Sistemas Operativos Avanzados

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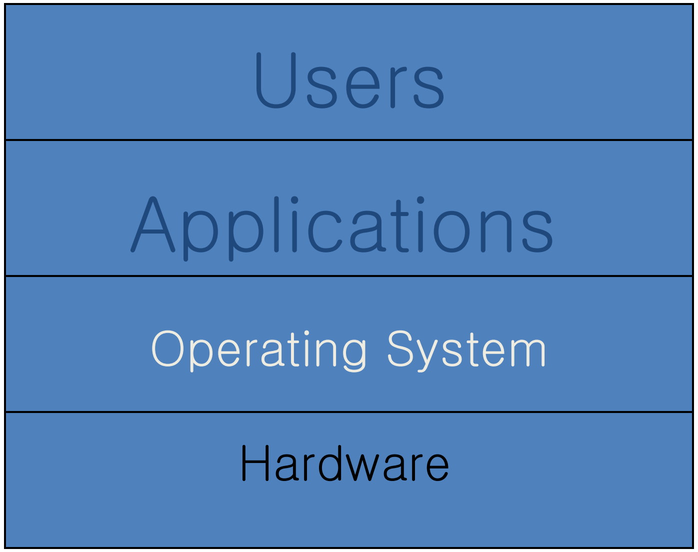
https://ceunican.github.io/aos/
https://www.ce.unican.es/course/soa/

What is an Operating System?

Operating System (OS):

Software that converts hardware into a useful form for applications

Not easy to define precisely…



Users

Applications

Operating System

Hardware

What DOES OS Provide?

- Role #1: Abstraction - Provide standard library for resources

- What is a resource?
  - Anything valuable (e.g., CPU, memory, disk, I/O device)

- What abstraction does modern OS typically provide for each resource?
  - CPU:
    - process and/or thread
  - Memory:
    - address space
  - Disk:
    - files

- Advantages of OS providing abstraction?
  - Allow applications to reuse common facilities
  - Make different devices look the same
  - Provide higher-level or more useful functionality

- Challenges
  - What are the correct abstractions?
  - How much of hardware should be exposed?

What DOES OS Provide?

- Role #2: Resource management – Share resources well

- Advantages of OS providing resource management?
  - Protect applications from one another
  - Provide efficient access to resources (cost, time, energy)
  - Provide fair access to resources

- Challenges
  - What are the correct mechanisms?
  - What are the correct policies?

OS Organization

- How to cover all the topics relevant to operating systems?

Three PIECES

- Virtualization:
  - Make each application believe it has each resource to itself

- Concurrency:
  - Events are occurring simultaneously and may interact with one another

- Persistence: Permanence of access to information
  - Lifetime of information is longer than the lifetime of a single process
  - Machine can be restarted, machine can lose power or crash unexpectedly

Advanced Topics (beyond our reach)

- Current systems
  - Multiprocessors
  - Networked and distributed systems
  - Virtual machines
  - Containers
  - …

- Many of the pushed by the explosive demand (a.k.a. Massive complexity under constrained cost)

- This is the support of the world: it will keep changing …

- Some of them covered in SVS (M1679)

Why study Operating Systems?

- Build, modify, or administer an operating system

- Understand system performance
  - Behavior of OS impacts entire machine
  - Tune workload performance
  - Apply knowledge across many layers
    - Computer architecture, programming languages, data structures and algorithms, and performance modeling

- Fun and challenging to understand large, complex systems

- **Is the glue that "holds" all the ideas in place**

Approach

- We will follow the "Operating System: Three Easy Pieces" (OSTEP) style
  - From the **basic** concepts to state-of-the-art approaches
  - Eminently **practical** style: all supported by "simulators" and simple coding examples
  - Assumes some **basic** knowledge in architecture, C, assembler and system administration
  - More than just a textbook…

- Structure
  - The three parts are split in small *pieces* (~40 in the book)
  - Each chapter builds on the previous one (can't miss the beat)
  - Each chapter has attached a "Homework" to reinforce it: from using python simulators to write small pieces of code (C)
  - 5 + 1 Labs, to develop on top of **xv6**

Lecture/Lab structure

- We mix dynamically both
  - The real thing is that there is no separation between “theory” and “lab”

- Sessions of:
  - 1st hour: Introduction to the topic
  - 2nd hour: Introduce/develop of Labs
  - Personal work (out the lab): 6 hours (labs and homework)
  - 10 hours/week
  - Strict schedule

- Although the original course/book is designed for 15-week semester (150h work), we will need to drop some details or advanced topics (and half of the labs)

Material

- Available in http://www.ce.unican.es/

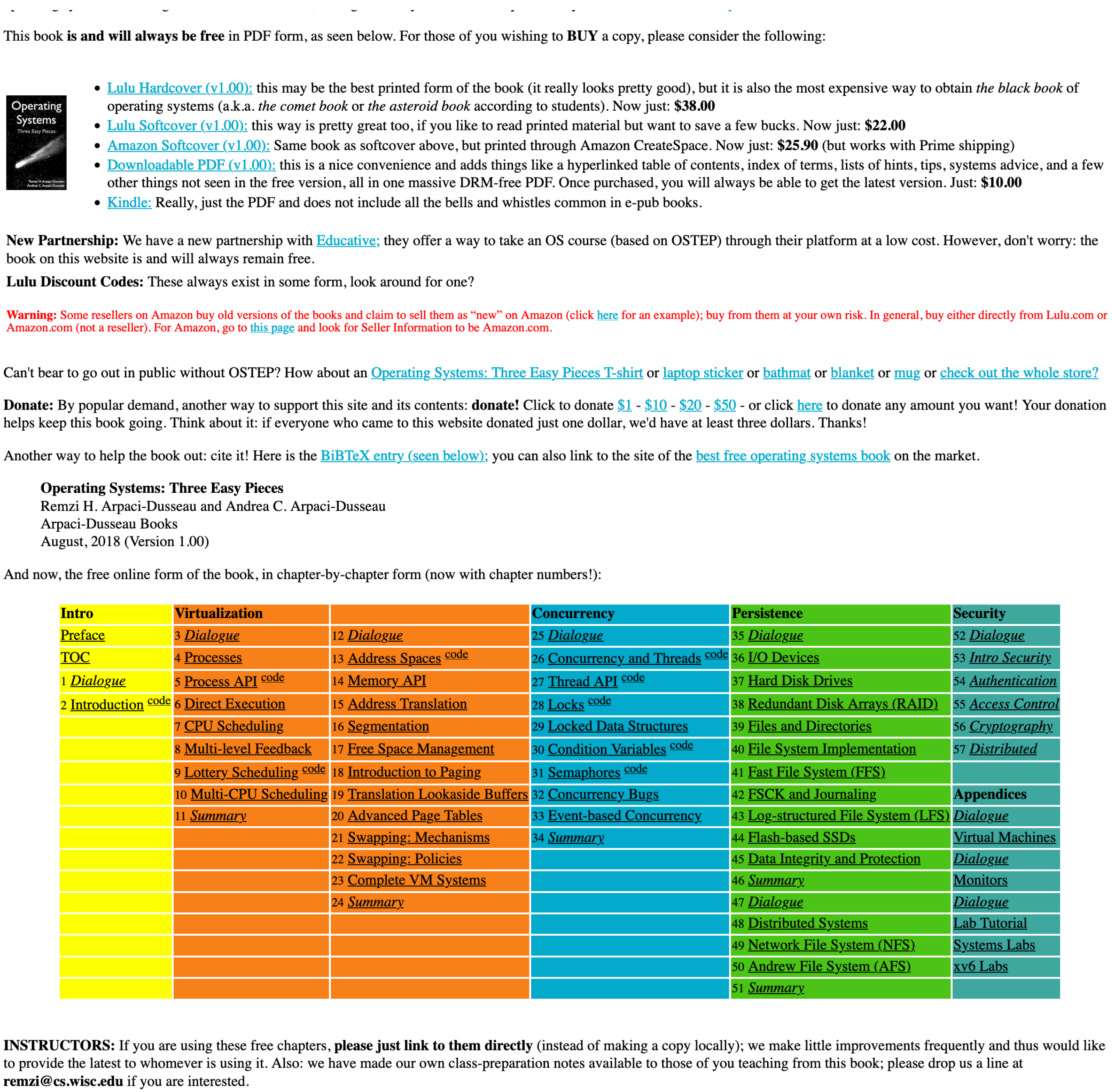
- All written material will be in "English"
  - Lecture notes, Homework/Lab guides, etc.…

- *Git* as communication "device": all material will be delivered via http://github.com
  - An e-mail inviting to join the course project will be sent to unican account
  - Slides, labs, other reference material is there
  - It uses "git" to have a "time-track"
    - Lecture notes updates
    - Additional material

- Use git to allow you and me "track" your personal work

- Use Github **Discussions** for questions

Book (ostep.org)



This book **is and will always be free** in PDF form, as seen below. For those of you wishing to **BUY** a copy, please consider the following:

- Lulu Hardcover (v1.00): this may be the best printed form of the book (it really looks pretty good), but it is also the most expensive way to obtain *the black book* of operating systems (a.k.a. *the comet book* or *the asteroid book* according to students). Now just: **$38.00**
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- Downloadable PDF (v1.00): this is a nice convenience and adds things like a hyperlinked table of contents, index of terms, lists of hints, tips, systems advice, and a few other things not seen in the free version, all in one massive DRM-free PDF. Once purchased, you will always be able to get the latest version. Just: **$10.00**
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Another way to help the book out: cite it! Here is the BiBTeX entry (seen below); you can also link to the site of the best free operating systems book on the market.

> **Operating Systems: Three Easy Pieces**
> Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau
> Arpaci-Dusseau Books
> August, 2018 (Version 1.00)

And now, the free online form of the book, in chapter-by-chapter form (now with chapter numbers!):

Intro	Virtualization		Concurrency	Persistence	Security
Preface	3 *Dialogue*	12 *Dialogue*	25 *Dialogue*	35 *Dialogue*	52 *Dialogue*
TOC	4 Processes	13 Address Spaces code	26 Concurrency and Threads code	36 I/O Devices	53 *Intro Security*
1 *Dialogue*	5 Process API code	14 Memory API	27 Thread API code	37 Hard Disk Drives	54 *Authentication*
2 Introduction code	6 Direct Execution	15 Address Translation	28 Locks code	38 Redundant Disk Arrays (RAID)	55 *Access Control*
	7 CPU Scheduling	16 Segmentation	29 Locked Data Structures	39 Files and Directories	56 *Cryptography*
	8 Multi-level Feedback	17 Free Space Management	30 Condition Variables code	40 File System Implementation	57 *Distributed*
	9 Lottery Scheduling code	18 Introduction to Paging	31 Semaphores code	41 Fast File System (FFS)	
	10 Multi-CPU Scheduling	19 Translation Lookaside Buffers	32 Concurrency Bugs	42 FSCK and Journaling	**Appendices**
	11 *Summary*	20 Advanced Page Tables	33 Event-based Concurrency	43 Log-structured File System (LFS)	*Dialogue*
		21 Swapping: Mechanisms	34 *Summary*	44 Flash-based SSDs	Virtual Machines
		22 Swapping: Policies		45 Data Integrity and Protection	*Dialogue*
		23 Complete VM Systems		46 *Summary*	Monitors
		24 *Summary*		47 *Dialogue*	*Dialogue*
				48 Distributed Systems	Lab Tutorial
				49 Network File System (NFS)	Systems Labs
				50 Andrew File System (AFS)	xv6 Labs
				51 *Summary*	

INSTRUCTORS: If you are using these free chapters, **please just link to them directly** (instead of making a copy locally); we make little improvements frequently and thus would like to provide the latest to whomever is using it. Also: we have made our own class-preparation notes available to those of you teaching from this book; please drop us a line at **remzi@cs.wisc.edu** if you are interested.

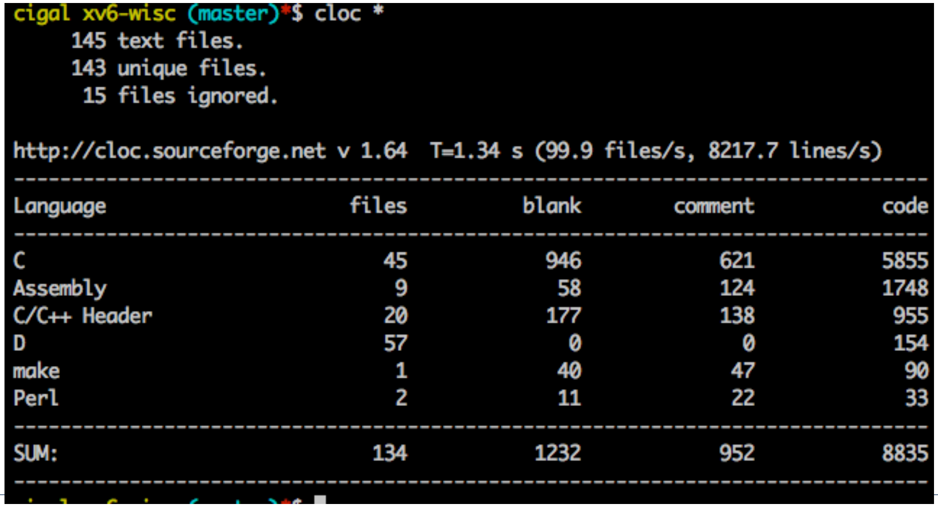
Homework

- Some chapter (most) include homework
  - Homework will reinforce your understanding of the material covered in each chapter.
  - Most homework assignments involve running simulators that **mimic** certain aspects of operating systems. For instance, a disk scheduling simulator can help in comprehending the functioning of various disk scheduling algorithms.
    - Most of them provides the **solution**
  - Some home-works are just short programming exercises, allowing you to explore how real systems work and complement Lab work.

- Homework are done in **personal-time**

Labs: C and xv6

- Refresh C knowledge
- Use a "toy" kernel to dig into implementation details
  - It is a clean and beautiful little kernel, and thus a perfect object for our study and use.
  - It was developed by OS Eng. In MIT as a port of K&R original Unix R6/PDP11 (6.828 and 6.S081)
  - Many possibilities
    - **X86**, **riscv**, ARM,….
    - **C**, rust,..



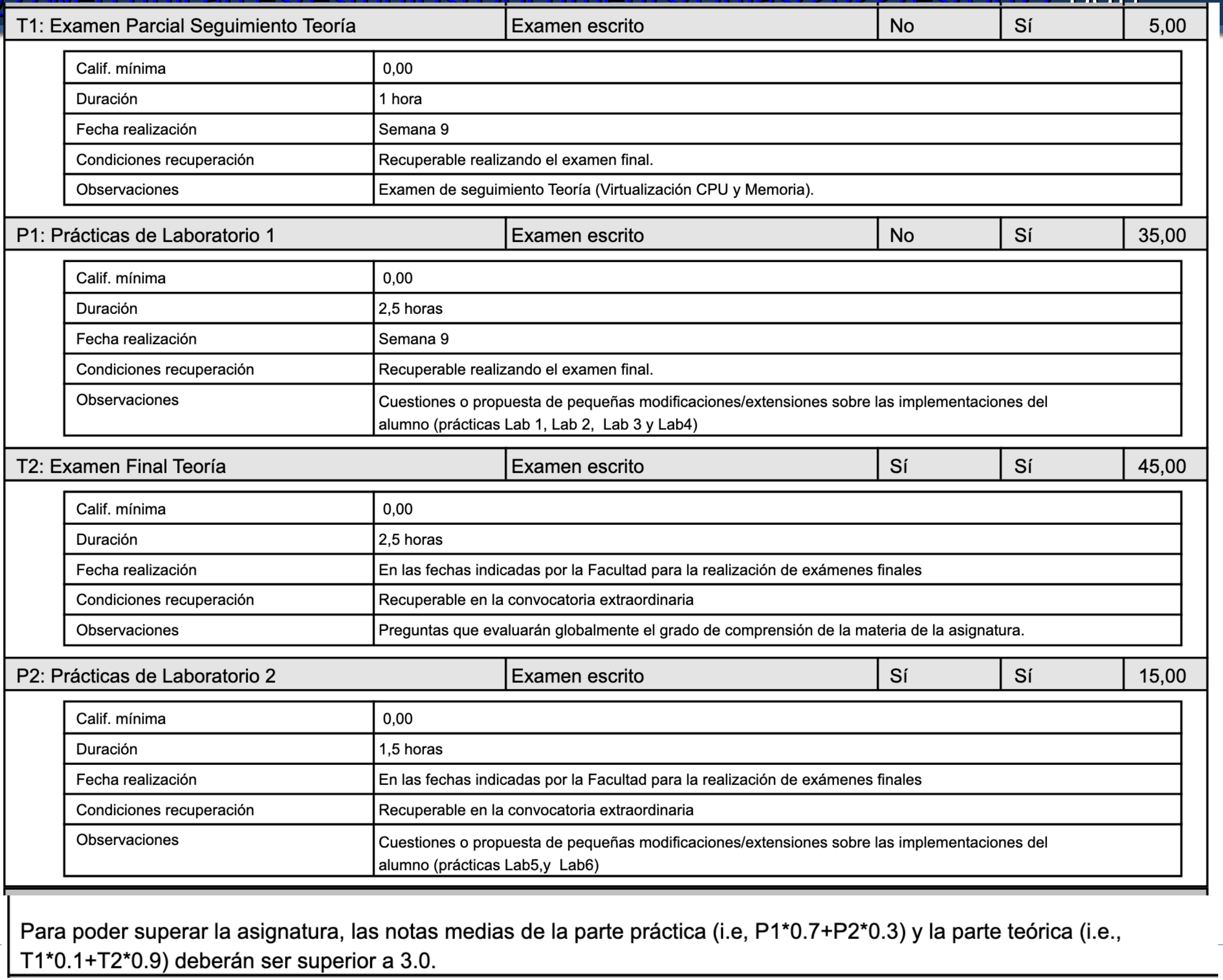
```
cigal xv6-wisc (master)*$ cloc *
     145 text files.
     143 unique files.
      15 files ignored.

http://cloc.sourceforge.net v 1.64  T=1.34 s (99.9 files/s, 8217.7 lines/s)
--------------------------------------------------------------------------------
Language                     files          blank        comment           code
--------------------------------------------------------------------------------
C                               45            946            621           5855
Assembly                         9             58            124           1748
C/C++ Header                    20            177            138            955
D                               57              0              0            154
make                             1             40             47             90
Perl                             2             11             22             33
--------------------------------------------------------------------------------
SUM:                           134           1232            952           8835
--------------------------------------------------------------------------------
```

Prerequisites

- All OS and architecture previous subjects(ugh!)

Evaluation (http://web.unican.es/estudios/Documents/Guias/2022/es/G677.pdf)



T1: Examen Parcial Seguimiento Teoría	Examen escrito	No	Sí	5,00

Calif. mínima	0,00
Duración	1 hora
Fecha realización	Semana 9
Condiciones recuperación	Recuperable realizando el examen final.
Observaciones	Examen de seguimiento Teoría (Virtualización CPU y Memoria).

P1: Prácticas de Laboratorio 1	Examen escrito	No	Sí	35,00

Calif. mínima	0,00
Duración	2,5 horas
Fecha realización	Semana 9
Condiciones recuperación	Recuperable realizando el examen final.
Observaciones	Cuestiones o propuesta de pequeñas modificaciones/extensiones sobre las implementaciones del alumno (prácticas Lab 1, Lab 2, Lab 3 y Lab4)

T2: Examen Final Teoría	Examen escrito	Sí	Sí	45,00

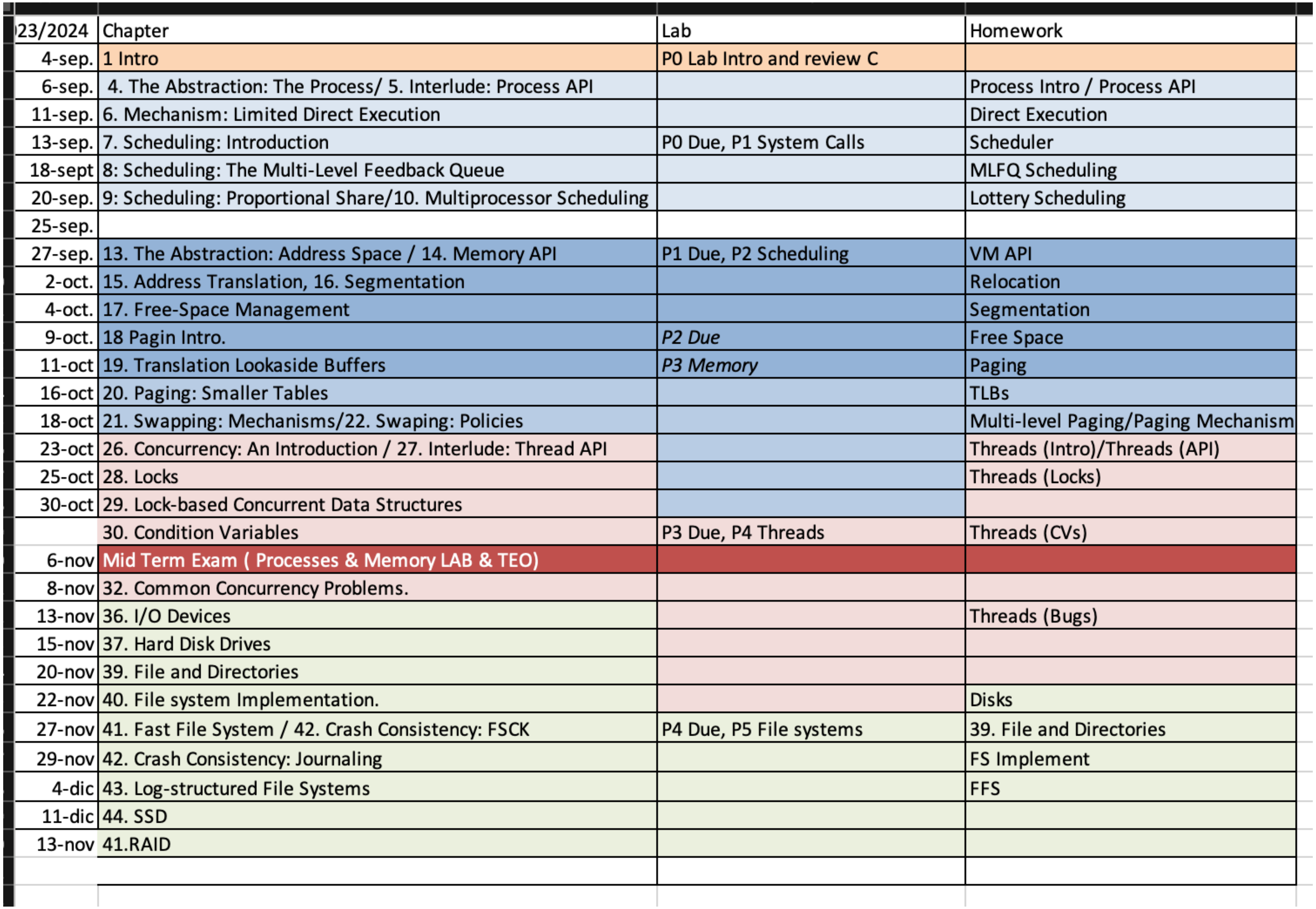
Calif. mínima	0,00
Duración	2,5 horas
Fecha realización	En las fechas indicadas por la Facultad para la realización de exámenes finales
Condiciones recuperación	Recuperable en la convocatoria extraordinaria
Observaciones	Preguntas que evaluarán globalmente el grado de comprensión de la materia de la asignatura.

P2: Prácticas de Laboratorio 2	Examen escrito	Sí	Sí	15,00

Calif. mínima	0,00
Duración	1,5 horas
Fecha realización	En las fechas indicadas por la Facultad para la realización de exámenes finales
Condiciones recuperación	Recuperable en la convocatoria extraordinaria
Observaciones	Cuestiones o propuesta de pequeñas modificaciones/extensiones sobre las implementaciones del alumno (prácticas Lab5,y Lab6)

Para poder superar la asignatura, las notas medias de la parte práctica (i.e, P1*0.7+P2*0.3) y la parte teórica (i.e., T1*0.1+T2*0.9) deberán ser superior a 3.0.

Schedule (tentative)



23/2024	Chapter	Lab	Homework
4-sep.	1 Intro	P0 Lab Intro and review C	
6-sep.	4. The Abstraction: The Process/ 5. Interlude: Process API		Process Intro / Process API
11-sep.	6. Mechanism: Limited Direct Execution		Direct Execution
13-sep.	7. Scheduling: Introduction	P0 Due, P1 System Calls	Scheduler
18-sept	8: Scheduling: The Multi-Level Feedback Queue		MLFQ Scheduling
20-sep.	9: Scheduling: Proportional Share/10. Multiprocessor Scheduling		Lottery Scheduling
25-sep.			
27-sep.	13. The Abstraction: Address Space / 14. Memory API	P1 Due, P2 Scheduling	VM API
2-oct.	15. Address Translation, 16. Segmentation		Relocation
4-oct.	17. Free-Space Management		Segmentation
9-oct.	18 Pagin Intro.	*P2 Due*	Free Space
11-oct	19. Translation Lookaside Buffers	*P3 Memory*	Paging
16-oct	20. Paging: Smaller Tables		TLBs
18-oct	21. Swapping: Mechanisms/22. Swaping: Policies		Multi-level Paging/Paging Mechanism
23-oct	26. Concurrency: An Introduction / 27. Interlude: Thread API		Threads (Intro)/Threads (API)
25-oct	28. Locks		Threads (Locks)
30-oct	29. Lock-based Concurrent Data Structures		
	30. Condition Variables	P3 Due, P4 Threads	Threads (CVs)
6-nov	Mid Term Exam (Processes & Memory LAB & TEO)		
8-nov	32. Common Concurrency Problems.		
13-nov	36. I/O Devices		Threads (Bugs)
15-nov	37. Hard Disk Drives		
20-nov	39. File and Directories		
22-nov	40. File system Implementation.		Disks
27-nov	41. Fast File System / 42. Crash Consistency: FSCK	P4 Due, P5 File systems	39. File and Directories
29-nov	42. Crash Consistency: Journaling		FS Implement
4-dic	43. Log-structured File Systems		FFS
11-dic	44. SSD		
13-nov	41.RAID		