NIRMA UNIVERSITY

Institute:	**Institute of Technology, School of Technology**
Name of Programme:	**BTech CSE**
Course Code:	4CS401ME25
Course Title:	**High Performance Computing**
Course Type:	**Department Elective-III**
Year of Introduction:	**2025-26**

L	T	Practical Component				C
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Course Learning Outcomes (CLO):

At the end of the course, the students will be able to –

1. explain parallel processing systems, parallel architectures, and fundamental issues in high performance computing system (BL2)
2. develop and optimize parallel programs using shared memory programming and message-passing interface (BL3)
3. develop scientific applications for exploiting the resources of HPC (BL3)
4. analyse profiling and benchmarking tools to measure the performance of HPC applications. (BL4)

Unit	Contents	Teaching Hours (Total 45)
Unit-I	**Parallel Processing Concepts:** Levels and model of parallelism: instruction, transaction, task, thread, memory, function, data flow models, demand-driven computation	06
Unit-II	**Parallel architectures**: superscalar architectures, multi-core, multi-threaded, server and cloud	06
Unit-III	**Fundamental design issues in HPC:** Load balancing, scheduling, synchronization, and resource management Algorithms for HPC, Parallel algorithms, analysis of algorithms, and task scheduling	07
Unit-IV	**Operating systems for scalable HPC**: Parallel Programming Models - Shared memory programming (OpenMP), Distributed memory programming (MPI), Hybrid programming models	07
Unit-V	**Performance Metrics and Optimization:** Performance metrics such as speedup, efficiency, and scalability, Profiling and benchmarking tools; **Optimization techniques:** loop unrolling, vectorization, and memory optimization	07
Unit-VI	**HPC Systems and Clusters:** Supercomputers, clusters, grid computing, Cloud computing for HPC, High-performance interconnects, and networking	06
Unit-VII	**Overview of Advances in computing:** Multicore computing, Quantum Computing, Cloud Computing, Petascale computing, Optics in Computing	06

Self-Study:
The self-study contents will be declared at the commencement of the semester. Around 10% of the questions will be asked from self-study content.

Suggested Readings/ References:

1. Georg Hager and Gerhard Wellein, *Introduction to High Performance Computing for Scientists and Engineers*, CRC Press
2. Kai Hwang, Naresh Jotwani, *Advance Computer Architecture: Parallelism, Scalability, Programmability*, McGraw Hill
3. Vipin Kumar, Ananth Grama, Anshul Gupta, George Karypis, *Introduction to Parallel Computing*, Pearson
4. John L. Hennessy and David A. Patterson. *Computer Architecture: A Quantitative Approach*, Elsevier
5. David B. Kirk and Wen-mei W. Hwu, *Programming Massively Parallel Processors: A Hands-On Approach*, Elsevier
6. J. L. Hennessy and D. A. Patterson, *Computer Architecture: A Quantitative Approach*, Morgan Kaufmann.

Suggested List of Experiments:

Sr. No.	Name of Experiments/Exercises	Hours
1	**Introduction to HPC Environment:** Practicing basic Linux commands for Familiarization of Cluster and basic programming using the mathematical library	02
2	Practice Linux commands needed for environmental setup of HPC cluster and accessing HPC resources	02
3	**Performance Profiling:** Profiling a simple serial program and Identifying bottlenecks using profiling tools (e.g., gprof, perf)	02
4	**OpenMP Programming:** Writing a simple parallel program using OpenMP	04
5	Using OpenMP directives, write a code for parallelization and understand Performance analysis compared with serial implementation	04
6	**MPI Programming**: Writing a basic MPI program for distributed memory systems	04
7	Implementing point-to-point communication using MPI_Send and MPI_Recv and Collective communication using MPI_Bcast, MPI_Reduce, and MPI_Gather	04
8-9	Implementing parallel sorting algorithms (e.g., parallel quicksort, merge sort)	06
10	Performance analysis and scalability study of deployed algorithms	02