-time data integration and processing with data virtualization. • Integrating data virtualization with big data platforms and blockchain. • Best practices for performance tuning and optimization in data virtualization. • Future trends in data virtualization and dashboard design.
Learning Outcome	• Students will be able to describe the benefits and challenges of data virtualization and how it differs from traditional data integration approaches. • Students will be able to create a virtual data layer using a popular data virtualization tool and connect to various data sources, including relational databases, big data systems, and cloud applications. • Students will be able to design effective dashboards using popular dashboard tools and connect virtual data sources to create interactive visualizations. • Students will be able to identify and apply advanced techniques in data virtualization and dashboard design, such as real-time data processing, self-service analytics, and integration with big data platforms and blockchain.
Assessment Method	Quiz / Assignment / ESE
Suggested Reading	1. Data Virtualization for Business Intelligence Systems: Revolutionizing Data Integration for Data Warehouses (Rick van der Lans) 2. Data Visualization: A Practical Introduction (Kieran Healy) 3. The Big Book of Dashboards: Visualizing Your Data Using Real-World Business Scenarios (Steve Wexler, Jeffrey Shaffer, and Andy Cotgreave) 4. Building a Modern Data Center: Principles and Strategies of Design (Scott D. Lowe and David M. Davis)

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Course Number	**ECC 6301**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Cloud Strategy Planning and Management**
Learning Mode	Online
Learning Objectives	● Understand the importance of developing a cloud computing-based IT strategy to deliver on strategic business objectives ● Explore the role of IT leaders in planning and managing IT strategic development in the organization ● Analyze various business strategy models to gain competitive advantage for organizations Learn the best practices for managing resources and realizing benefits from Private/Public Cloud IT services
Course Description	This course emphasizes developing a cloud computing-based IT strategy to meet business objectives and explores the role of IT leaders in strategic planning and management. It covers business strategy models for gaining competitive advantage and best practices for managing resources and leveraging private/public cloud IT services.
Course Outline	**MODULE 1: Developing Business Strategy** Investigating business strategy models to gain competitive advantage for organizations, SWOT/PEST, Economies of scale, Porter's 3 Strategies and 5 Competitive Forces, D'Aveni's hyper-competition models **MODULE 2: Strategic IT Leadership in the Organization** Roles of the strategic IS/IT leaders such as Chief Information Officer (CIO) and the Chief Technology Officer (CTO) in planning and managing IT Strategic development in the organization **MODULE 3: Planning a Cloud Computing-based IT Strategy** Developing an IT strategy to deliver on strategic business objectives in the business strategy. IT Project planning in the areas of ITaaS, SaaS, PaaS and IaaS are essential in delivering a successful strategic IT Plan **MODULE 4: SOA and Business Agility** Shared services delivered by a Service Oriented Architecture (SOA) in a Private or Public Cloud.

	Services, Databases, and Applications on demand The effect on Enterprise Architecture and its traditional frameworks such as Zachman and The Open Group Architecture Framework (TOGAF) **MODULE 5: Benefit Realization and IT Governance** Managing resources (people, process, technology), to realize benefit from Private/Public Cloud IT services (IaaS, PaaS, PraaS, SaaS) Gartner's 5 pillars of benefit realization IT governance as a service in measuring the delivery of IT Strategy from Cloud IT Services using Sarbannes Oxley (CobiT) and other commonly- used approaches
Learning Outcome	By the end of this course, students will be able to: ● Develop an IT strategy to deliver on strategic business objectives ● Understanding of the role of IT leaders in planning and managing IT strategic development in the organization ● Acquire knowledge of various business strategy models to gain competitive advantage for organizations. Acquire knowledge of best practices for managing resources and realizing benefits from Private/Public Cloud IT services.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. "Cloud Computing: Principles, Systems and Applications" by Nick Antonopoulos and Lee Gillam
2. "Enterprise Cloud Computing: A Strategy Guide for Business and Technology Leaders" by Brian J. Salkowski and Jay J. Heiser
3. "Cloud Computing: From Beginning to End" by Mr. Ray J Rafaels
4. "Cloud Computing for Business: The Open Group Guide" by Chris Harding

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Course Number	**ECC 6302**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Cloud-based DevOps**
Learning Mode	Online
Learning Objectives	• Understand the principles of DevOps and its integration with cloud computing. • Learn how to automate infrastructure provisioning, deployment, and monitoring in cloud environments. • Explore tools and technologies for implementing continuous integration and continuous deployment (CI/CD) pipelines. • Gain proficiency in containerization and orchestration using Docker and Kubernetes in cloud-native environments. • Develop hands-on skills in managing cloud-based applications using DevOps practices and cloud-native tools.
Course Description	This course provides an in-depth exploration of DevOps practices in cloud environments, focusing on automating infrastructure, deploying scalable applications, and implementing continuous integration and continuous delivery (CI/CD) pipelines. Students will learn to use cloud-native tools for provisioning and monitoring cloud infrastructure, containerization, and orchestrating microservices using Docker and Kubernetes. The course emphasizes practical, hands-on learning to equip students with the skills needed to implement DevOps in real-world cloud-based systems.
Course Outline	**Module 1: Introduction to Cloud-based DevOps** • Overview of DevOps: Principles and benefits. • Understanding the cloud-DevOps integration: Automation, scalability, and flexibility in cloud environments. • Introduction to Infrastructure as Code (IaC) for managing cloud infrastructure. • Cloud-native DevOps tools and services: AWS, Azure, Google Cloud. **Module 2: Infrastructure Automation and IaC (Infrastructure as Code)** • Overview of Infrastructure as Code (IaC): Concepts and best practices. • Tools for IaC: Terraform, AWS CloudFormation, and Ansible. • Automating cloud infrastructure provisioning using Terraform and CloudFormation. • Version control for infrastructure: Managing infrastructure code in Git. • Hands-on lab: Automating the deployment of cloud infrastructure using Terraform. **Module 3: Continuous Integration and Continuous Deployment (CI/CD)** • Introduction to CI/CD pipelines: Key concepts and benefits. • Building and managing CI/CD pipelines using Jenkins, GitLab CI, and AWS CodePipeline. • Integration with cloud platforms: Deploying applications to AWS, Azure, or GCP.

	• Automating testing and deployment workflows in the cloud. • Hands-on lab: Building a CI/CD pipeline and deploying an application on AWS. **Module 4: Containerization and Orchestration with Docker and Kubernetes** • Introduction to containers: Docker basics, containerization in the cloud. • Docker images and containers: Building, deploying, and managing containers. • Introduction to Kubernetes: Orchestrating containerized applications in the cloud. • Deploying and scaling microservices with Kubernetes in AWS EKS, Google Kubernetes Engine (GKE), or Azure AKS. • Hands-on lab: Deploying and scaling containerized applications using Docker and Kubernetes. **Module 5: Monitoring, Logging, and Security in Cloud-based DevOps** • Cloud-native monitoring and logging tools: AWS CloudWatch, Azure Monitor, and Google Stackdriver. • Implementing centralized logging with ELK (Elasticsearch, Logstash, Kibana) stack. • Securing DevOps pipelines: Role-based access control (RBAC), secret management, and securing containerized applications. • Managing and monitoring application performance and security in the cloud. • Hands-on lab: Setting up monitoring and logging for a cloud-native application using AWS CloudWatch.
Learning Outcome	• Ability to automate cloud infrastructure provisioning using Infrastructure as Code (IaC) tools. • Proficiency in building and managing CI/CD pipelines for cloud-native applications. • Skills in containerization using Docker and orchestrating microservices with Kubernetes in cloud environments. • Understanding of cloud-native monitoring, logging, and security practices. • Practical experience with cloud-based DevOps tools and technologies for real-world cloud deployments.
Assessment Method	Quiz / Assignment / End Semester Exam (ESE)

TEXTBOOKS:

- "The DevOps Handbook: How to Create World-Class Agility, Reliability, & Security in Technology Organizations" by Gene Kim, Jez Humble, Patrick Debois, and John Willis, IT Revolution Press.
- "Infrastructure as Code: Managing Servers in the Cloud" by Kief Morris, O'Reilly Media.
- "Kubernetes Up & Running: Dive into the Future of Infrastructure" by Kelsey Hightower, O'Reilly Media.
- "Learning Docker: Automating Infrastructure and Container Deployment with Docker" by Pethuru Raj, Jeeva S. Chelladhurai, and Vinod Singh, Packt Publishing.
- "Site Reliability Engineering: How Google Runs Production Systems" by Niall Richard Murphy, Betsy Beyer, Chris Jones, and Jennifer Petoff, O'Reilly Media.

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Course Number	**ECC 6303**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Distributed Systems**
Learning Mode	Online
Learning Objectives	● To introduce the fundamental concepts of parallel computing and distributed systems. ● To develop an understanding of the structures of parallel and distributed systems. ● To explore the different algorithms and programming techniques used in parallel and distributed systems. ● To analyze the performance, synchronization, coordination, and fault tolerance of distributed systems.
Course Description	Gain foundational knowledge in parallel computing and distributed systems, exploring their structures, algorithms, and programming techniques. Analyze performance, synchronization, coordination, and fault tolerance to optimize distributed system designs for robustness and efficiency.
Course Outline	**Module 1: Introduction to Parallel and Distributed Systems** ● Introduction to parallel computing and distributed systems. ● Solving problems in parallel. ● Structures of parallel and distributed systems. ● Instruction level parallel processing. ● Performance evaluation of parallel and distributed systems. **Module 2: Communication and Network Protocols** ● Characterization of distributed systems. ● Communication and computer networks. ● Distributed processing. ● Distributed operating systems. ● Client-server communications. **Module 3: Distributed Systems Services** ● Remote procedure calls. ● File service. ● Name service. **Module 4: Fault Tolerance and Security** ● Distributed transactions and concurrency control. ● Fault tolerance and security. ● Synchronization and coordination. ● Distributed algorithms and research issues.

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Learning Outcome	● Students will be able to describe the basic concepts and structures of parallel and distributed systems. ● Students will be able to implement parallel algorithms and programming techniques to solve problems in distributed systems. ● Students will be able to analyze the performance and synchronization of distributed systems. ● Students will be able to design fault-tolerant distributed systems.
Assessment Method	● Quiz / Assignment / ESE

Suggested Reading

- "Distributed Systems: Concepts and Design" by George Coulouris, Jean Dollimore, and Tim Kindberg. Published by Pearson Education.
- "Parallel Computing: Architectures, Algorithms and Applications" by Kai Hwang and Jack Dongarra. Published by McGraw-Hill Education.
- "Distributed Systems: Principles and Paradigms" by Andrew S. Tanenbaum and Maarten Van Steen. Published by Pearson Education.
- "Distributed Algorithms" by Nancy Lynch. Published by Morgan Kaufmann Publishers.

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Course Number	**ECC 6304**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Machine Learning for Cloud Computing**
Learning Mode	Online
Learning Objectives	• Understand the principles of machine learning (ML) and how it integrates with cloud computing platforms. • Learn how to implement, deploy, and scale machine learning models using cloud-based services. • Explore cloud-native machine learning tools and frameworks for developing, training, and optimizing models. • Gain proficiency in using cloud infrastructure for machine learning workflows, including data preprocessing, model training, and deployment. • Develop practical skills in applying machine learning to real-world applications in cloud environments, such as AWS, Google Cloud, and Azure.
Course Description	This course provides a comprehensive introduction to machine learning (ML) techniques with a focus on cloud computing platforms. Students will learn how to leverage cloud services to build, train, and deploy machine learning models efficiently. The course covers various machine learning algorithms, cloud-based tools, and ML workflows from data preprocessing to deployment. Hands-on labs will enable students to work with popular cloud ML services such as Amazon SageMaker, Google AI Platform, and Azure Machine Learning, applying these tools to solve real-world problems at scale.
Course Outline	**Module 1: Introduction to Machine Learning and Cloud Computing** • Overview of machine learning: Concepts, algorithms, and use cases. • Machine learning in cloud environments: Benefits, challenges, and opportunities. • Overview of cloud platforms: AWS, Azure, and Google Cloud. • Cloud-native machine learning services: Amazon SageMaker, Google AI Platform, Azure Machine Learning. • Introduction to cloud-based data storage and computing resources for ML. **Module 2: Data Preprocessing and Feature Engineering in the Cloud** • Data collection and storage in cloud environments: S3, Google Cloud Storage, Azure Blob Storage. • Data preprocessing techniques: Cleaning, normalization, encoding, and transformation. • Feature selection and extraction for machine learning models. • Tools for data preprocessing in the cloud: AWS Glue, Google Dataflow, Azure Data Factory. • Hands-on lab: Preprocessing large datasets using cloud-native tools.

	Module 3: Machine Learning Algorithms and Model Training in the Cloud • Overview of supervised, unsupervised, and reinforcement learning algorithms. • Training machine learning models in the cloud: AWS SageMaker, Google AI Platform, Azure ML. • Distributed training: Leveraging cloud infrastructure for parallel model training. • Hyperparameter tuning and optimization using cloud-based services. • Hands-on lab: Training a machine learning model using Amazon SageMaker. **Module 4: Machine Learning Model Deployment and Monitoring in the Cloud** • Deploying machine learning models in the cloud: Real-time and batch inference. • Model serving and endpoint management in cloud environments. • Monitoring model performance: Model drift, retraining, and continuous monitoring. • Autoscaling machine learning models in cloud environments for real-time predictions. • Hands-on lab: Deploying and monitoring a machine learning model using Azure Machine Learning. **Module 5: Advanced Topics in Machine Learning for Cloud Computing** • Using AutoML for building machine learning models in the cloud. • Machine learning pipelines: Automating end-to-end workflows. • Security and privacy concerns in cloud-based machine learning. • Case studies: Real-world applications of machine learning in cloud computing (e.g., healthcare, finance, IoT). • Future trends: Federated learning, edge computing, and AI/ML integration in cloud environments.
Learning Outcome	• Ability to build, train, and deploy machine learning models using cloud-based platforms and services. • Proficiency in using cloud-native tools for data preprocessing, feature engineering, and model optimization. • Understanding of distributed machine learning and the benefits of cloud infrastructure for large-scale ML tasks. • Practical skills in deploying and monitoring machine learning models in production environments. • Knowledge of advanced topics in cloud-based machine learning, including AutoML, pipelines, and security considerations.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS

- "Hands-On Machine Learning on Google Cloud Platform" by Giuseppe Ciaburro, Packt Publishing.
- "Practical Deep Learning for Cloud, Mobile, and Edge: Real-World AI & Computer-Vision Projects Using Python, Keras & TensorFlow" by Anirudh Koul, O'Reilly Media.
- "Data Science on the Google Cloud Platform" by Valliappa Lakshmanan, O'Reilly Media.
- "Machine Learning Engineering in Action" by Ben Wilson, Manning Publications.
- "Mastering Machine Learning on AWS" by Saket S. R. Mengle, Packt Publishing.

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Course Number	**ECC 6401**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Meta Learning**
Learning Mode	Online
Learning Objectives	This course aims to help the students : (a) Gain a solid understanding of the foundational principles of meta-learning, including model evaluation, basic machine learning concepts, and their limitations. (b) Delve into advanced techniques such as deep learning, transfer learning, and multitask learning, and understand how these methodologies enhance meta-learning capabilities. (c) Develop proficiency in key meta-learning strategies, including model-based, metric-based, and optimization-based approaches, and familiarize yourself with advanced architectures like memory-augmented networks and conditional sequential neural networks (CSNNs). (d) Apply meta-learning techniques to practical applications in various domains, such as computer vision, natural language processing (NLP), reinforcement learning, healthcare, recommendation systems, and climate science, demonstrating the ability to solve complex real-world problems.
Course Description	This comprehensive course provides an in-depth overview of meta- learning, guiding students from foundational principles to advanced techniques. The curriculum begins with the basics of model evaluation, machine learning concepts, and their inherent limitations. Students will then explore advanced topics such as deep learning, transfer learning, and multitask learning, gaining a robust understanding of how these methodologies enhance the capabilities of meta-learning systems.Key meta-learning strategies are thoroughly examined, including model-based, metric-based, and optimization-based approaches. The course features advanced architectures like memory-augmented networks and conditional sequential neural networks (CSNNs), showcasing their roles in improving learning efficiency and effectiveness.Practical applications of meta-learning are highlighted across various fields, including computer vision, natural language processing (NLP), reinforcement learning, healthcare, recommendation systems, and climate science. These examples demonstrate the versatility and power of meta-learning in addressing complex, real-world problems. By the end of the course, students will be equipped with a robust understanding of meta-learning principles and techniques, enabling them to leverage these advanced methodologies to solve intricate problems across diverse domains.

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Course Outline	**Module 1: Meta-Learning Basics and Background**
	• **Introduction to Meta-Learning**
	  ○ What is meta-learning?
	  ○ Importance of meta-learning
	• **Key Concepts**
	  ○ Learning to learn
	  ○ Few-shot learning
	  ○ Generalization across tasks
	Module 2: Evaluation of Meta-Learning
	• **Evaluation Metrics**
	  ○ Accuracy, loss functions, and few-shot performance
	  ○ Common benchmarks (Omniglot, Mini-ImageNet)
	• **Challenges**
	  ○ Overfitting and task distribution
	  ○ Measuring generalization
	Module 3: Model-Based Meta-Learning Approaches
	• **Overview**
	  ○ Model-based methods overview
	  ○ Memory-augmented models
	• **Techniques**
	  ○ LSTM-based meta-learning
	  ○ Neural Turing Machines (NTMs)
	  ○ Memory Networks
	Module 4: Metric-Based Meta-Learning Approaches
	• **Key Concepts**
	  ○ Learning similarity metrics
	• **Techniques**
	  ○ Siamese networks
	  ○ Prototypical networks
	  ○ Matching networks
	Module 5: Optimization-Based Meta-Learning Approaches
	• **Overview**
	  ○ Optimization-based methods overview
	• **Techniques**
	  ○ Model-Agnostic Meta-Learning (MAML)
	  ○ Reptile algorithm
	  ○ First-order methods

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Learning Outcome	1. Understand and articulate the foundational principles of meta-learning 2. Apply probabilistic modeling and Bayesian inference to quantify uncertainty and improve model robustness in decision-making processes. 3. Analysis of Optimization-Based Meta-Learning Approaches. 4. Explore and address new challenges in emerging applications.
Assessment Method	Quiz / Assignment / ESE

Textbook:

1. Zou, L., 2022. *Meta-learning: Theory, algorithms and applications*.
2. Brazdil, P., Van Rijn, J.N., Soares, C. and Vanschoren, J., 2022. *Metalearning: applications to automated machine learning and data mining* (p. 346).

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Course Number	**ECC 6402**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Service Oriented Architecture and Web Security**
Learning Mode	Online
Learning Objectives	● To provide an overview of XML Technology and modeling databases in XML. ● To provide an overview of Service Oriented Architecture and Web services and their importance. ● To introduce Security solutions in XML and Web Services and to introduce Security standards for Web Services.
Course Description	Explore XML technology and database modeling, along with an introduction to Service Oriented Architecture (SOA) and Web services, emphasizing their significance in modern IT landscapes. Delve into XML and Web services security solutions, covering essential standards and best practices for securing web-based applications.
Course Outline	**Module 1: XML TECHNOLOGY** ● Introduction to XML and its usage in Web technology ● Name Spaces and their usage in XML ● XML Document Structure ● Structuring with Schemas and DTD ● Modeling Databases in XML ● XQuery **Module 2: SOA BASICS** ● Service Oriented Architecture (SOA) ● Comparison of SOA with Client-Server and Distributed architectures ● Characteristics and Benefits of SOA ● Principles of Service Orientation ● Service Layers ● Business Process Management **Module 3: WEB SERVICES** ● SOA and Web Services ● Web Services Protocol Stack ● Service descriptions ● WSDL (Web Services Description Language) ● Messaging with SOAP (Simple Object Access Protocol) ● Service discovery ● UDDI (Universal Description, Discovery, and Integration)

	● Service-Level Interaction patterns ● XML and Web Services ● Enterprise Service Bus ● .NET and J2EE Interoperability **Module 4: WS TECHNOLOGIES AND STANDARDS** ● Web Services Technologies: JAX-RPC, JAX-WS ● Web Service Standards: WS-RM (Web Services Reliable Messaging), WS-Addressing, WS-Policy ● Service Orchestration and Choreography ● Composition Standards: BPEL (Business Process Execution Language) ● Service Oriented Analysis and Design **Module 5: XML AND WS SECURITY** ● XML Security Overview ● Canonicalization ● XML Security Framework ● XML Encryption ● XML Signature ● XKMS (XML Key Management Specification) Structure ● Web Services Security ● XACML (eXtensible Access Control Markup Language) WS-Security ● WS-Security
Learning Outcome	By the end of this course, students will be able to: ● Understand the basics of XML. ● Learn the concepts of SOA and Web services, some of the prevailing standards and technologies of Web Services. ● Learn the approaches for providing security for XML documents as well as messages exchanged among Web Services.
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

1. Ron Schmelzer et al. "XML and Web Services", Pearson Education, 2008. (Unit 1 and 3)
2. Thomas Erl, " Service Oriented Architecture: Concepts, Technology, and Design", Pearson Education, 2005 (Unit 2, 3, 4, and 5)
3. Frank P.Coyle, "XML, Web Services and the Data Revolution", Pearson Education, 2002 (Unit 5)
4. James McGovern, Sameer Tyagi, Michael E Stevens, Sunil Mathew, "Java Web Services Architecture", Elsevier, 2011.
5. Mark O' Neill, et al., "Web Services Security", Tata McGraw-Hill Edition, 2003.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: Executive M. Tech in Cloud Computing
Curriculum and Syllabus-2024

Course Number	**ECC 6403**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Reinforcement Learning**
Learning Mode	Online
Learning Objectives	This course aims to help the students: **(a)** Understand the foundational concepts and mathematical frameworks of reinforcement learning. **(b)** Gain proficiency in key reinforcement learning algorithms, including dynamic programming, Monte Carlo methods, and temporal- difference learning **(c)** Apply deep reinforcement learning techniques to solve complex problems using methods such as deep Q-networks and policy gradient algorithms. **(d)** Explore recent advancements and applications of reinforcement learning, including multi-agent systems and ethical considerations.
Course Description	This specialized course on reinforcement learning aims to give students a deep understanding of the algorithms and methodologies used to train agents to make decisions through trial and error. Students will learn to develop and implement reinforcement learning models by focusing on foundational theories and practical applications. Students will explore key concepts such as Markov decision processes, policy gradients, Q- learning, and deep reinforcement learning through a mix of theoretical lectures, coding exercises, and project-based learning. Upon completion, students will be equipped to design and apply reinforcement learning solutions to complex problems in fields such as robotics, game development, and autonomous systems, enhancing their expertise in this dynamic area of artificial intelligence.
Course Outline	● **Foundations**: Basics of machine learning and reinforcement learning (RL) terminology. ● **Probability Concepts**: Axioms of probability, random variables, distributions, and correlation. ● **Markov Decision Process**: Introduction to MDPs, Markov property, and Bellman equations. ● **State and Action Value Functions**: Concepts of MDP, state, and action value functions. ● **Tabular Methods and Q-networks**: Dynamic programming, Monte Carlo, TD learning, and deep Q-networks. ● **Policy Optimization**: Policy-based methods, REINFORCE algorithm, and actor-critic methods. ● **Recent Advances and Applications**: Meta-learning, multi-agent RL, ethics in RL, and real-world applications.

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Learning Outcome	1. Mastery of fundamental principles and mathematical frameworks of reinforcement learning. 2. Proficiency in implementing key reinforcement learning algorithms and techniques. 3. Ability to apply deep reinforcement learning methods to complex, real-world problems. 4. Understanding of recent advancements in reinforcement learning and their ethical implications.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading:

- Reinforcement Learning: An Introduction by Richard S. Sutton and Andrew G. Barto, The MIT Press (1 January 1998).
- Deep Reinforcement Learning Hands-On by Maxim Lapan, Packt Publishing Limited (21 June 2018).
- Algorithms for Reinforcement Learning by Csaba Szepesvari, Morgan and Claypool Publishers (2010)
- Deep Reinforcement Learning: Fundamentals, Research and Applications by Hao Dong, Springer Verlag (2020)

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Course Number	**ECC 6404**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Data Warehousing**
Learning Mode	Online
Learning Objectives	• Understand the core concepts of data warehousing and its role in decision support systems. • Learn to design and implement data warehouses, including data modeling and ETL (Extract, Transform, Load) processes. • Explore various data warehousing architectures and the role of OLAP (Online Analytical Processing) in analyzing large datasets. • Gain proficiency in query optimization and performance tuning for large-scale data warehouses. • Develop practical skills in using data warehousing tools and technologies for real-world applications.
Course Description	This course provides a comprehensive introduction to data warehousing, focusing on the design, implementation, and management of large-scale data warehouses. Students will learn about data modeling techniques, the ETL process, and the design of data warehouse architectures. The course also covers OLAP systems and their role in performing multidimensional data analysis. Emphasis will be placed on optimizing query performance and implementing scalable solutions. Real-world applications and case studies will be used to demonstrate the role of data warehousing in business intelligence and decision-making processes.
Course Outline	**Module 1: Introduction to Data Warehousing** • Definition and significance of data warehousing in business intelligence. • Key characteristics of a data warehouse: subject-oriented, integrated, time-variant, and non-volatile. • Difference between operational databases and data warehouses. • Overview of decision support systems and the role of data warehousing. • Introduction to data warehousing architectures: centralized, federated, and multi-tier. **Module 2: Data Warehouse Design and Modeling** • Data modeling for data warehouses: star schema, snowflake schema, and galaxy schema. • Fact and dimension tables: characteristics, types, and relationships. • Dimensional modeling: attributes, hierarchies, and measures. • Surrogate keys and slowly changing dimensions (SCD). • Case studies of designing a data warehouse for various industries (e.g., retail, finance, healthcare).

	Module 3: ETL Process (Extract, Transform, Load) • Overview of the ETL process: extracting data from source systems, transforming data for consistency and accuracy, and loading it into the data warehouse. • Data cleansing, validation, and transformation techniques. • Tools and technologies for automating the ETL process (e.g., Apache Nifi, Talend, Informatica). • Managing ETL performance and error handling in large-scale environments. • Real-world examples of ETL processes for data warehousing. **Module 4: Online Analytical Processing (OLAP)** • Introduction to OLAP and its role in multidimensional data analysis. • OLAP operations: roll-up, drill-down, slicing, dicing, and pivoting. • Types of OLAP systems: MOLAP (Multidimensional OLAP), ROLAP (Relational OLAP), and HOLAP (Hybrid OLAP). • OLAP query performance optimization techniques. • Applications of OLAP in business intelligence and decision-making. **Module 5: Data Warehouse Performance Optimization and Scalability** • Indexing and partitioning strategies for improving query performance in large data warehouses. • Materialized views and query rewriting for optimization. • Distributed and parallel data warehouses: managing performance across large datasets. • Data warehouse maintenance: incremental loading and refreshing strategies. • Best practices for scaling data warehouses in cloud environments. **Module 6: Advanced Topics in Data Warehousing** • Data warehousing in the cloud: AWS Redshift, Google BigQuery, and Azure Synapse Analytics. • Big data and data warehousing integration: Hadoop and NoSQL systems in data warehousing. • Data governance, security, and compliance in data warehouses. • Real-world case studies of data warehouse implementation in business intelligence, finance, and healthcare industries. • Future trends in data warehousing: real-time data warehousing, data lakes, and integration with AI/ML.
Learning Outcome	• Ability to design, implement, and optimize large-scale data warehouses for decision support systems. • Proficiency in dimensional modeling, ETL processes, and OLAP systems for data analysis. • Skills in query optimization, indexing, and performance tuning in data warehouses. • Practical experience in using data warehousing tools and technologies for real-world business intelligence applications.

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Assessment Method	Quiz / Assignment / End Semester Exam (ESE)

TEXTBOOKS:

- "Data Warehousing: Concepts, Techniques, Products and Applications" by C.S.R. Prabhu, Prentice-Hall India.
- "The Data Warehouse Toolkit: The Definitive Guide to Dimensional Modeling" by Ralph Kimball and Margy Ross, Wiley.
- "Building the Data Warehouse" by W.H. Inmon, Wiley.
- "Data Warehouse Design: Modern Principles and Methodologies" by Matteo Golfarelli and Stefano Rizzi, McGraw-Hill.