INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

CLUSTER COMPUTING								
VII Semester: CSE(DS) | CSE (AI&ML)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
ACDD28	**Core**	3	0	0	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisites: Basic knowledge of computer networks, operating systems, and parallel/distributed computing.								

I. COURSE OVERVIEW:

This course introduces the principles and architecture of Cluster Computing systems that connect multiple computers to work as a single system. It focuses on cluster architecture, communication mechanisms, parallel programming models, middleware, resource management, fault tolerance, and real-world applications of cluster-based environments.

II. COURSE OBJECTIVES:

The students will try to learn:

I. The architecture and components of cluster systems **as** a foundation for building scalable and high-availability computing environments.
II. The Middleware platforms and cluster frameworks as essential infrastructures for managing distributed tasks and computational resources.
III. The Communication, coordination, and synchronization techniques as core mechanisms to ensure consistency and reliability in clustered systems.
IV. The Performance metrics and application scenarios as practical insights into deploying clusters in scientific, industrial, and data-driven fields.

III. COURSE OUTCOMES:

At the end of the course students will be able to:

CO1 **Identify** the basic concepts, classifications, and architecture of cluster computing systems.
CO2 **Explain** the role of cluster middleware, components, and the principles of task scheduling and load balancing.
CO3 **Demonstrate** the use of programming models like MPI or PVM to develop parallel applications in a cluster environment.
CO4 **Examine** cluster communication, synchronization techniques, and resource management for performance optimization.
CO5 **Assess** different cluster configurations and benchmark tools for measuring scalability, efficiency, and fault tolerance.
CO6 **Design** and **implement** a real-time cluster-based solution for a selected application domain such as scientific computing or big data analytics.

IV. COURSE CONTENT:

MODULE I: INTRODUCTION TO CLUSTER COMPUTING (9)
Cluster computing basics, Need and benefits of clusters, Types of clusters (HPC, HA, Load Balancing), Cluster architecture, Cluster vs Grid computing, Hardware and software components, Examples of cluster deployments in real-world applications.

Module II: Cluster Middleware and Resource Management (9)
Cluster operating systems and middleware, Cluster job and resource management, Job scheduling strategies, Load balancing techniques, Introduction to SLURM and TORQUE, Cluster management tools (Rocks, OpenHPC), Configuration and monitoring tools.

Module III: Parallel Programming Models for Clusters (10)
Parallelism in clusters, Message Passing Interface (MPI), Parallel Virtual Machine (PVM), Shared vs Distributed memory models.

MPI programming constructs – point-to-point and collective communication, Process synchronization, Fault handling in parallel execution.

Module IV: Cluster Communication and Coordination (10)
Network protocols for clusters, Inter-process communication, Synchronization and coordination mechanisms, Clock synchronization, Barrier and mutual exclusion algorithms, Data consistency models, Performance bottlenecks in communication.

Module V: Applications, Performance, and Case Studies (10)
Cluster applications in scientific computing, bioinformatics, and big data analytics, Performance metrics – speedup, scalability, efficiency, Benchmarking tools (LINPACK, SPEC), Real-world case studies (Beowulf cluster, Hadoop cluster), Future trends in cluster computing.

V. TEXTBOOKS:

1. **Rajkumar Buyya**, Cluster Computing, Pearson Education, 1999.
2. **Rajkumar Buyya** (Editor), High Performance Cluster Computing: Architectures and Systems (Volume 1), Prentice Hall PTR, 1999.
3. **Kai Hwang, Geoffrey Fox, and Jack Dongarra,** Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, Morgan Kaufmann, 2011.

VI. REFERENCE BOOKS:

1. **Dieter Gollmann**, *Computer Security*, 3rd Edition, Wiley India, **2011**
2. **Michael J. Quinn,** Parallel Programming in C with MPI and OpenMP, McGraw-Hill, 2003.
3. **Georg Hager and Gerhard Wellein**, Introduction to High Performance Computing for Scientists and Engineers, CRC Press, 2010.

VII. ELECTRONICS RESOURCES:

1. NPTEL – High Performance Computing by Prof. Madhavan Mukund, IIT Madras
   https://nptel.ac.in/courses/106106179
2. Coursera – Parallel, Concurrent, and Distributed Programming in Java (Rice University)
   https://www.coursera.org/learn/parallel-concurrent-distributed-java
3. MPI Tutorial – Lawrence Livermore National Laboratory
   https://hpc-tutorials.llnl.gov/mpi/
4. OpenHPC Documentation – Community-supported HPC cluster tools and guides
   https://openhpc.community/documentation/

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open-ended experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper – II
9. Lecture notes
10. PowerPoint presentation
11. E-Learning Readiness Videos (ELRV)