Course Review

and Preparing for the Final Exam

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News & Agenda

- P5: Threads due Tonight 11:59 PM ET
  - Late submissions close April 24th 11:59 PM ET
- Last Recitation
- No Office Hours During Finals Week
  - Will respond to questions via Discord
- OMETs
  - Recitation TA feedback survey will be sent out at term's end (via email)

Today

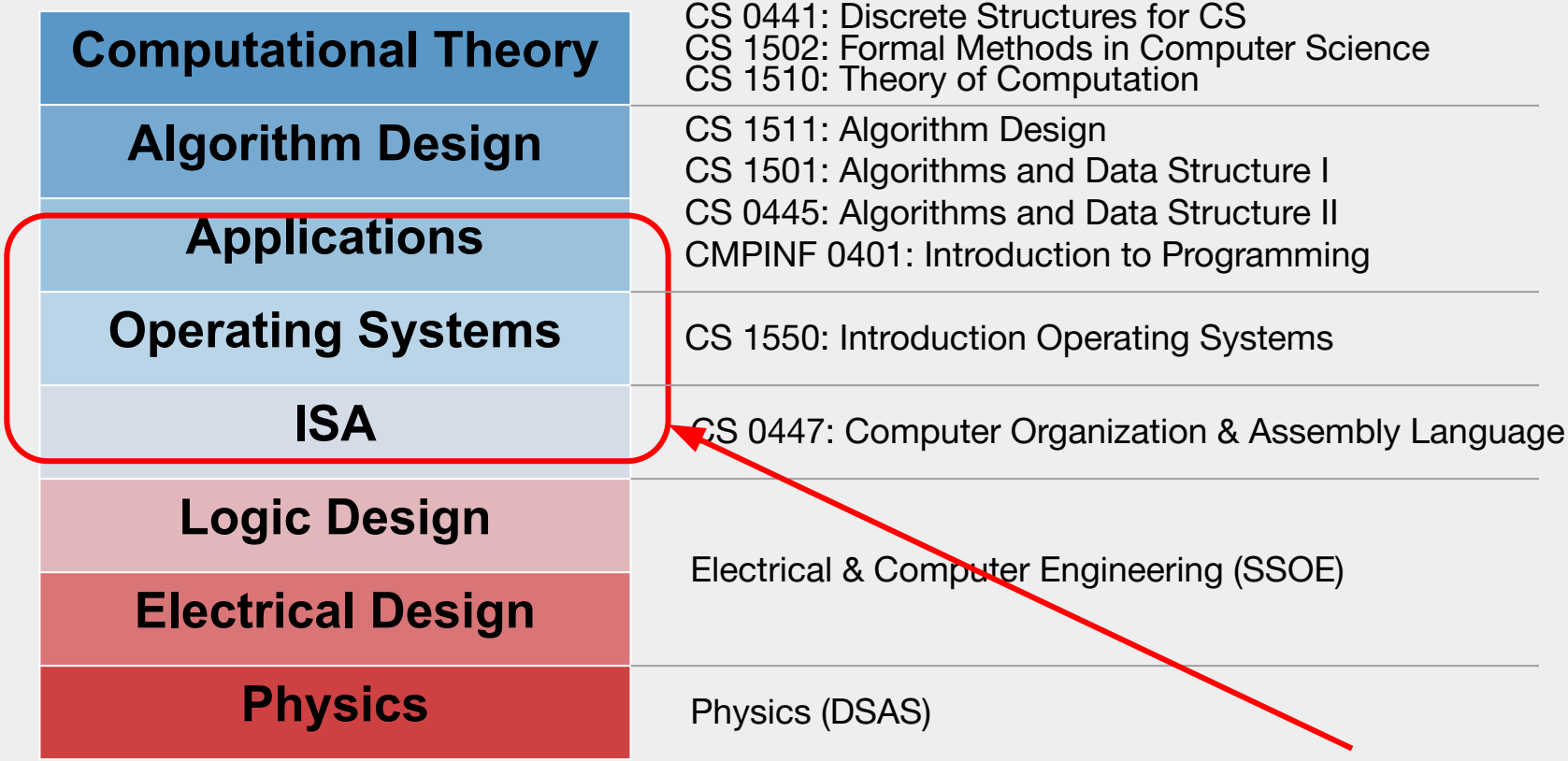
- Course Review
- Final Review

Course Review

What we've been building up to

Course Review:

CS 0449 is a broad course



Course Theme:

Abstraction Is Good, but Don't Forget Reality

- Most computer science courses emphasize abstraction
  - In CS 0445, you used Java to *abstract* the details of your data structures (ADTs)
    - You *computed* run-time using asymptotic analysis (Big-Oh)
- But in reality, abstractions have limits
  - Especially in the presence of bugs
  - Sometimes, you need to understand details of underlying implementations
- CS 0449 aims to make you a better programmer
  - By teaching you to find and eliminate bugs efficiently
  - By teaching you to understand and tune for program performance
- CS 0449 prepares for later "systems" courses in CS
  - Operating Systems, Compilers, Networks, Computer Architecture, Embedded Systems, Storage Systems, etc.

Final Exam Review

Final Exam

My Exam Schedule > Spring Term 2022-2023 > University of Pittsburgh Personalize | |

Class	Class Title	Exam Date	Exam Time	Exam Room	Enrolled
CS 0449-1200 (23984)	INTRO TO SYSTEMS SOFTWARE (Lecture)	4/26/2023, Wednesday	8:00AM - 9:50AM	405 Information Sciences Build	50
CS 0449-1300 (29544)	INTRO TO SYSTEMS SOFTWARE (Lecture)	4/26/2023, Wednesday	4:00PM - 5:50PM	5201 Wesley W Posvar Hall	50

- Similar in format to Exam I & II
  - 110 minutes allotted
  - Cumulative, but an **emphasis** on new topics
- Study Materials
  - Solutions to Exam I & II on Discord
  - Past exams, quizzes, GS labs

Potential Topics non-inclusive

Content from first ⅓ of course

- Data Representation
  - Binary, Hexadecimal, Signed, Unsigned, C data types (their sizes and implications)
- C Programming
  - Syntax, Properties, Pre-processor, Types of Variables, Structs, Quirks of C
  - Bitwise Manipulation
- Memory
  - C Memory Model, Address Space (stack/heap), Memory Allocation methods, Endianness
  - Pointers & Arrays, Pointer Arithmetic, Strings
  - Where does *x* live?
- Input/Output (BMP project)
  - Syntax
  - Streams

Potential Topics non-inclusive

Content from second ⅓ of course

- Memory Management (Malloc project!)
  - Static vs Dynamic Memory Allocation
    - Malloc!
  - Linked Lists and other approaches/implementations
- Assembly (Bomb project!)
  - x86-64 syntax, common patterns, Stack
- Buffer Overflow (Attack project!)
- Linking and Loading
  - Steps of compilation
  - *X* happens in what step?
- Process Management (Shell project!)
  - Fork-Exec Model

Potential Topics non-inclusive

Content from last ⅓ of course

- Process Management
  - Scheduling and Interrupts
  - System Calls
- Virtual Memory
  - Address Space
  - Segmentation, Paging (← calculations needed!)
- Threads & Synchronization (Thread project!)
  - Creating, Managing Threads via Pthread Library
  - Synchronization Primitives
  - Parallel Pitfalls

Final Exam Review

Lab 6 Solutions

Q1.1 Scheduling Processes

- Which of the following would not be part of the process metadata, as tracked by the operating system?

(1) CPU Registers
(2) Normal Page Table Address
(3) Inverted Page Table
(4) Process ID

Correct Answer Rate: 61%

Q1.2 Scheduling Processes

- If we have 5 processes in a round-robin scheduler with a quantum of 50ms a piece, and we increase the priority of ONE process such that it now runs for 200ms, how much time of the entire scheduling cycle does the prioritized process run?

Correct Answer Rate: 86%

Q1.2 Scheduling Processes

Which of the following would need to be changed as part of context switching?

- [ ] Register values
- [ ] Which Page Table is being used
- [ ] Decrement the process ID
- [ ] Increment the process ID

Correct Answer Rate: 79%

Q2

- If one of a process's memory addresses is bigger than a second one, then its corresponding value must appear before the second one's value in physical memory. True or False?

Correct Answer Rate: 98%

Q3 Virtual Memory

- A program tries to load a word at address X that does not cause a page fault. Are the following statements True or False?
  - The page table does not contain a valid mapping for the virtual page corresponding to the address X
  - The word that the program is trying to load is present in physical memory

Correct Answer Rate: 90%

Q4 Virtual Memory

External fragmentation is caused when:

- [ ] A memory needs to be padded for alignment purposes.
- [ ] A user writes data to a part of the memory that doesn't belong to the page.
- [ ] There are many disjoint free pages in the heap.
- [ ] Many pages are being used.

Correct Answer Rate: 91%

Q5 Page Tables

Consider the following hypothetical system:

- It uses a normal page table (indexed by virtual page)
- 16-bit virtual addresses
- 64 KiB of RAM with 4kiB pages
- A PTE (Page Table Entry) contains bits for valid (V), read (hidden), write (W), and execute (X) totaling 32b

Q5.1 Translation for the 16-bit virtual address 0xe8d3

index	valid	write	execute	page address
0	0	0	0	0x6
…				
8	0	1	0	0x4
9	1	0	0	0x4
10	1	0	0	0x2
11	0	0	0	0x4
12	0	0	0	0x3
13	0	1	0	0xa
14	1	1	1	0x3

Correct Answer Rate: 54%

Q5.2

- Segment of the process mapped above must start at no less than which virtual address

index	valid	write	execute	page address
0	0	0	0	0x6
1	0	0	0	0x6
2	0	0	0	0x2
3	1	0	0	0xf
4	0	0	1	0xc
5	1	1	0	0xd
6	1	1	0	0xc
7	0	1	0	0x3

index	valid	write	execute	page address
...				
8	0	1	0	0x4
9	1	0	0	0x4
10	1	0	0	0x2
11	0	0	0	0x4
12	0	0	0	0x3
13	0	1	0	0xa
14	1	1	1	0x3

Correct Answer Rate: 35%

Q5.3 How much memory required to store PT?

- It uses a normal page table (indexed by virtual page)
- 16-bit virtual addresses
- 64 KiB of RAM with 4kiB pages
- A PTE (Page Table Entry) contains bits for valid (V), read (hidden), write (W), and execute (X) totaling 32b

Correct Answer Rate: 66%

Q6

- Consider a slightly more realistic system. The system has 32-bit virtual addresses and 4KiB pages. The system has 2GiB of addressable memory.

Correct Answer Rate: 70%

Q6.1 How many bits needed to represent a PT offset?

- Consider a slightly more realistic system. The system has 32-bit virtual addresses and 4KiB pages. The system has 2GiB of addressable memory.

Correct Answer Rate: 60%

Q6.3 How many bits are needed to represent a PPN?

- Consider a slightly more realistic system. The system has 32-bit virtual addresses and 4KiB pages. The system has 2GiB of addressable memory.

Correct Answer Rate: 51%

Q 6.4

- Assuming it uses a normal page table, each page entry is 32-bits (4 Bytes), and the system where it is used can run up to 4 processes, how much memory is required to store all necessary page tables?

Correct Answer Rate: 54%

Q 6.5

- Now, assume it uses an inverted page table to map its 2GiB of physical memory, each page entry is 32-bits, and the system where it is used can run up to 4 processes, how much memory is required to store all necessary page tables?

Correct Answer Rate: 72%

Closing out the semester

Where to go from here

Where to go from here

- **Architecture**
  - **CS 1541 Introduction to Computer Architecture**
    - Requires CS 445 and CS 447
  - **CS 1567 Programming and System Design Using a Mobile Robot**
    - Requires CS 1550 + Instructor's permission
- **Operating Systems**
  - **1550 Introduction to Operating Systems (Required!)**
    - Requires CS 447 and CS 449(✔)
  - **1651 Advanced Systems Software**
  - Requires CS 1550 or instructor permission

Where to go from here

A graduate electives!

- **Compilers/Programming Languages**
  - **1621 Structure of Programming Languages**
    - Requires CS 0441 and CS 0445
  - **1622 Introduction to Compiler Design**
    - Requires CS 0441 and CS 0447
- **Parallel Computing**
  - 1645 Introduction To High Performance Computing Systems
    - Requires CS 0447 and CS 1501
  - **1538 Introduction to Simulation**
    - Requires CS 0447 and a statistics course
- **Networking**
  - **1652 Data Communications and Computer Networks**
    - Requires CS 1550

Thanks for a great semester

Good luck on your final exams!