FACULTY OF SCIENCE

ACADEMY OF COMPUTER SCIENCE AND SOFTWARE ENGINEERING

MODULE	**COMPUTER SCIENCE 3B** CSC3B
CAMPUS	AUCKLAND PARK CAMPUS (APK)
SUPPLEMENTARY EXAM	JANUARY 2021 - **MEMO**
DATE: 2021-01	**SESSION:** Normal
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MODERATOR:	**EXTERNAL: MR. J. PRINSLOO (NWU)**
DURATION: 180 MINUTES	**MARKS:** 150

Please read the following instructions carefully:

1. You are not allowed to assist or gain assistance from anyone during the assessment.
2. Complete the **Honesty Declaration: Online Assessment** and submit it.
3. If you **do not have access to a computer** then you can do a pen and paper submission. Write legibly and use CamScanner to create a PDF.
4. No communication concering this test is permissible during the assessment session except with **ACSSE** staff members.
5. Answer each of the five main questions in its own pdf document.
6. Upload each pdf document seperately to eve.
7. This paper consists of **14** pages (**10** questions).

QUESTION 1: Operating Systems - General

(a) **Discuss** how ***multithreaded*** *processors* differ from ***multi-core*** *processors*? **[04]**

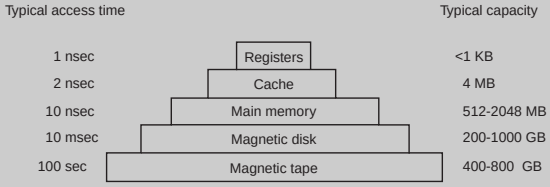
Solution:

(✓ each, max 2 per section)

- **Multithreaded processors**
  - One processor per CPU die
  - Able to switch between two threads very quickly.
  - One thread executes at a time.
  - Holds the state of the two threads.
- **Multi-core processors**
  - More than one processor per CPU die.
  - Each core can switch very quickly between threads.
  - More than one thread executes at a time.
  - Can also be multithreaded.

(b) **Discuss** the ***memory hierarchy*** found in a *computer*. Your discussion must include access times and capacity as well as why this concept is important to programmers. You may use diagrams to aid in your discussion. **[04]**

Solution:



(✓ each)

- Access times faster closer to CPU
- Capacity smaller closer to CPU
- Cache hit vs miss
- Programmer must be aware of different access times for performance

(c) **State** whether the following instructions should be run in ***user mode*** or ***kernel mode***.

i. Disable all interrupts **Solution:**Kernel **[01]**

ii. Read the time of day clock **Solution:**User **[01]**

iii. Set the time of day clock **Solution:**Kernel **[01]**

iv. Change the memory map **Solution:**Kernel **[01]**

(d) **Name** the three (3) *groups* of ***system calls***. **[03]**

Solution:

(✓ per group, max 3)

- Process Management
- File Management
- Directory Management
- Miscellaneous System Calls

Total: 15

QUESTION 2: Processes and Threads

(a) **List** two (2) *events* that result in ***process creation*** **[02]**

Solution:

(✓ each, any 2)

- System initialization.
- Execution of a process-creation system call by a running process.
- A user request to create a new process.
- Initiation of a batch job.

(b) **Describe** the ***concept of pseudoparallelism***. **[02]**

Solution:

(✓ each)

- CPU executes multiple processes, each separately.
- Quick execution appears as if all processes are running at the same time.

(c) **Discuss *monitors***, ***semaphores***, and ***locking variables*** as *methods of synchronisation*. **[06]**

Solution:

(✓ for concept, ✓ per discussion)

	Concept	**Discussion**
Monitors	Compiler driven	Notifications are provided by the programmer
Semaphores	Sleep and Wakeup	Threads blocks when waiting for a lock to be released
Locking Variables	Busy waiting	Threads are in a spin lock while waiting for the lock to be released

(d) Consider the following processes in a *preemtive* system (Highest priority = 0): **[05]**

Process	**Priority**	**Burst Time (msec)**
A	1	3
B	0	6
C	1	12
D	2	14

Using the ***priority scheduling with priority decrease*** algorithm with a `5 msec` quanta provide the order execution in the following format (copy and complete the table into your answer sheet):

Solution:

Time Spent	5	3	1	5	5	5	5	2	4
Process	B	A	B	C	D	C	D	C	D
Priority when run	0	1	1	1	2	2	3	3	4

Total: 15

QUESTION 3: Memory Management

(a) Given a fictional CPU. **Determine the 7-bit physical memory address in decimal** for the following 8-bit virtual address, given the following page table. **[06]**

Virtual address: 227.

Index	Page Frame	Present
7	01	1
6	00	1
5	00	0
4	00	0
3	10	1
2	00	0
1	00	0
0	01	1

Show all the steps from converting from decimal to binary and then from looking up the address to converting back from binary to decimal.

Solution:

Convert:227 to binary: 1110 0011 (1 mark)

Lookup: 111 (7) (2 marks)

Result: 01 (Page frame) (1 mark)

Physical address: 010 0011 (1 mark)

Decimal: 35 (1 mark)

(b) A computer has four page frames. The time of loading, time of last access and the R and M bits for each page are shown below:

Pages	Loaded	Last ref.	R	M
A	173	340	1	1
B	188	213	0	1
C	126	362	1	0
D	210	295	0	0

Answer the following in context of page replacement algorithms.

i. Which page will Not Recently Used (NRU) replace? **Solution:**D **[01]**

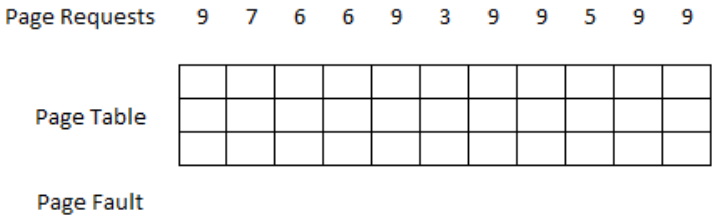
ii. Which page will First In First Out (FIFO) replace? **Solution:**C **[01]**

iii. Which page will Least Recently Used (LRU) replace? **Solution:**B **[01]**

iv. Which page will second chance replace? **Solution:**B **[01]**

(c) The following diagram shows a page table with three entries. The diagram further describes a sequence of requests for pages. **Redraw** the diagram on your answer sheet and indicate how pages are paged into and out of the page table given the ***FIFO*** page replacement algorithm for each request in the sequence. **[05]**

Clearly indicate the number of page faults and where they occur.



Solution:

Page Requests	9	7	6	6	9	3	9	9	5	9	9
Page Table			6	6	6	6	6	6	5	5	5
		7	7	7	7	7	9	9	9	9	9
	9	9	9	9	9	3	3	3	3	3	3
Page Fault	1	2	3			4	5		6		

Total: 15

QUESTION 4: File System

(a) Given the command prompt below, **answer** the following questions:

```
E:\Reports>tree \ /F
Folder PATH listing for volume SYSRCD603
Volume serial number is 269A-47DE
E:\
├───Reports
│       Summary.docx
│
└───Data
    ├───2020
    │       Infect.dat
    │
    └───2019
```

i. **Provide** the *absolute path* for the ***working directory***. **[02]**

ii. **Provide** the *relative path name* for the file called `Infect.dat` from the current working directory **[02]**

Solution:

- `E:\Reports`(1 mark if it is an absolute path, but incorrect path) (2 marks if it is the correct path)
- `..\Data\2020\Infect.dat`(1 mark if is a relative path, but incorrect) (2 marks if correct path)

(b) Answer the following questions, given the following directory and file allocation table (FAT).

File Name	Starting Block
.	1
..	15
File A	3
File B	12
File C	7

Table 1: Directory

0	FREE	11	EOF
1	EOF	12	9
2	10	13	FREE
3	19	14	EOF
4	2	15	EOF
5	8	16	FREE
6	FREE	17	FREE
7	11	18	FREE
8	EOF	19	5
9	4	20	FREE
10	14	21	FREE

Table 2: File Allocation Table

i. **Name** the block number of the current working directory. **[01]**

ii. **Name** the block number of the parent directory. **[01]**

iii. **List** the blocks that stores the content of File . **[02]**

iv. **Draw** and i-node representation for File B **[03]**

Solution:

- 1
- 15
- 3,19,5,8 (2 marks)
- Should be a table with the top entry ”Attributes” and then, 12,9,4,2,10,14 (1 Mark for the table, 1 Mark for Attributes, 1 Mark for data blocks)

(c) You have been asked to help configure a server. The server will store a mixture of both large database files and small system files. Taking into consideration block sizes, data rates and disk utilisation, **describe** how you will format the hard disk volumes on the server. **[04]**

Solution:

The student must somehow describe that bigger blocks give better performance, but it is not efficient wrt disk utilisation.

Smaller blocks makes better use of disk utilisation, but has a negative impact on performance.

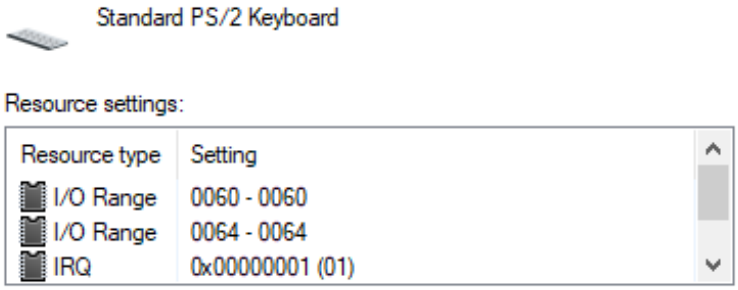
Any four facts that describes this type of solution.

- Create two volumes
- One for the operating system
- One for the database files
- The operating system will have small blocks to ensure good disk utilisation.
- The database files will have larger blocks for better disk performance.

Total: 15

QUESTION 5: Input/Output

(a) The following picture describes the resources used by the PS/2 Keyboard. Answer the following questions related to this resource



i. **Name** the approach the CPU can use to interface with the control registers and data buffers of the keyboard **[01]**

Solution: I/O Ports (1)

ii. **Write** a realistic assembly instruction that will be able to read from one of the two ports. **[01]**

Solution: IN al, 0060h OR IN al, 0064h

iii. **Discuss** three disadvantages of the methods depicted in this scenario **[03]**

Solution:

- I/O ports must be written in assembly language (1).
- I/O ports require special mechanisms to keep ports secure from user level processes (1).
- I/O ports requires extra commands to first read the value in a port (IN) then testing the value (1)

(b) The image displayed in Question 5(a) shows an IRQ as one of the resources available to a PS/2 Keyboard. **[05]**

Discuss the fundamental method used by the code to perform I/O. Include in your discussion the following aspects:

- The name of the fundamental method.
- The CPUs involvement in the method.
- One advantage of the method.
- One disadvantage of the method.

Solution:

- Interrupt-Driven I/O (1)
- The CPU is responsible for transferring data between the memory and PS/2 Keyboard (2)
- The method frees up the CPU to process other requests (1)
- Special interrupt handlers and interrupt hardware is required (1)

(c) **Discuss** the problem of an input buffer in a user process. Include in your discussion the following aspects: **[05]**

- What problems can occur with only an input buffer in a user process.
- A possible solution to this problem and why the solution will solve the problem.

Solution:

Any five of the following aspects may be mentioned.

1. An input buffer acts a storage for data arriving into a user process.(1)
2. The problem occurs when data arrives, but the user process my either not be running or may be swopped to disk (2)
3. In this case the data buffer is not available and data may be lost (1)
4. One solution is to create one or two buffers in kernel mode. (1)
5. These buffers are handled by the OS and may not be swopped to disk. (1)
6. Data will not be lost when the user process is swopped to disk because the kernel buffer will still be available. (1)

(d) On an imaginary disk with 40 cylinders a request comes in to read cylinder 14. While the hard disk is busy servicing the request on cylinder 14, requests to the following cylinders come in: ***21,19,1,40,36***. Given these cylinders, if the operating system uses the ***elevator*** algorithm, **write** the order in which the cylinders will be serviced. **[02]**

The directional bit for the elevator algorithm is currently set to **0**, which indicates an **downwards** (descending) direction.

Write only the cylinder numbers in order of service.

(Example if you think it will be cylinder 1 then 2 then 3 etc, write 1 2 3).

Solution:

14,1,19,21,36,40

(e) **Describe** how the keyboard software interprets the fact that a '@'-key has been pressed by the user. **[03]**

Solution:

Any three (3) of the following or similar:

- The keyboard hardware sends an interrupt when a key is pressed and depressed.
- The item in the buffer is known as a scan code.
- The software interprets a sequence of scan codes as a specific character:
- Example: Shift-Press, 2-Press. This creates a '@' key.

Total: 20

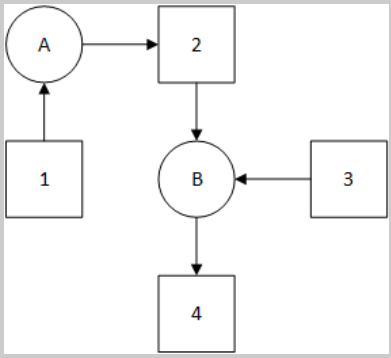
QUESTION 6: Deadlocks

(a) **Draw** a ***resource allocation graph*** for the following states **and** specify whether the system is in a deadlock: **[04]**

- Process A holds 1 and requests 2
- Process B holds 2 and 3 and requests 4

Solution:

- Processes as circles (1 mark)
- Resources as squares (1 mark)
- Correct arrows (1 mark)
- System is NOT deadlocked (1 mark)



(b) Consider the following resource matrices and vectors (E - existing resources, A - available resources): **[05]**

	Printers	DVD Roms	Scanners	Tape Drives
E = (	5	3	6	3)

	Printers	DVD Roms	Scanners	Tape Drives
A = (	2	1	0	0)

Current allocation matrix

Process 1	1	1	4	1
Process 2	2	0	1	1
Process 3	0	1	1	1

C =

Request matrix

	2	1	0	0
	1	1	4	0
	5	0	5	0

R =

Use the deadlock detection algorithm to determine if the current state is in a deadlock. For each round of the algorithm provide the available resource vector (A vector).

After the final round of the algorithm state whether system is **deadlocked or not**.

Solution:

- Process 1: A=(3 2 4 1) (1)
- Process 2: A=(5 2 5 2) (1)
- Process 3: A=(5 3 6 3) (1)

This scenario is NOT deadlocked scenario. (2)

(c) **Discuss** two (2) solutions for deadlock preventions. Include in your discussion the following aspects: **[06]**

- A description of the prevention technique.
- A realistic example that implements the technique.

Solution:

3 Marks for discussing each solution. Only two solutions need to be discussed.

Attacking the mutual exclusion condition

- If we can stop a process from claiming exclusive use over a resource then the problem will be solved.
- This can be done by making resources read only.
- When writing or updating try to ensure only one process can use the resource.
- The print spooler is an example of such a solution.
- Writing to the resource is not possible from multiple processes.

Attacking the hold and wait condition

- If a process can hold a resource and wait for another resource then it can cause a deadlock.
- If a process cannot wait for another resource then the process can be forced to release the resource.
- You must request all the resources in the beginning before you can start. Not always realistic.
- Some systems can be written that way, like batch or job processing systems.

Attacking the no preemption condition

- If the resource can be modified to allow it to be foricbly removed.
- Virtual resources are examples of this. Virtual memory, virtual disks, print spooler etc.

Attacking the circular wait condition

- Allowing access to only one resource at a moment will eliminate circular wait.
- If you can design your system to ensure processes do not require multiple resources then it will work.
- You can also number all the resources in a system. Requests must be made in numerical order.
- If resources are required out of order. All the resources must first be released and then requested.

Total: 15

QUESTION 7: Virtualization and MPS

(a) You have been employed at a small insurance organisation. Part of your job responsibility is to develop software that can work on multiple operating systems. You require a testing environment that you can easily start on your development server. Your development server runs Windows Server 2018. **[05]**

Name the hypervisor type (Type-1 or Type-2) and **motivate** why you have chosen the hypervisor type for the test server.

Solution:

The student can choose either Type-1 or Type-2, but the argument for Type 2 has to be very strong to be valid.
2 marks per reason and 1 extra mark for a well devised argument.
Type-1:

- The virtual machine responds in general faster on Type-1 than on Type-2.
- The CPU and existing operating system must support easy Type-1 implementation otherwise the whole computer may need to be reinstalled.
- Windows Server has easy built-in support for Type-1 hypervisors.

Type-2:

- The student may have a preference for a specific Type-2 software, but there is very little reason why a Type-2 would have been selected.
- No special operating system is required to support a Type-2 hypervisor and it can be installed just like an application.
-

(b) You have noticed that a number of the hardware servers at one of your clients are using NUMA architectures. Your line manager would like to know more about NUMA and how your software can make user of NUMA architectures. **[06]**

Discuss NUMA architecture. Include in your discussion the following aspects related to the above scenario.

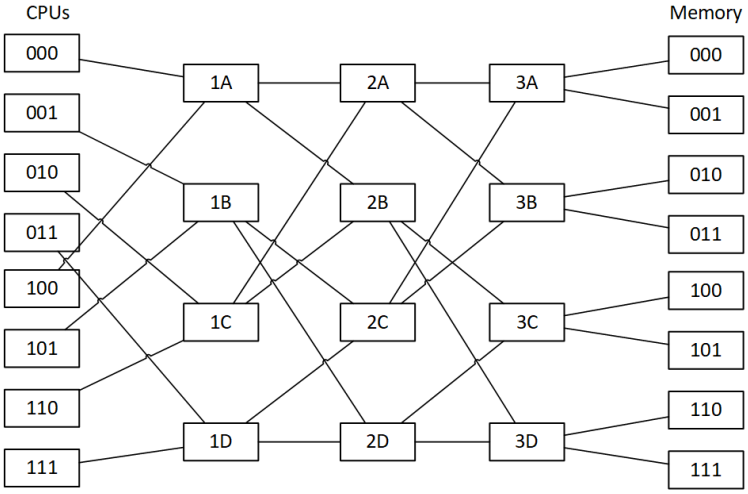
- Why server hardware may require a NUMA architecture.
- Comment on whether you need to do anything specific in the application software to ensure it continues running on NUMA architecture.
- Comment on whether you can build in extra features if you make your software NUMA-aware

Solution:

2 Marks for why servers may require NUMA architecture. 2 Marks for indicating that the operating systems hides the complexity of the LOAD and STORE instructions. 2 Marks for realising that application software can make efficient use of NUMA architecture for better performance.

- Servers require NUMA architecture when the CPU and Memory modules does not have consistent speed between them.
- Some memory modules can be accessed faster than other memory modules.
- The operating system has a single address space
- Access to remote memory modules are achieved using LOAD and STORE instructions.
- Since operating system handles this, no specific changes are necessary to make a user application function on the hardware.
- If you make your application NUMA aware, you can ask the operating system, to assign Processes and Memory related to each other 'close' to each other.

(c) Given the following ***omega switching network*** answer the questions which follow:



i. **Which** switches will be accessed when CPU 110 needs to access Memory 111. **[01]**

Solution:
1C 2B 3D

ii. **Which** switches will be accessed when CPU 100 needs to access Memory 000. **[01]**

Solution:
1A 2A 3A

iii. Can the request in (i) and (ii) be simultaneously processed? Justify your answer. **[02]**

Solution:
Yes (1 mark), No switches are shared. (only 1 mark)

Total: 15

QUESTION 8: Security

(a) **Name** an example of an attack or that threatens each of the following security goals of an operating system desing:

i. Confidentiality **[02]**

Solution:
Any example where data could be read by an attacker. Example: Keylogger or files left on USB drives.

ii. Integrity **[02]**

Solution:
Any example where data could be modified. Example: Malware that modifies files.

iii. Availability **[02]**

Solution:
Any example where system can denied services. Example: DoS. Ransomware attack.

(b) Given the following protection matrix. **List** the ***capability lists (C-List)*** for users on the databases. **[02]**

	PracMarks_DB	ExamMarks_DB	FinalMarks_DB
Lecturer	Read and Write		Read
HOD	Read	Read	Read

Solution:

- Lecturer - PracMarks_DB:RW;FinalMarks_DB:R
- HOD - PracMarks_DB:R;ExamMarks_DB:R;FinalMarks_DB:R

(c) Given the following mono alphabetic substitution cipher, and cipher text. **Provide** the plain text for the following cipher text. **[02]**

Key: A -> H **Cipher text**: mpupzo **Solution:**finish

Total: 10

QUESTION 9: 80x86 Theory

(a) **Discuss** how ***division*** is handled when using *CPU arithmetic* in 80x86 assembly. Your discussion must include instructions used, the registers that are affected, the data types involved and procedure followed. **[05]**

Solution:

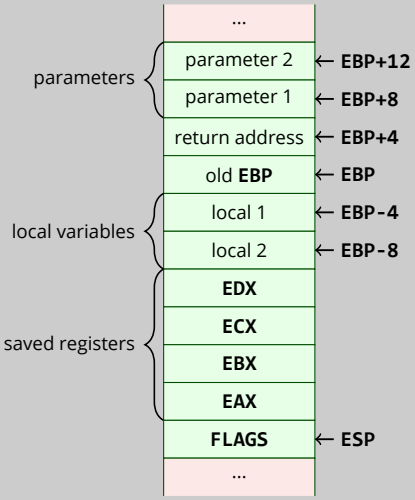
(✓ each)

- **DIV** or **IDIV** used on CPU.
- **EAX** and **EDX** are used for the dividend
- Need to prepare for division using **CDQ**
- After execution **EAX** contains quotient and **EDX** contains remainder
- Only integers are involved.

(b) **Draw** the stack as it will exist after the following function in the **C** programming language is called (after the stack frame is set up). The function contains local variables. **[05]**

```
1 void add(int* destination, int* source)
2 {
3   int tau = 3;
4   int rat = 66;
5 }
```

Solution:



Cells are 4 bytes (**DWORD**)

- ✓ for correct parameter order and types.
- ✓ for correct local variables.
- ✓ for return address
- ✓ for old base pointer
- ✓ for registers and flags

(c) **Show** the conversion of 48.125_{10} into ***IEEE Single-Precision Representation***. Show *all the steps of your calculation* and show the final result as a *hexadecimal number*. **[05]**

Solution:

Convert to binary: $48.125_{10} = 110000.0010_2$ ✓

Scientific notation: $1.100000010_2 \times 2^5$ ✓

S bit = 0 (positive number) ✓
E bits = 5 + 127 = 10000100_2 ✓
F bits = 10000010_2 padded with 0

Binary : 0100 0010 0100 0000 1000 0000 0000 0000
Hex : 0x42408000 ✓

Total: 15

QUESTION 10: 80x86 Cold code

Write an 80x86 assembly program that contains the following function:

A iterative ***paws*** function that takes the following parameters:

`arrRef` array address
`size` array length

The function will subtract each element in the array by 5. The function operates iteratively.

Note: The function must make use of iteration. (If you provide a solution that does not use iteration you will not be eligible for the full allocation of marks)

Solution:

- **Entry code**
  - Setup stack frame ✓
  - Push registers and flags ✓
- **Loop condition test**
  - Test condition using **CMP**/**JECXZ** ✓
  - Jump to end of function ✓
- **Perform subtract**
  - Get correct address of element ✓✓
  - Modify value ✓
  - Save value in correct address ✓
- **Loop increment**
  - Move to next iteration ✓✓
  - **JMP** or **LOOP** to start of loop ✓
- **Exit code**
  - Pop registers and flags reverse order ✓
  - Destroy stack frame ✓
- **Return**
  - **RET** ✓
  - Correct operand for **RET** ✓

Total: 15

~~ THE END ~~