McGill

APRIL 2022
FINAL EXAMINATION

Operating Systems – COMP-310-001 / ECSE-427-001

April 20th 2022, 14:00 – 17:00

EXAMINER: **Prof. Oana Balmau**

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STUDENT NAME:		**McGILL ID:**									

EXAM:	CLOSED BOOK ☒ OPEN BOOK ☐
	PRINTED ON BOTH SIDES OF THE PAGE ☐ SINGLE-SIDED ☒
	MULTIPLE CHOICE ANSWER SHEETS: YES ☐ NO ☒ NOTE: The Examination Security Monitor Program detects pairs of students with unusually similar answer patterns on multiple-choice exams. Data generated by this program can be used as admissible evidence, either to initiate or corroborate an investigation or a charge of cheating under Section 17 of the Code of Student Conduct and Disciplinary Procedures. ANSWER BOOKLET REQUIRED: YES ☐ NO ☒ EXTRA BOOKLETS PERMITTED: YES ☐ NO ☒ ANSWER ON EXAM: YES ☒ NO ☐
	SHOULD THE EXAM BE: RETURNED ☒ KEPT BY STUDENT ☐
CRIB SHEETS:	PERMITTED ☐ Specifications: (ex: one 8 1/2X11 handwritten double-sided sheet) NOT PERMITTED ☒
DICTIONARIES:	TRANSLATION ☒ REGULAR ☐ NOT PERMITTED ☐
CALCULATORS:	NOT PERMITTED ☒ PERMITTED (Non-Programmable) ☐ PERMITTED (Programmable) ☐
ANY SPECIAL INSTRUCTIONS: **e.g. molecular models**	**- This document has 11 pages.** Please make sure that you have all the pages. - Please write your name and McGill ID **on every page. This is very**

	important, as your exam will be separated for grading.

Question 1. Operating System Structure [10 points]

Provide a short answer to the following questions:

A. Describe the sequence of steps the **hardware** and the **operating system** go through **when a trap occurs**. Make sure to identify what steps are performed by the hardware and what steps are performed by the operating system. **[4 points]**

B. Which operation is faster: switching between **two different processes** or switching between **two different threads in one process**, or do both have the same cost? **Why?** If your answer is that one is more expensive than the other, then your explanation should include a clear statement of where the extra cost comes from. If there are several contributions to the extra cost, rank them from larger to smaller. **[4 points]**

C. How many times will the program below print hello? Briefly explain why. **[2 points]**

```
main() {
  int i;
  for(i=0; i<3; i++) fork();
  printf("hello\n");
}
```

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Question 2. Process Scheduling [10 points]

Suppose 5 processes arrive at times 0, 2, 4, 5, 8, respectively, and that they take CPU times 4, 5, 4, 2, and 3, respectively. A process becomes ready as soon as it arrives. Show the execution schedule (timelines) on a **single-core machine** for:

A. Preemptive SJF scheduling. **[3 points]**

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P1																					
P2																					
P3																					
P4																					
P5																					

B. A new policy that we call Shortest Remaining Time First (SRTF). With SRTF a newly arriving process preempts the currently running process if its CPU time is smaller than the remaining CPU time of the currently running process. When the currently running process finishes, the ready process with the shortest remaining CPU is allowed to run. **[3 points]**

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P1																					
P2																					
P3																					
P4																					
P5																					

C. From your results of (A) and (B) name one advantage and one disadvantage of SJF and SRTF for this scenario? **[4 points]**

SJF Advantage:

SJF Disadvantage:

SRTF Advantage:

SRTF Disadvantage:

Question 3. Address Translation [10 points]

Given a CPU with 5-bit instructions, and 16 Bytes byte-addressable of physical memory, with the following 3 segments in main memory: SEG 0 (base address: 7_{10}, bound: 2_{10}), SEG 1 (base address: 3_{10}, bound: 3_{10}), SEG 2 (base address: 10_{10}, bound 4_{10}). X_{10} means X in base 10 (decimal).

Compute the virtual to physical address translations (or Segmentation Faults), for the following virtual addresses and explain your answers, e.g. by drawing a schema.

0_{10}, 20_{10}, 17_{10}, 8_{10}, 24_{10}.

Question 4. Multithreading [10 points]

A browser is, basically, an infinite loop consisting of handling events and updating the screen. If you run on a machine with a single core, does it make sense to use multiple threads in the browser? If yes, why? If not, why not?

Question 5. Multi-Level Page Tables [10 points]

Assume that you have a machine with a 16-bit virtual address. The machine is paged, with a page size of 256 Bytes, and a two-level page table scheme, with 16 entries in the top-level page table.

To represent a program with a sparse address space, with valid addresses from 0 to 6K, from 12K to 14K, and from 56K to 64K **what is the number of second-level page table entries needed**? Explain your answer.

Question 6. Caching [10 points]

A. Explain what the terms *write-through* and *write-behind* cache mean. **[2 points]**

B. What is the main advantage of a write-through cache, and what is the main advantage of a write-behind cache? **[4 points]**

C. Most file system caches maintain an exact LRU to govern replacement. Why is this possible for file systems, and not possible for page replacement? **[4 points]**

Question 7. Free Space Management [10 points]

Consider a file system like the basic one seen in class, where free space is tracked by bitmaps: one bitmap tracks the free space for data blocks and the other bitmap tracks free space for inode blocks.

A. Suppose that the bitmap tracking free space in the data blocks is lost, but the inode bitmap is still accessible. Can the file system reconstruct the data blocks bitmap? Explain your answer. **[5 points]**

B. Suppose that the bitmap tracking free space in the inode blocks is lost, but the data blocks bitmap is still accessible. Can the file system reconstruct the inodes bitmap? Explain your answer. **[5 points]**

Question 8. Disk Scheduling [10 points]

None of the disk-scheduling policies, except FCFS, is truly fair. In this context, we call an algorithm “unfair” if starvation may occur. Starvation happens when older requests are delayed by newer requests that arrive later in the I/O queue but are preferred by the disk-scheduling policy.

A. Given this definition of fairness, briefly explain why FCFS is fair and why the SCAN algorithm seen in class is not fair. **[2 points]**

B. Describe a way to modify the SCAN algorithm to increase fairness. **[4 points]**

C. Give a concrete example where I/O requests served by the original version of SCAN would be starved, but your modification in point C would increase fairness. **[4 points]**

Question 9. File System Indexing [10 points]

Assume a hard disk with 1024-byte disk sectors and 4-byte disk addresses. The file system uses inodes with 10 direct block pointers, 2 indirect block pointers, and 1 double-indirect block pointer. The block size is identical to the sector size of the disk.

A user process opens a file of length 2GB, and issues read requests for the following blocks of this file: 50, 200, 51, 199, 10000. **What is the number of disk sector accesses for each block?** Complete the table below and briefly explain how you obtained each result.

Assume that prior to the open, the inode of the file and the blocks belonging to the file are *not* in the cache, but that there is space in the cache to store all of them. You may also assume that there is no file system activity going on, other than the accesses to this particular file.

Block accesses **[5 points]**:

Block	50	200	51	199	10000
#Accesses					

Explanations **[5 points]**:

50:

200:

51:

199:

10000:

Question 10. RAID [10 points]

For a RAID system with a total of 5 disks, answer the following for RAID levels 0 and 5.

A. How much usable storage does the system have, if each individual disk has 2 GBytes of storage? Explain your answer. **[2 points]**

B. For a workload consisting only of reads of a single stripe, evenly distributed, what is the throughput in stripe reads per second, assuming a single disk does 100 stripe reads per second? **[4 points]**

C. For a workload consisting only of writes of a single stripe, evenly distributed, what is the throughput in stripe writes per second, assuming a single disk does 100 stripe writes per second? **[4 points]**