THE UNIVERSITY of ADELAIDE

Semester 2, 2021

4468,9901	**Operating Systems** **(Undergraduate, Postgraduate)** **COMPSCI 3004, 7064**

Course Coordinators: **Andrey Kan, Bernard Evans**

Total Duration: 90 mins This exam worth 30% of your final mark

Parts	**Questions**	**Recommended Time**	**Marks**
A	6 simple multiple choice questions	10 mins	6 marks
B	5 advanced multiple choice questions	20 mins	10 marks
C	6 short answer questions	25 mins	13 marks
D	6 open-ended questions	35 mins	21 marks
			50 Total

Instructions for Candidates

- This is a Closed-book examination.
- Answer all questions in the spaces provided.
- Examination materials must not be removed from the examination room.
- Write your name on the Front Cover of the Exam Paper.

Permitted Materials

- Standard calculator
- Paper translation dictionary
- 2-side A4 page of student's own notes (*must remain in the examination room after the exam*)

DO NOT COMMENCE WRITING UNTIL INSTRUCTED TO DO SO

Part A. Simple Multiple Choice Questions (6 marks in total)
Circle one answer only. Each question is worth 1 mark

A1 Which of the following statements is FALSE? There is only one false statement

A The number of processes executing an application (e.g., MS Word) is unbounded
B A single program can be executed by multiple processes
C An operating system has a way to distinguish between processes executing the same code
D Two processes can simultaneously execute different parts of the same program

A2 Which of the following statements about CPU scheduling is FALSE? There is only one false statement

A There are times when CPU does not execute instructions of any user process
B Preemptive CPU schedulers rely on interrupts
C Some CPU schedulers will wait until a process voluntary relinquishes the CPU
D Doubling the number of CPU cores reduces the time required for any calculation by half

A3 Which of the following statements about synchronisation is FALSE? There is only one false statement

A Busy waiting is a necessary requirement for a solution to critical section problem
B Race condition can occur on a system with a single CPU core
C Shared access to read-only resources do not need to be protected by a mutex
D Disabling interrupts can be used to achieve mutual exclusion

A4 Which of the following is NOT a possible consequence of a page fault in demand paging? Select one answer

A Context switch
B Reading data from a solid-state drive
C Sensing a timer interrupt
D Executing a page replacement algorithm

A5 Consider error correction and detection codes. Which of the following statements is FALSE? There is only one false statement

A The use of the parity bit will always tell whether the data was corrupted
B The use of an error correction code imposes space overhead
C Parity bit can be used for error correction only if additional information is available
D Not every RAID level uses parity bits

A6 Consider an access matrix that describes who can access which object. Which of the following statements is FALSE? There is only one false statement

A The same access matrix can be stored in different ways
B The access matrix defines a protection policy
C Access matrix can specify who is allowed to modify this matrix
D Each cell of the access matrix describes at most one operation

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Part B. Advanced Multiple Choice Questions (10 marks in total)
Multiple answers are possible. Each question is worth 2 marks

B1. Which of the following statement(s) about synchronisation tools are TRUE?

A Binary semaphore is equivalent to a mutex lock
B A mutex can be unlocked only by a process that locked it
C A process can only acquire one mutex at a time
D Mutex lock contention indicates a deadlock

B2. Consider communication between the CPU and an I/O device controller. Which of the following statement(s) are TRUE?

A I/O controller is a piece of hardware
B Polling and interrupts are two approaches for synchronizing the CPU with an I/O device
C CPU is blocked (cannot execute instructions) while I/O is in operation
D I/O controller can write results to CPU registers

B3. Which of the following statement(s) about secondary storage are TRUE?

A In a block-based secondary storage device, blocks can only be read in consecutive order
B Operating system accumulates several I/O requests before sending them to a device
C Combining multiple storage devices in a RAID array does not always increase reliability
D A file system is necessary in order to store data on a block-based device (e.g., HDD)

B4. Consider using a linked list for keeping track of free blocks in a block-based secondary storage device. Which of the following statement(s) are TRUE?

A Half of the free space will be lost due to overhead incurred by the list
B I/O required for each step of list traversal
C Identifying an empty block can be done efficiently
D Using the list will result in contiguous location of all free blocks on the device

B5. Consider an online shopping platform that stores user passwords in the hashed form. Salting is NOT applied. Which of the following statement(s) are TRUE?

A The admin of this platform can unambiguously recover original plain text passwords
B There is a non-zero probability that a user will be able to login with a wrong password
C Several users can have identical hashes for their passwords
D Hashes can be decrypted using a private key

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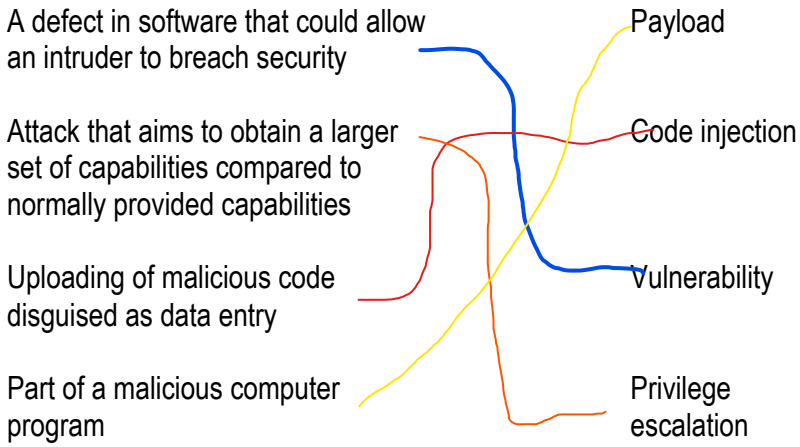
Part C. Short Answer Questions (13 marks in total)
Answer all questions in the spaces provided.

C1. (2 marks) Identify the technical name / term for each of the following descriptions. Write your answer in the empty box next to each description. The first row shows an example. You need to complete other rows.

Description	Term (one or two words)
A table that maps page numbers to frame numbers. This table has a row for each page	Page table
Set of pages referenced within the most recent window of time with a predefined duration	working set
Empirical observation that within a short period of time processes tend to access the same set of memory locations	locality
Process is busy swapping pages in and out, while CPU utilization is low	thrashing
The page referenced by a process is not mapped to a memory frame	page fault

C2. (2 marks) Draw four lines connecting concepts with the best matching description



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C3. (3 marks) Consider the following sets of processes, with the length of the CPU-burst time given in milliseconds.

Process	Arrival Time	Burst Time
P1	0	6
P2	1	4
P3	4	6
P4	2	3

(i) Identify average waiting time under First-Come-First-Served scheduling
Numerical answer for (i):

5.5

waiting time is the time a P wait in queue

(ii) Identify average waiting time under Shortest-Remaining-Job-First scheduling (preemptive).
Numerical answer for (ii):

4.75

C4. (3 marks) A machine has 32 bit virtual addresses and 24 bit physical addresses. The page size is 1K bytes. Here is the TLB:

Page number	Frame number
0x000789	0x0030
0x000084	0x050a
0x000021	0x1000
0x000860	0x268b

Hint: Recall that 0x … denotes a hexadecimal number. A hexadecimal number can be easily converted to a binary number by converting each hexadecimal digit into four binary digits. For example hexadecimal number 0x1a3 is 000110100011, because hexadecimal digit 1 is 0001, hexadecimal digit a is 1010, and hexadecimal digit 3 is 0011.

(i) What is the size of **physical memory** in this system?
Numerical answer for (i):

(ii) Which physical frame contains virtual address 0x002183a6?
Numerical answer for (ii) in hexadecimal format:

PLEASE SEE NEXT PAGE

C5. (1 mark) Consider locality in memory referencing. Suppose that a process referenced memory pages in the following order: 7 7 2 3 5 3 2 4 3 5 3 2 6 7 6 7 3. Consider a working-set windows of 5 references. What is the size of the latest working set? Provide a numerical answer only.

Numerical answer:

C6. (2 marks) Consider a secondary storage device (e.g., hard disk drive) treated as an array of blocks. Each block is 1024 bytes. There are 2^{16} = 65,536 blocks in total. Indexed allocation is used for this device.

In your answer, provide a number with the most appropriate size unit (e.g., KB, MB, etc.).

(i) What is the maximum file size in case there is no indirection (one-level index)?
Numerical answer for (i):

256 x 1024

(ii) What is the maximum file size with one level of indirection (two levels in total)?
Numerical answer for (ii):

256^2 x 1024

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Part D. Open-ended Questions (21 marks in total)
Answer all questions in the spaces provided.

D1. (3 marks) **Processes**: Explain and compare the terms program, process and thread

Program: static code stored in the disk

Process: execution stream of instructions in the context of a process state or a running program

Thread: a lightweight process. Multiple threads share the same memory space, but each has its own stack, so they can execute independently.

D2. (3 marks) **CPU scheduling**: Explain how priority scheduling can result in starvation of some processes. Propose a solution that allows priority scheduling without process starvation

Higher priority processes can monopolize the CPU, leading lower priority processes do not have any runtime.

A solution: round robin policy, or periodically push every process into the highest priority level.

PLEASE SEE NEXT PAGE

D3. (4 marks) **Virtual memory**: Consider two choices for a memory page size: a large page (e.g., 4 KB) and a small page (e.g., 1KB). Discuss advantages and disadvantages of each choice

A large page: increase TLB hit but is bigger so slower. Increase internal fragmentation. Smaller page table.

A small page: decrease TLB hit, but is faster to access. Reduce internal fragmentation. Bigger page table.

D4. (4 marks) **Virtual memory**: Describe a limitation of the optimal page replacement algorithm. How to get around this limitation?

It is not practical, since we can not look into the future.

We can use LRU, or the CLOCK, which can somewhat predict the future using historical data.

PLEASE SEE NEXT PAGE

D5. (3 marks) **Synchronization**: Does an implementation of a mutex require hardware support? Explain why or why not

Mutex requires hardware support to achieve atomic behaviors.

D6. (4 marks) **Cryptography**: Consider secure communication between parties A and B. Summarize steps for sending a secure message from A to B using a hybrid encryption scheme. Why is symmetric algorithm alone not sufficient? Why is asymmetric algorithm alone not sufficient?

END OF EXAMINATION PAPER