

# ECE531: Advanced Operating Systems

University of Maine — Fall 2023

## Instructor:

Vincent Weaver, [vincent.weaver@maine.edu](mailto:vincent.weaver@maine.edu)

Office Hours: Barrows 203, 11:00am - noon Wed/Thurs (or e-mail for appointment)

**Lectures:** Barrows 123, Tuesday/Thursday 12:30pm-1:45pm

This course is offered in-person, synchronous

**Course Website:** [https://web.eece.maine.edu/~vweaver/classes/ece531\\_2023f/](https://web.eece.maine.edu/~vweaver/classes/ece531_2023f/)

## Course Description:

This course covers advanced concepts in modern operating system kernels, including virtual memory, filesystems, scheduling, device drivers, multitasking, and security. Assignments will involve writing a small custom operating system kernel from scratch that runs on actual hardware.

## Prerequisites:

ECE471 or ECE331 or permission of instructor (The course requires C programming skills and it would be helpful to be familiar with ARM assembly language)

**Required Textbooks:** None

## Optional Textbooks:

- *Modern Operating Systems* by A.S. Tanenbaum.
- *Understanding the Linux Kernel* by Bovet and Cesati.
- *UNIX Systems for Modern Architecture* by Schimmel

## Required Hardware:

We will be using a Raspberry Pi Model 2 or 3 for the homeworks. At a minimum you will need a Pi, a memory card, a USB-micro cable, and a USB-serial adapter. If you have trouble obtaining these I can possibly loan them out for the semester.

**Student Learning Outcomes:** Upon completing this course, you will be able to:

1. Define the characteristics of an Operating System
2. Know how to program Raspberry Pi Hardware at a low-level
3. Know what a bootloader is and how it works
4. Know what constitutes a compiler, assembler, and linker
5. Understand and be able to write device drivers
6. Know about simple console input and output (serial UARTs and Graphics / Framebuffer)
7. Know how Virtual Memory works
8. Understand what filesystems are for (fat32, ext4, btrfs, journaling)
9. Understand how to implement a multi-tasking OS, including Job Scheduling
10. Understand the challenges of Operating Systems on multi-core machines
11. Explore computer security issues found on modern processors.

## Topics Covered:

1. General Operating System Concepts
2. Operating System Programming
  - Compiler and assembler
  - Linkers and Linker scripts
3. Operating System Booting
  - Bootloader design
  - Resource enumeration with Device-tree
4. Low-Level ARM Processor Programming
  - Bare-metal programming
  - Interrupts and DMA
  - Timers and clocks
5. Device Driver Programming
  - Serial Port Input/Output
  - Graphics/GPU Programming
6. Kernel / Userspace Communication
  - Executable File Formats
  - System Calls
  - `io_uring`
7. Filesystem Concepts
  - Modern filesystem design concepts such as journaling and btree usage
  - ext4, btrfs, and fat32 case studies
8. Multi-tasking, Multi-threading and Multi-core
  - Job scheduling
  - Context Switching
  - Locking
9. Virtual Memory
10. Computer Security

## Grading:

Class Participation (5%)

11 homework assignments (50% total), the lowest grade will be dropped

The homeworks will encompass the low-level coding of the custom operating system.

2 midterm exams (25% total)

1 final project (with writeup and in-class presentation) (20%)

## **Course Policies:**

Please submit work on time.

Late work is penalized at 10% a day.

Once solutions are published late work cannot be accepted for credit.

## **Requesting Help on Coding Assignments:**

If you have trouble with your code not working, the easiest way for me to help is if you send me your code. The full code is much easier to debug than screenshots. I'll do my best to respond in a timely manner, but for best results try to give me at least 24 hours to respond.

## **Covid/Mask Policy:**

We will generally follow UMaine policy. If you have COVID, please don't come to class, let me know we'll work something out. If you're feeling sick for any reason you are encouraged to wear a mask.

## **Academic Honesty:**

- Please do not submit other people's work as your own
- Do not copy, cut-and-paste or re-type code that you didn't write yourself (this includes code from classmates, the internet, or AI).
- Do not use AI when completing assignments
- Do not share copies of other people's code, from this or previous years. It's distressingly common for people to somehow "accidentally" submit code they receive this way
- What can you do?
  - + You may always discuss assignments and share code with the Professor
  - + You may always discuss assignments and share code with with the TA
  - + You may discuss assignments at a high level with classmates
  - + You may have classmates look at your code to look for obvious problems (ideally over your shoulder and not by sending them the full code)
  - + When actually writing the code the submitted code must be yours and yours alone
- Those committing academic dishonesty will obtain a zero for all assignments involved in the incident with possibly more consequences depending on the seriousness of the incident

## University of Maine Campus Policies

### Academic Honesty Statement

Academic honesty is very important. It is dishonest to cheat on exams, to copy term papers, to submit papers written by another person, or generated by software or systems without the explicit approval of the instructor, to fake experimental results, or to copy or reword parts of books or articles into your own papers without appropriately citing the source. Students committing or aiding in any of these violations may be given failing grades for an assignment or for an entire course, at the discretion of the instructor. In addition to any academic action taken by an instructor, these violations are also subject to action under the University of Maine Student Conduct Code. The maximum possible sanction under the student conduct code is dismissal from the University.

Please see the University of Maine System's Academic Integrity Policy listed in the Board Policy Manual as Policy 314: <https://www.maine.edu/board-of-trustees/policy-manual/section-314/>

### Students with disabilities statement

If you have a disability for which you may be requesting an accommodation, please contact Student Accessibility Services, 121 East Annex, [um.sas@maine.edu](mailto:um.sas@maine.edu), 581.2319, as early as possible in the term. Students may begin the accommodation process by submitting an accommodation request form online and uploading documentation at [https://umaine-accommodate.symplicity.com/public\\_accommodation/](https://umaine-accommodate.symplicity.com/public_accommodation/). Once students meet with SAS and eligibility has been determined, students submit an online request with SAS each semester to activate their approved accommodations. SAS creates an accessibility letter each semester which informs faculty of potential course access and approved reasonable accommodations; the letter is sent directly to the course instructor. Students who have already been approved for accommodations by SAS and have a current accommodation letter should meet with me (the instructor of the course) privately as soon as possible.

### Course Schedule Disclaimer (Disruption Clause)

In the event of an extended disruption of normal classroom activities (due to COVID-19 or other long-term disruptions), the format for this course may be modified to enable its completion within its programmed time frame. In that event, you will be provided an addendum to the syllabus that will supersede this version.

### Observance of Religious Holidays/Events

The University of Maine recognizes that when students are observing significant religious holidays, some may be unable to attend classes or labs, study, take tests, or work on other assignments. If they provide adequate notice (at least one week and longer if at all possible), these students are allowed to make up course requirements as long as this effort does not create an unreasonable burden upon the instructor, department or University. At the discretion of the instructor, such coursework could be due before or after the examination or assignment. No adverse or prejudicial effects shall result to a student's grade for the examination, study, or course requirement on the day of religious observance. The student shall not be marked absent from the class due to observing a significant religious holiday. In the case of an internship or clinical, students should refer to the applicable policy in place by the employer or site.

### Sexual Discrimination Reporting

The University of Maine is committed to making campus a safe place for students. Because of this commitment, if you tell a faculty or staff member who is deemed a "responsible employee" about an experience of sexual assault, sexual harassment, stalking, relationship abuse (dating violence and domestic violence), sexual misconduct or any form of gender discrimination involving members of the campus, they are required to report this information to Title IX Student Services or the Office of Equal Opportunity.

**If you want to talk in confidence** to someone about an experience of sexual discrimination, please contact these resources:

For *confidential resources on campus*: Counseling Center: 207-581-1392 or Cutler Health Center: at 207-581-4000.

For *confidential resources off campus*: Rape Response Services: 1-800-871-7741 or Partners for Peace: 1-800-863-9909.

Other resources: The resources listed below can offer support but may have to report the incident to others who can help:

For support services *on campus*: Title IX Student Services: 207-581-1406, Office of Community Standards: 207-581-1406, University of Maine Police: 207-581-4040 or 911.

Visit the Title IX Student Services website at [umaine.edu/titleix/](http://umaine.edu/titleix/) for more information.