University of St Andrews

MARTINMAS 2024-25 EXAMINATION DIET
SCHOOL OF COMPUTER SCIENCE

MODULE CODE: **CS3104**

MODULE TITLE: OPERATING SYSTEMS

EXAM DURATION: 3 hours

EXAM INSTRUCTIONS:
(1) Answer **ALL THREE** questions.
(2) Each question carries 20 marks.
(3) Answer questions in the script booklet.

YOU MUST HAND IN THIS EXAM PAPER AT THE END OF THE EXAM

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1. **Memory**

(a) Assume a virtual address space size of 38-bits, and a physical address space size of 24-bits. The system page size is 2 KiB, and 32-bit page table entries are in use.

i. In a hierarchical paging system, how many page table entries fit into a single page?

[1 mark]

ii. How many bits in the page table entry can be used to store page table entry flags?

[1 mark]

iii. How many levels of page tables are required to map the full 38-bit virtual address space? Identify the bit ranges of the virtual address that correspond to the index for each level, and the offset in the page.

[4 marks]

(b) Consider an x86 page table entry:

Physical Page Address	AVL	G	0	D	A	CD	WT	U	W	P

i. What is the purpose of the *present* (P) flag?

[1 mark]

ii. What is the purpose of the *user/supervisor* (U) flag?

[2 marks]

iii. What is the purpose of the *dirty* (D) flag, and what components update the flag's value? Give an example of how the Operating System can use this flag to its advantage.

[3 marks]

(c) How is the *Translation Lookaside Buffer* (TLB) used to accelerate virtual-to-physical address calculations? In what circumstances does the Operating System interact with the TLB, and what operations does it need to perform on it?

[4 marks]

(d) Explain the concept of a *memory mapped I/O* (MMIO) interface, and its advantages. Give a concrete example of an MMIO operation.

[4 marks]

[Total marks 20]

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2. **Scheduling**

(a) Consider the following chronological list of processes, with the associated characteristics:

Process	Burst Time	Arrival Time
P1	8	0
P2	3	2
P3	1	3
P4	4	3
P5	4	5
P6	2	6

i. Draw Gantt charts for the execution of these processes using **First-Come-First-Served (FCFS)**, **Shortest-Job-First (SJF)**, and **Round-Robin (RR)** (with a quantum of 2) scheduling algorithms.

[6 marks]

ii. What is the turn around time for each process, for each algorithm?

[3 marks]

iii. Compute the average waiting time for each schedule. Which algorithm gives the minimal average waiting time?

[3 marks]

(b) How does a timer interrupt enable Operating Systems to support pre-emptive multitasking?

[2 marks]

(c) Considering mutexes as a form of synchronisation:

i. Give brief descriptions of two incorrect usages of a mutex, and how they can lead to a deadlock.

[2 marks]

ii. Give an example of how one of these deadlocks can be mitigated in the design of the mutex itself.

[1 mark]

(d) Explain the difference between concurrency and parallelism, giving an example that demonstrates this difference.

[3 marks]

[Total marks 20]

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3. **File Systems**

(a) Give examples of *two* different types of removable media, and a brief overview of their physical architecture.

[4 marks]

(b) A hard disk has the following queue of disk cylinders to be accessed:

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180, 174, 43, 80, 22, 190, 25, 195
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Assume a disk cylinder range of 0–199, with the head starting at 60.

i. Give the order of access under both a **Shortest Seek Time First (SSTF)** and **C-SCAN** schedule (assume the head is moving *up*).

[4 marks]

ii. Which of these scheduling strategies provides the least disk head movement?

[1 mark]

(c) Assume a system contains four 1 TiB hard-disk drives.

i. What is the total storage capacity, when all four drives are configured for the following RAID strategies: RAID0, RAID1, RAID5?

[3 marks]

ii. Explain the characteristics of the RAID6 strategy, in terms of layout, performance and resilience.

[3 marks]

(d) Describe the file system interface presented by a Linux/Unix system, and explain three different file system operations.

[3 marks]

(e) Give one example each of *per-process* and *system-wide* file system state.

[2 marks]

[Total marks 20]

***** END OF PAPER *****