Version: 11/3/2023

# ECE/ME/EMA/CS 759: High Performance Computing for Engineering Applications

Fall 2023 – Tentative Syllabus

| Date | Title | HW Assigned<br>Quiz dates | Recommended Reading.<br>Other Observations |
|---|---|---|---|
| 09/06<br>[L01] | Syllabus related issues.<br>Course overview. | | Linux Command Line basics. |
| 09/08<br>[L02] | From Code to Machine Instructions. The FDX Cycle.<br>Instruction Level Parallelism. | HW01 out (due 09/14):<br>C programming related | Clone this GitHub repo and read the FAQ and Slurm scripts therein.<br>Read & re-read the C material covered in ME459. Read about Euler and "`module`". |
| 09/11<br>[L03] | Superscalar architectures. Measuring Computer Performance. Memory Aspects | | Read `gdb` tutorial in ME459.<br>Read Chapter 5 of Brian W. Kernighan and Dennis M. Ritchie "The C Programming Language" book. |
| 09/13<br>[L04] | The memory hierarchy. Caches. | In-class quiz – 1. | Build Management & CMake in ME459 (p.387 & on). |
| 09/15<br>[L05] | Caches, wrap up. Virtual Memory | HW02 out (due 09/21):<br>C programming related | Read the `git` material covered in ME459 (p.484 & on). Read how to produce a good commit comment. |
| 09/18<br>[L06] | The Walls to Sequential Computing. Moore's Law. Parallel Computing. Flynn's Taxonomy. Amdahl's Law. | | Read the Amdahl article.<br>Good & short writeup on Virtual Memory |
| 09/20<br>[L07] | GPU Computing Intro. The CUDA Programming Model. CUDA Execution Configuration | In-class quiz – 2. | Knuth paper on premature optimization. |
| 09/22<br>[L08] | GPU Memory Spaces | HW03 out (due 09/28):<br>GPU/CUDA related | Read Lighterra article. |
| 09/25<br>[L09] | GPU Scheduling Issues. Execution Divergence. Control Flow in CUDA. | | Read ACM article about C++ compiler optimizations |
| 09/27 | **NO CLASS** | **DAN OUT OF TOWN** | Read about the Latest Tesla Architecture |
| 09/29<br>[L10] | CUDA Shared Memory Issues. | HW04 out (due 10/05):<br>GPU/CUDA related | Skim through CUDA Programming Guide. |
| 10/02<br>[L11] | Global Memory Access Patterns and Implications. | | GPU computing evolution article of Nickolls & Dally |
| 10/04<br>[L12] | Atomic operations in CUDA.<br>GPU code optimization rules of thumb | In-class quiz – 3. | Intro discussion on Unified Memory in CUDA |
| 10/06<br>[L13] | CUDA Case Studies:<br>a) 1D Stencil Operation. | HW05 out (due 10/12):<br>GPU/CUDA related. | Maximizing Unified Memory Performance in CUDA |
| 10/09<br>[L14] | CUDA Case Studies<br>b) Vector Reduction in CUDA<br>c) Parallel Prefix Scan on the GPU. | In-class quiz – 4. | White paper on NVIDIA's Grace Hopper.<br>Skim through GPU Tech Conference (GTC) talk titles. [use "Search" feature & keywords].<br>1990 paper on prefix scan. A 2017 paper on prefix scan. |
| 10/11<br>[L15] | Streams, and overlapping data copy with execution.<br>Debugging & Profiling execution on the GPU | | Detailed micro-benchmarking study, for Volta.<br>CUDA C Best Practices Guide.<br>CUDA Warp-Level primitives. |
| 10/13<br>[L16] | GPU Computing: Advanced Features. | HW06 out (due 10/19):<br>GPU/CUDA related. | GTC 2022 talk on CUDA. |
| 10/16<br>[L17] | GPU Computing with `thrust` and `cub` | | Paper on `thrust` in GPU Gems 4, by Nathan Bell and Jared Hoberock. |

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| 10/18 [L18] | GPU Tensor Core Aspects | In-class quiz – 5. | Material on doing GPU computing via Python |
| 10/20 [L19] | Hardware aspects relevant in multi-core, shared memory parallel computing | HW07 out (due 10/26): thrust/cub related | Document on unified memory, a chronological take |
| 10/23 [L20] | Multi-core Parallel Computing with OpenMP. Parallel Regions | | GTC talk about multi-GPU computing. |
| 10/25 [L21] | OpenMP Work Sharing | In-class quiz – 6. | Workshop material on node performance optimization (Supercomputing 2019) |
| 10/27 [L22] | OpenMP synchronization<br>Scoping aspects in OpenMP<br>[OpenMP NUMA Aspects – supplemental]<br>Caching and OpenMP | HW08 out (due 11/02): OpenMP related | Workshop material OpenMP 5.0 and advanced host performance (Supercomputing 2019)<br>Workshop material on OpenMP tasks (Supercomputing 2019) |
| 10/30 [L23] | Critical Thinking. Code Optimization Aspects | | **Final Project Proposal due 9 PM** |
| 11/01 [L24] | Computing with Supercomputers. | In-class quiz – 7. | Chapter 12, from Agner Fog's optimization tutorial |
| 11/03 [L25] | MPI Parallel Programming<br>General Introduction, Point-to-Point Communication | HW09 out (due 11/09): OpenMP related | 2005 article of Dongarra et al. for an overview of HPC |
| 11/06 [L26] | MPI Parallel Programming<br>Point-to-Point communication:<br>Blocking vs. Non-blocking sends | | Workshop material, advanced MPI programming (Supercomputing 2019) [advanced] |
| 11/08 [L27] | MPI Parallel Programming:<br>MPI Collectives<br>Overview of topics covered in the class | In-class quiz – 8. | |
| 11/10 | NO CLASS | HW10 out (due 11/**17** - 9 PM): OpenMP/MPI related | |
| 11/13 | NO CLASS | | |
| 11/15 | **EVENING EXAM** | **Review @ 7:30 PM, on **TUESDAY**<br>Exam @ 7:30 – 9:30 PM.<br>Room: 1800EH** | **NOTE: Review will be online, via Zoom. It will be recorded. Exam is face-to-face.** |
| 11/17 | NO CLASS | | |
| 11/20 | NO CLASS | | |
| 11/22 | NO CLASS | | |
| 11/24 | NO CLASS | | |
| 11/27 | NO CLASS | | |
| 11/29 | NO CLASS | | |
| 12/01 | NO CLASS | | |
| 12/04 | NO CLASS | | |
| 12/06 | NO CLASS | | |
| 12/08 | NO CLASS | | |
| 12/11 | NO CLASS | | |
| 12/13 | NO CLASS | **Final Project Due @ 9 PM<br>Portfolio for "Class Participation" Due @ 9PM** | |

**Comprehensive Exam: November 15, at 7:00 PM**
**(Review Session: November 14, at 7 pm – online, will be recorded)**

**Final Project due date: 12/13/2022, 9 PM**
**(submitted via `GitLab`)**