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

Fall 2023 – Tentative Syllabus

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| Date | Title | HW Assigned Quiz dates | Recommended Reading. Other Observations | | |
| 09/06 [L01] | Syllabus related issues.  Course overview. |  | Linux Command Line [basics](https://www.guru99.com/linux-commands-cheat-sheet.html). | | |
| 09/08 [L02] | From Code to Machine Instructions. The FDX Cycle. Instruction Level Parallelism. | HW01 out (due 09/14):  C programming related | Clone this [GitHub repo](https://github.com/DanNegrut/ME759-2023) and read the FAQ and Slurm scripts therein. Read & re-read the C material covered in [ME459](https://uwmadison.app.box.com/s/e140oyofn3sbm2zck642pq7vem3ze4ep). Read about [Euler and “module”](https://uwmadison.box.com/s/ftr8kuqzpjata9fdl7r6l79czzp5x0ul). | | |
| 09/11 [L03] | Superscalar architectures. Measuring Computer Performance. Memory Aspects |  | Read gdb tutorial in [ME459](https://uwmadison.app.box.com/s/e140oyofn3sbm2zck642pq7vem3ze4ep). Read Chapter 5 of Brian W. Kernighan and Dennis M. Ritchie “The C Programming Language” [book](https://uwmadison.box.com/s/2ll8t5dz4ldk5k2sypip76u8jwoh1je7). | | |
| 09/13 [L04] | The memory hierarchy. Caches. | In-class quiz – 1. | Build Management & CMake in [ME459](https://uwmadison.app.box.com/s/e140oyofn3sbm2zck642pq7vem3ze4ep) (p.387 & on). | | |
| 09/15 [L05] | Caches, wrap up. Virtual Memory | HW02 out (due 09/21):  C programming related | Read the git material covered in [ME459](https://uwmadison.app.box.com/s/e140oyofn3sbm2zck642pq7vem3ze4ep) (p.484 & on). Read how to produce a [good commit comment](https://chris.beams.io/posts/git-commit/). | | |
| 09/18 [L06] | The Walls to Sequential Computing. Moore’s Law. Parallel Computing. Flynn’s Taxonomy. Amdahl’s Law. |  | Read the [Amdahl](https://uwmadison.box.com/s/z21zx63u3n3swxk23luex6mv0n9az96a) article.  Good & short [writeup](https://uwmadison.box.com/s/29ouafiyxr3wp2sqxhzich230jnfozw2) on Virtual Memory. [Nice article](https://www.wsj.com/tech/silicon-alternatives-diamond-glass-boron-arsenide-ab1d340a?st=92wx0vxrlks3ixo&reflink=desktopwebshare_permalink) about somewhat mitigating Power Wall | | |
| 09/20 [L07] | GPU Computing Intro. The CUDA Programming Model. CUDA Execution Configuration | In-class quiz – 2. | [Knuth paper on premature optimization.](https://uwmadison.box.com/s/40oh4cw2j0tlouf6ip6fqv2guegrn6rz) | | |
| 09/22 [L08] | GPU Memory Spaces | HW03 out (due 09/28):  GPU/CUDA related | Read Lighterra [article](http://www.lighterra.com/papers/modernmicroprocessors/). | | |
| 09/25 [L09] | GPU Scheduling Issues. Execution Divergence. Control Flow in CUDA. |  | Read [ACM article](https://queue.acm.org/detail.cfm?id=3372264) about C++ compiler optimizations | | |
| 09/27 | **NO CLASS** | **DAN OUT OF TOWN** | Read about the [Latest Tesla Architecture](https://uwmadison.box.com/s/c3j9jiy6feq31qh4nuuli9ce40xebvlb) | | |
| 09/29  [L10] | CUDA Shared Memory Issues. | HW04 out (due 10/05):  GPU/CUDA related | Skim through [CUDA Programming Guide](https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html). | | |
| 10/02 [L11] | CUDA Shared Memory Issues  Global Memory Access Patterns and Implications. |  | GPU computing evolution [article](https://uwmadison.box.com/s/o63jve7gq6kn9f473btedx2k4tp33m34) of Nickolls & Dally | | |
| 10/04 [L12] | Global Memory Access Patterns and Implications.  Data hazard in parallel computing | In-class quiz – 3. | [Intro discussion on Unified Memory in CUDA](http://www.drdobbs.com/parallel/unified-memory-in-cuda-6-a-brief-overvie/240169095) | | |
| 10/06 [L13] | Atomic operations in CUDA.  GPU code optimization rules of thumb  CUDA Case Studies:  a) Vector Reduction in CUDA. | HW05 out (due 10/12):  GPU/CUDA related. | [Maximizing Unified Memory Performance in CUDA](https://devblogs.nvidia.com/maximizing-unified-memory-performance-cuda/) | | |
| 10/09 [L14] | CUDA Case Studies  b) Parallel Prefix Scan on the GPU.  c) 1D Stencil Operation. |  | White paper on NVIDIA’s [Grace Hopper](https://nvdam.widen.net/s/qjzrmfdn2j/nvidia-grace-hopper-superchip-architecture-whitepaper-v1.0).  Skim through GPU Tech Conference (GTC) talk [titles](http://on-demand-gtc.gputechconf.com/gtcnew/on-demand-gtc.php).  [use “Search” feature & keywords].  1990 [paper](https://uwmadison.box.com/s/777us22pryzbo9sp0v6i2hvqt4hggiy6) on prefix scan. A 2017 [paper](https://uwmadison.box.com/s/l9xwdodapjc6c6ki5dru0ztqp740y5ed) on prefix scan. | | |
| 10/11 [L15] | Streams, and overlapping data copy with execution. | In-class quiz – 4. | Detailed micro-benchmarking [study](https://uwmadison.box.com/s/qdmt5f9qxpnbx431t2oo7neh6a7ri6zs), for Volta. [CUDA C Best Practices Guide](http://docs.nvidia.com/cuda/pdf/CUDA_C_Best_Practices_Guide.pdf).  [CUDA Warp-Level primitives](https://developer.nvidia.com/blog/using-cuda-warp-level-primitives/). | | |
| 10/13 [L16] | GPU Computing: Advanced Features.  Debugging & Profiling execution on the GPU | HW06 out (due 10/19):  GPU/CUDA related. | GTC 2022 [talk](https://rd.yyrcd.com/CUDA/2022-GTC/S41486-CUDA%20New%20Features%20and%20Beyond.pdf) on CUDA. | | |
| 10/16 [L17] | GPU Computing with thrust and cub |  | [Paper](https://uwmadison.box.com/s/5gdq2gaqf15xjl1cd550ttsko782fbaz) on thrust in GPU Gems 4, by Nathan Bell and Jared Hoberock. | | |
| 10/18 [L18] | GPU Tensor Core Aspects | In-class quiz – 5. | Material on doing [GPU computing via Python](https://uwmadison.box.com/s/mrtjqny4szl83tw5qze0ny8y9rtb85n4) | | |
| 10/20 [L19] | Hardware aspects relevant in multi-core, shared memory parallel computing | HW07 out (due 10/26):  thrust/cub related | [Document](https://sbel.wisc.edu/wp-content/uploads/sites/569/2018/05/TR-2014-09.pdf) on unified memory, a chronological take | | |
| 10/23 [L20] | Multi-core Parallel Computing with OpenMP. Parallel Regions |  | | | GTC [talk](https://developer.download.nvidia.com/video/gputechconf/gtc/2019/presentation/s9139-multi-gpu-programming-models.pdf) about multi-GPU computing. |
| 10/25  [L21] | OpenMP Work Sharing Scoping aspects in OpenMP | In-class quiz – 6. | | Workshop material on [node performance optimization](https://uwmadison.box.com/s/cvva3ybaq0867e160hqf6l92yp9gbthx)  (Supercomputing 2019) | |
| 10/27 [L22] | OpenMP synchronization  [OpenMP NUMA Aspects – supplemental]  Performance issues, OpenMP related | HW08 out (due 11/02):  OpenMP related | Workshop material [OpenMP 5.0 and advanced host performance](https://uwmadison.box.com/s/dftxq7z83u6bc1e33lbihhcuvb5ek2uc) (Supercomputing 2019)  Workshop material on [OpenMP tasks](https://uwmadison.box.com/s/40yxdvu41prgvfuzvv668lhx78eafos0) (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](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwju75C19_zVAhWp7IMKHUkrBd0QFggoMAA&url=http%3A%2F%2Fwww.agner.org%2Foptimize%2Foptimizing_cpp.pdf&usg=AFQjCNGP0nMMAIT_TFVmh4NvK43_Ef-dOw) | |
| 11/03 [L25] | MPI Parallel Programming General Introduction, Point-to-Point Communication | HW09 out (due 11/09):  OpenMP related | | 2005 article of Dongarra et al. for an [overview of HPC](https://uwmadison.box.com/s/fi2h0s0d4rgvviepc1dd92m9jqoemq86) | |
| 11/06 [L26] | MPI Parallel Programming  Point-to-Point communication:  Blocking vs. Non-blocking sends |  | | Workshop material, advanced [MPI programming](https://uwmadison.box.com/s/ymhcrw7xc49u3cvs86jeva9bnek99sfe) (Supercomputing 2019) [advanced] | |
| 11/08 [L27] | MPI Parallel Programming: MPI Collectives  Overview of topics covered in the class | In-class quiz – 8. | |  | |
| 11/10 | NO CLASS | HW10 out (due 11/**20** - 9 PM):  OpenMP/MPI related | |  | |
| 11/13 | NO CLASS |  | |  | |
| 11/15 | **EVENING**  **EXAM** | **Review @ 7:30 PM, on \*\*TUESDAY\*\***  **Exam @ 7:25 – 9:05 PM.** **Room:  Biochem 1120 (even last digit) Microb Sc. 1520 (otherwise)** | | **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**  **Portfolio for “Class Participation” Due @ 9PM** | | | |

**Comprehensive Exam: November 15, at 7:25 – 9:05 PM**  
**(Review Session: November 14, at 7 pm – online, will be recorded)**

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