PARALLEL COMPUTING		Semester	VII
Course Code	**BCS702**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 8-10 Lab slots	Total Marks	100
Credits	04	Exam Hours	03
Examination nature (SEE)	Theory/Practical		

Course objectives:

This course will enable to,

- Explore the need for parallel programming
- Explain how to parallelize on MIMD systems
- To demonstrate how to apply MPI library and parallelize the suitable programs
- To demonstrate how to apply OpenMP pragma and directives to parallelize the suitable programs
- To demonstrate how to design CUDA program

Teaching-Learning Process (General Instructions)

These are sample Strategies that teachers can use to accelerate the attainment of the various course outcomes.

1. Lecturer method (L) need not to be only traditional lecture methods, but alternative effective teaching methods could be adopted to attain the outcomes.
2. Use of Video/Animation to explain functioning of various concepts.
3. Encourage collaborative (Group Learning) Learning in the class.
4. Ask at least three HOT (Higher order Thinking) questions in the class, which promotes critical thinking.
5. Adopt Programming assignment, which fosters student's Analytical skills, develop design thinking skills such as the ability to design, evaluate, generalize, and analyze information rather than simply recall it.

MODULE-1

Introduction to parallel programming, Parallel hardware and parallel software – Classifications of parallel computers, SIMD systems, MIMD systems, Interconnection networks, Cache coherence, Shared-memory vs. distributed-memory, Coordinating the processes/threads, Shared-memory, Distributed-memory.

MODULE-2

GPU programming, Programming hybrid systems, MIMD systems, GPUs, Performance – Speedup and efficiency in MIMD systems, Amdahl's law, Scalability in MIMD systems, Taking timings of MIMD programs, GPU performance.

MODULE-3

Distributed memory programming with MPI – MPI functions, The trapezoidal rule in MPI, Dealing with I/O, Collective communication, MPI-derived datatypes, Performance evaluation of MPI programs, A parallel sorting algorithm.

MODULE-4

Shared-memory programming with OpenMP – openmp pragmas and directives, The trapezoidal rule, Scope of variables, The reduction clause, loop carried dependency, scheduling, producers and consumers, Caches, cache coherence and false sharing in openmp, tasking, tasking, thread safety.

MODULE-5

GPU programming with CUDA - GPUs and GPGPU, GPU architectures, Heterogeneous computing, Threads, blocks, and grids Nvidia compute capabilities and device architectures, Vector addition, Returning results from CUDA kernels, CUDA trapezoidal rule I, CUDA trapezoidal rule II: improving performance, CUDA trapezoidal rule III: blocks with more than one warp.

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	Write a OpenMP program to sort an array on n elements using both sequential and parallel mergesort(using Section). Record the difference in execution time.
2	Write an OpenMP program that divides the Iterations into chunks containing 2 iterations, respectively (OMP_SCHEDULE=static,2). Its input should be the number of iterations, and its output should be which iterations of a parallelized for loop are executed by which thread. For example, if there are two threads and four iterations, the output might be the following: a. Thread 0 : Iterations 0 —— 1 b. Thread 1 : Iterations 2 —— 3
3	Write a OpenMP program to calculate n Fibonacci numbers using tasks.
4	Write a OpenMP program to find the prime numbers from 1 to n employing parallel for directive. Record both serial and parallel execution times.
5	Write a MPI Program to demonstration of MPI_Send and MPI_Recv.
6	Write a MPI program to demonstration of deadlock using point to point communication and avoidance of deadlock by altering the call sequence
7	Write a MPI Program to demonstration of Broadcast operation.
8	Write a MPI Program demonstration of MPI_Scatter and MPI_Gather
9	Write a MPI Program to demonstration of MPI_Reduce and MPI_Allreduce (MPI_MAX, MPI_MIN, MPI_SUM, MPI_PROD)

Course outcomes (Course Skill Set):
At the end of the course, the student will be able to:
- Explain the need for parallel programming
- Demonstrate parallelism in MIMD system.
- Apply MPI library to parallelize the code to solve the given problem.
- Apply OpenMP pragma and directives to parallelize the code to solve the given problem
- Design a CUDA program for the given problem.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of the IPCC (maximum marks 50)

- IPCC means practical portion integrated with the theory of the course.

- CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.

- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.

- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.

- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

- **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks** for the test to be conducted after the completion of all the laboratory sessions.

- On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.

- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.

- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to **10 marks.**

- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.

- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC
Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours**)
1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

Suggested Learning Resources:
Textbook:
1. Peter S Pacheco, Matthew Malensek – An Introduction to Parallel Programming, second

edition, Morgan Kauffman.
2. Michael J Quinn – Parallel Programming in C with MPI and OpenMp, McGrawHill.

Reference Books:
1. Calvin Lin, Lawrence Snyder – Principles of Parallel Programming, Pearson
2. Barbara Chapman – Using OpenMP: Portable Shared Memory Parallel Programming, Scientific and Engineering Computation
3. William Gropp, Ewing Lusk – Using MPI:Portable Parallel Programing, Third edition, Scientific and Engineering Computation

Web links and Video Lectures (e-Resources):
1. Introduction to parallel programming: https://nptel.ac.in/courses/106102163

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Programming Assignment at higher bloom level (10 Marks)