THE UNIVERSITY OF QUEENSLAND
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School of Information Technology and Electrical Engineering

Semester Two Examinations, 2022

COMP3301 Operating Systems Architecture

This paper is for St Lucia Campus students.

Examination Duration: 120 minutes

Planning Time: 10 minutes

Exam Conditions:

•This is a Closed Book examination - no written materials permitted
•Casio FX82 series or UQ approved and labelled calculator only
•During Planning Time - Students are encouraged to review and plan responses to the exam questions
•This examination paper will be released to the Library

Materials Permitted in the Exam Venue:
(No electronic aids are permitted e.g. laptops, phones)

None

Materials to be supplied to Students:
Additional exam materials (e.g. answer booklets, rough paper) will be provided upon request.

None

Instructions to Students:
If you believe there is missing or incorrect information impacting your ability to answer any question, please state this when writing your answer.

Answer all questions.
Total: 120 Marks

For Examiner Use Only

Question	Mark
1	
2	
3	
4	
5	
6	

Total _____

Question 1. (20 marks)

Calculate performance metrics for various process schedulers.

All of the schedulers are pre-emptive – a process is pre-empted as soon as a higher priority process appears.

In the following tables, times are all in milliseconds.
Assume processes do not stall for I/O. Ignore scheduler delays.
Processes that miss their deadline are not included in the calculation of individual and average completion time, turnaround time, waiting time or throughput. The CPU time of aborted processes is included in CPU utilisation.

(a) Complete the following tables for an Earliest Deadline First (EDF) Scheduler.

Process Number	Arrival Time	Execution Time	Deadline	Completion Time	Turnaround Time	Waiting Time
P1	0	4	7			
P2	5	4	15			
P3	6	1	11			
P4	10	4	14			
P5	13	1	30			
P6	14	4	25			

Average Waiting Time	
Average Turnaround Time	
Actual CPU Utilisation	
Average Throughput	

Process Timeline Table. Mark where a process Starts (S), Runs (R), Pauses (P), Ends (E). You can add more columns if required.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
P1																																								
P2																																							
P3																																							
P4																																							
P5																																							
P6																																							

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Question 1 (continued).

(b) Repeat part a) but now assume that two CPU cores (core 1 and core 2) can be used to run processes, concurrently. Complete the following tables for an Earliest Deadline First (EDF) Scheduler. You must consider the core affinity (core 1, core 2 or X – any core). You can assume that a process with no affinity (X) can run on any core.

Process Number	Arrival Time	Execution Time	Deadline	Core Affinity	Completion Time	Turnaround Time	Waiting Time
P1	0	4	7	1			
P2	5	4	15	2			
P3	6	1	11	X			
P4	10	4	14	2			
P5	13	1	30	1			
P6	14	4	25	X			

Average Waiting Time	
Average Turnaround Time	
Actual CPU Utilisation	
Average Throughput	

Process Timeline Table (Mark where a process Starts (S), Runs (R), Pauses (P), Ends (E). You can add more columns if required.

Core 1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
P1																																								
P5																																							
P3																																							
P6																																							

Core 2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
P2																																								
P4																																							
P3																																							
P6																																							

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Total ____ / 20

Question 2. (20 marks)

Consider a file system where disk block addresses are represented by a 32-bit integer. A disk block is **2048** bytes long.

Assume that a single command (read or write) to the disk controller consists of a starting disk block address, the number of contiguous blocks to read/write, and the location of the memory buffer for the data. Assume that commands can be sent continuously to the controller (you don't need to wait until the previous one has been serviced unless the next read needs the contents of the previous block). Assume that disk requests are serviced in the order received and with a latency of **5ms** between each request (from the end of the previous data transfer or from the time the command was received, whichever is longer), and a streaming transfer rate of one block per **50µs**.

Now, consider a direct access file currently consisting of the following blocks, listed below, and calculate the requested information for each particular file system below. Assume that CPU operation times can be neglected. Assume that the whole file can fit into memory if needed.

Disk Blocks used for a file:
50, 78, 96, 101, 234, 321, 456, 678, 789, 890, 1234, 2340, 3459, 5623, 8990, 12056, 23560, 37450, 78900

../Question 2 continued over the page

Question 2 (continued)

(a) Index allocation File System
Assumptions – the file control block is in memory, the file index allocation table is in memory, any new data that needs to be written to the file is in memory. Assume the disk blocks in the file are not contiguous.

Calculate the number of disk controller commands, the number of disk block I/O operations (i.e. total number of disk block reads and writes), and the total time to complete each of the following operations.

Disk Blocks used for a file (copied from previous page for convenience):
50, 78, 96, 101, 234, 321, 456, 678, 789, 890, 1234, 2340, 3459, 5623, 8990, 12056, 23560, 37450, 78900

	Number of disk controller commands	Number of disk block I/O operations	Total Time
(i) One block is added to the end of the file.			
(ii) One block is added to the beginning of the file.			
(iii) Data in location 8066 (bytes, from top of file) is altered.			
(iv) One block is removed from the end of the file.			
(v) Block 890 is removed from the file.			
(vi) The file is deleted (data does not need to be overwritten).			

Working

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../Question 2 continued over the page

Question 2 (continued)
(b) Linked File System
Assumptions – the file control block is in memory, each file block contains a link to the next file block, any new data that needs to be written to the file is in memory. Assume the disk blocks in the file are not contiguous.

Calculate the number of disk controller commands, the number of disk block I/O operations (i.e. total number of disk block reads and writes), and the total time to complete each of the following operations.

Disk Blocks used for a file (copied from previous page for convenience):
50, 78, 96, 101, 234, 321, 456, 678, 789, 890, 1234, 2340, 3459, 5623, 8990, 12056, 23560, 37450, 78900

	Number of disk controller commands	Number of disk block I/O operations	Total Time
(i) One block is added to the end of the file.			
(ii) One block is added to the beginning of the file.			
(iii) Data in location 8066 (bytes, from top of file) is altered.			
(iv) One block is removed from the end of the file.			
(v) Block 890 is removed from the file.			
(vi) The file is deleted (data does not need to be overwritten).			

Working

/6

../Question 2 continued over the page

Question 2 (continued)

(c) Free Space Map
You can assume the last disk block in the file is the last disk block of the disk volume.
Disk Blocks used for a file (copied from previous page for convenience):
50, 78, 96, 101, 234, 321, 456, 678, 789, 890, 1234, 2340, 3459, 5623, 8990, 12056, 23560, 37450, 78900

(i) Calculate the minimum memory (in Kbytes – assume 1K is 1024 bytes) required to store the bitmap of free space blocks of the disk volume?

/2

(ii) Show a subset of the first 8 bits of the free space bitmap of the file.

/2

(iii) Calculate the minimum memory (in disk sectors – assume sector is 2048 bytes and a pointer is 32 bits long) required to store a linked list of the free space blocks?

/2

(iv) Which file allocation method is best for keeping track of free space and explain why?

/2

Total ____/ 20

Question 3. (20 marks)

The following memory pages are accessed:

1,2,3,1,2,3,0,1,2,4,4,5,5,1,2,1,2,0,1,7,3,1

(a) Calculate the number of page faults if the First In First Out (FIFO) page replacement algorithm is used, with **i)** 3 page buffer and **ii)** 5 page buffer. Also state what the minimum buffer size is to ensure that no page faults occur.

/5

(b) Calculate the number of page faults if the Least Recently Used (LRU) page replacement algorithm is used, with **i)** 3 page buffer and **ii)** 5 page buffer. Also state what the minimum buffer size is to ensure that no page faults occur.

/5

(c) List four different methods of implementing the Least Recently Used (LRU) page replacement algorithm.

/4

../Question 3 continued over the page

Question 3 (continued)

(d) Explain when a page is considered a 'victim' and what must occur?

/3

(e) What is Copy-on-Write? And what variation of the fork function uses it?

/3

Total ____ / 20

Question 4. (20 marks)

(a) What are four benefits of multi-threaded architectures?

/4

(b) For the following multi-threading models, briefly describe each model.

Many to One)

One to One)

Many to Many)

/6

../Question 4 continued over the page

Question 4 (continued)

(c) For the previous multi-threading models, state which model is best for concurrency and why?

/2

(d) What is the difference between a user thread and a kernel thread?

/2

(e) What is a thread library? Also list two ways of implementing it.

/3

(f) What is a hardware thread and state an advantage? Also state the type of CPU architecture that supports hardware threads.

/3

Total ____ / 20

Question 5 (20 marks)

(a) In an OS, what four groups can Input/Output (IO) devices be grouped into? Also give an example application or peripheral (e.g. USB stick) of each type.

i)

ii)

iii)

iv)

/8

(b) Which two IO device registers can be accessed using the c function ioctl()?

/2

../Question 5 continued over the page

Question 5 (continued)

(c) For each IO operation listed below, give a brief explanation and also state a disadvantage.

i) Blocking

ii) Nonblocking

iii) Asynchronous

/6

../Question 5 continued over the page

Question 5 (continued)

(d) For each Kernel IO subsystem listed below, give a brief explanation and also give an example application (e.g. CCID).

i) Caching

ii) Spooling

/4

Total ____ / 20

Question 6. (20 marks)

You have been asked to design an operating system for the new Alset self-driving electric vehicle. The vehicle uses a smart card (with CCID) as a key to lock/unlock the doors and start the vehicle. The vehicle is equipped with realtime parking cameras (high priority and 1ms latency), LIDAR (Laser) scanner for realtime driving (high priority and 1s latency), GPS used for navigation (low priority and 60s latency) and a video display for entertainment (low priority and 1ms latency). The vehicle also comes with a built-in solar panel for power charging and must be kept in direct sunlight. This leads to extreme temperature conditions that causes errors in various electronic devices such as hard drive storage and affect the running of CPU cores.

You can also assume the following:

- The operating systems uses multiple CPU cores for redundancy.
- Magnetic disk mass storage is used, to save cost.
- A list of authorised users is kept in a file on the onboard file system.
- A large video library (stored as files) must be kept on board for the user's selection.
- The vehicle can run for 4 hours before requiring charging.

For each of the indicated aspects of the operating system:

(i) Describe your suggested design alternative,

(ii) Give one other less favourable choice,

(iii) Explain two advantages of the suggested alternative compared to the less favourable choice

(a) What type of Parallelism should be used (Data vs Task)? (i) Suggested solution (ii) Less favoured alternative (iii) Two advantages of suggested solution
/5

../Question 6 continued over the page

Question 6 (continued)

(b) What type of CPU scheduler should be used?
(i) Suggested solution (ii) Less favoured alternative
(iii) Two advantages of suggested solution

/5

../Question 6 continued over the page

Question 6 (continued)

(c) What security mechanism should be used to ensure that only authorised users can access the vehicle?
(i) Suggested solution (ii) Less favoured alternative
(iii) Two advantages of suggested solution

/5

./Question 6 continued over the page

Question 6 (continued)

(d) What RAID Disk level (0 to 6) should be used?
(i) Suggested solution (ii) Less favoured alternative
(iii) Two advantages of suggested solution

/5

Total ____ / 20

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