

# COMP 3511 Operating System (Fall 2021)

## Midterm Exam

Date: 26-Oct-2021 (Tue)  
Time: 19:00 – 21:00 (2 hours)

<b>Name</b> (Write the name printed on your Student ID card)	
<b>Student ID</b>	
<b>ITSC email</b>	

Exam format and rules:

- It is an **open-book, open-notes exam** (Reference: Chapter 1.10)
- We have 18 pages. The last 2 pages can be teared off for rough work
- For students taking the on-site exam:
  - Physical calculator is allowed
  - Other electronic devices are not allowed
  - Write your answers in the spaces provided
- For students taking the online exam (For approved students only)
  - Allowed devices: a device to record your Zoom video and a computer
  - In the last 15 minutes (i.e. starts at 8:45 pm), you can remove the camera to take pictures of your hand-written answers
  - Submit your work via Canvas
- Other details are already sent to students via exam-related emails

Multiple Choices (MC1 - MC25)	/25
Process and Thread (Q1.1 - 1.3)	/30
CPU Scheduling (Q2.1 - 2.3)	/30
Synchronization (Q3.1 - 3.4)	/15
Total	/100

## Part I. Multiple Choices [25 \* 1 points]

Write down your answers in the boxes below:

MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10

MC11	MC12	MC13	MC14	MC15	MC16	MC17	MC18	MC19	MC20

MC21	MC22	MC23	MC24	MC25

### [Introduction]

MC1. Which of the following statement is not true for a multicore system?

- A. Communication between processors on the same chip is faster than processors residing on separate chips
- B. Processors on the same chip communicate with each other through a common bus
- C. It utilizes less power
- D. It places multiple computing cores on a single chip

MC2. Which of the following technology reduces the overhead for large amount of data movement between main memory and devices?

- A. Non-uniform Memory Access (NUMA)
- B. Storage Area Network (SAN)
- C. Direct Memory Access (DMA)
- D. Symmetric Multiprocessing (SMP)

### [Operating System Structures]

MC3. Which of the following statement is true?

- A. iOS is open-sourced, Android is closed-sourced
- B. iOS is a hybrid system consisting of Mach microkernel and BSD UNIX kernel
- C. Both iOS and Android run Java programs in a virtual machine
- D. All of the above

MC4. Which of the following statement is not an advantage of a microkernel design?

- A. It provides more security and reliability
- B. The kernel is easier to port to a different platform
- C. Inter Process Communication (IPC) enables easier communication between different components
- D. New services are added to user space without modification on the kernel

MC5. What is relationship between library call *printf()* and *write()* system call?

- A. *printf()* and *write()* system call are concurrent
- B. *write()* system call is an alternate version of *printf()*
- C. *write()* system call invokes *printf()* to perform the print function
- D. *printf()* invokes *write()* system call to get service from operating system

MC6. Which of the following statement is true for loadable kernel module design?

- A. It combines the benefits of both the layered and microkernel design
- B. It is flexible to enable the modules communicate with one another
- C. The user can dynamically load modules into the kernel if more functionality is required
- D. all of the above

### [Processes]

MC7. Which of the following component is not considered to be part of address space of a process?

- A. registers
- B. program or text section
- C. data section
- D. heap

MC8. Which of the following events trigger a change from user mode to kernel mode?

- A. system call
- B. trap or exception
- C. interrupt
- D. All of the above

MC9. Which of the following statement about ordinary pipes is not true?

- A. Ordinary pipes allow bi-directional communication
- B. Only the parent and child processes can use ordinary pipes for communication.
- C. Ordinary pipes cease to exist after the communicating processes have finished.
- D. Reading and writing to ordinary pipes are performed like file I/O

MC10. Which of the following events might be able to force a process to leave the CPU?

- A. make a fork system call
- B. make an I/O request
- C. interrupt
- D. all of the above

MC11. How many child processes will be created by the following C code fragment?  
(suppose all *fork()* are successful)

```
for( int i = 0; i < n ; ++i )
{
    fork();
}
```

- A. n
- B. 2n
- C.  $2^n$
- D.  $2^n - 1$

MC12. How many processes will be created by the following C code fragment?  
(suppose all *fork()* are successful)

```
for( int i = 0; i < 2 ; ++i )
{
    if (fork() != 0) fork();
}
```

- A. 3
- B. 6
- C. 9
- D. 16

MC13. Which might be the possible output for the following C code?  
(suppose all *fork()* are successful)

```
void fork_demo()
{
    int x = 2;
    if (fork() == 0)
        printf("x1 = %d ", ++x);
    else
        printf("x2 = %d ", --x);
}
int main()
{
    fork_demo();
    return 0;
}
```

- A. x1 = 2 x2 = 2
- B. x1 = 3 x2 = 2
- C. x2 = 1 x1 = 3
- D. x2 = 2 x1 = 3

### [Threads]

MC14. Which of the following is unique for different threads within a process?

- A. heap
- B. data section
- C. text section
- D. stack

MC15. Which of the following would be an acceptable signal handling scheme for a multithreaded program?

- A. Deliver the signal to the thread to which the signal applies.
- B. Deliver the signal to every thread in the process.
- C. Deliver the signal to only certain threads in the process.
- D. All of the above

MC16. According to Amdahl's Law, what is the speedup for an application that is 80% parallel and we run it on a machine with 2 processing cores?

- A. 1.60
- B. 0.60
- C. 1.67
- D. 2

MC17. Which of the following statement is true for *clone()* ?

- A. It creates a process that can share the address space of the calling process.
- B. It uses a set of flags to determine the extent of sharing
- C. It loads a new function to execute in the child process.
- D. All of the above

### [CPU Scheduling]

MC18. In a non-preemptive scheduling scheme, which of the following events will not trigger scheduling?

- A. A process completes its CPU burst time
- B. A process arrives on the ready queue
- C. A process initiates an I/O operation
- D. A process waits on a signal and blocks itself

MC19. Which of the following statement is not true about priority scheduling with round-robin or RR scheme when a higher priority process arrives and the CPU is currently occupied with a lower priority process?

- A. There are multiple queues, each associated with a priority
- B. The process running on CPU will be preempted and placed at the end of the queue associated with its priority
- C. The preempted process will not get a new quantum but continues with its remaining quantum next time when it is scheduled to run.
- D. The higher priority process will be scheduled to run immediately

MC20. A significant problem with any priority scheduling algorithms is \_\_\_\_.

- A. complexity
- B. determining the length of the next CPU burst
- C. determining the length of the time quantum
- D. starvation

MC21. In multilevel feedback queue scheduling, which of the following statement is true?

- A. It requires the knowledge on the next CPU burst time
- B. Processes are assigned to a queue permanently
- C. It handles interactive jobs well by delivering similar performance as SJF.
- D. It suffers from belady's anomaly

MC22. Which of the following statement about EDF scheduling is not true?

- A. It requires processes' processing time to be known
- B. It does not require processes to be periodic
- C. It requires the deadlines of processes to be known
- D. It does not require a process processing time (CPU burst time) to be a constant

### [Synchronization Tools]

MC23. A solution to the critical section problem does not have to satisfy which of the following requirements?

- A. mutual exclusion
- B. atomicity
- C. process
- D. bounded waiting

MC24. When using semaphores, a process invokes the *wait()* operation before accessing its critical section, followed by the *signal()* operation upon completion of its critical section. Consider reversing the order of these two operations – first calling *signal()*, then calling *wait()*. What would be a possible outcome of this?

- A. Starvation is possible.
- B. Mutual exclusion is still guaranteed.
- C. Deadlock is possible.
- D. Several processes could be active in their critical sections at the same time.

MC25. Suppose the binary variable *lock* is initialized to be 0, which of the following can be an implementation of the entry section to solve the critical-section problem?

- A. while (compare\_and\_swap(&lock, 0, 1) == 0), do nothing;
- B. while (compare\_and\_swap(&lock, 1, 0) != 0), do nothing;
- C. while (compare\_and\_swap(&lock, 0, 1) != 0), do nothing;
- D. while (compare\_and\_swap(&lock, 0, 0) != 0), do nothing;

## Part II. Calculations [75 points]

### 1. [30 Points] Process and Thread

- 1) Consider the following program, where M and N will be replaced by different values in the following questions: (suppose all *fork()* are successful)

```
#include <stdio.h>
#include <unistd.h>

int main() {
    int i, j;
    for (i=0; i<M; i++) {
        fork();
        for (j=0; j<N; j++)
            fork();
    }
    return 0;
}
```

- a) (4 marks) What is the total number of process(es) if  $M = 1$  and  $N = 1$ . Briefly explain your answer



b) (4 marks) What is the total number of process(es) if  $M = 2$  and  $N = 3$ . Briefly explain your answer.

c) (4 marks) What is the total number of process(es) in term of  $M$  and  $N$ ? Briefly explain your answer:

- 2) (8 points) You have learned a number of system calls to handle input and output redirection. The following program will execute the following command:

```
wc -l < input.txt > output.txt
```

The above command counts the number of lines in the file input.txt and stores the result to the file output.txt. For example, if input.txt contains the following lines:

```
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```

After running the program, output.txt becomes:

3

Assume input.txt exists in the same directory of the program, and output.txt does not exist. You cannot include extra header files and cannot add extra variables

```
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <fcntl.h>

int main() {
    char* args[256] = {"wc", "-l", NULL};
    int perm = S_IRUSR | S_IWUSR;
    int fd_in, fd_out;
    fd_in = open("input.txt", O_RDONLY, perm);
    fd_out = open("output.txt", O_CREAT | O_WRONLY, perm);
    close(1);
    BLANK1;
    close(0);
    BLANK2;
    execvp(BLANK3, BLANK4);
    return 0;
}
```

Write your answers in the following table

BLANK1	
BLANK2	
BLANK3	
BLANK4	

3) Consider the following C program,

```
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
int main() {
    pid_t pid;
    pid = fork();
    if ( pid > 0 ) {
        sleep(10);
        wait(0);
    } else {
        sleep(1);
    }
    return 0;
}
```

System call `sleep()` temporarily suspends the current process for a specified number of seconds. For example, `sleep(1)` means suspending the current process for 1 second. Except the `sleep()` system call, assume that the running time of all other programming statements is neglectable. (suppose all `fork()` are successful)

- a) (5 points) In the above program, are there any zombie process? If yes, write down the occurrence time using the format: "Yes, the zombie process occurs at  $t = ??s$ ". If no, write down "No, there is no zombie process". Briefly explain your answer.
- b) (5 points) In the above program, are there any orphan process? If yes, write down the occurrence time using the format: "Yes, the orphan process occurs at  $t = ??s$ ". If no, write down "No, there is no orphan process". Briefly explain your answer.

## 2. [30 Points] CPU Scheduling

1) Consider the following single-thread process, arrival times, burst time and priority:

Process	Arrival Time	Burst Time	Priority
P <sub>1</sub>	0	5	3
P <sub>2</sub>	2	4	2
P <sub>3</sub>	3	3	1
P <sub>4</sub>	9	4	2
P <sub>5</sub>	11	3	3
P <sub>6</sub>	14	6	1

a) (6 points) Draw the Gantt chart depicting the scheduling procedures for these processes using a priority scheduling with Round-Robin (RR) scheme, and RR time quantum is 2 ms.

b) (4 points) Calculate the average waiting time.

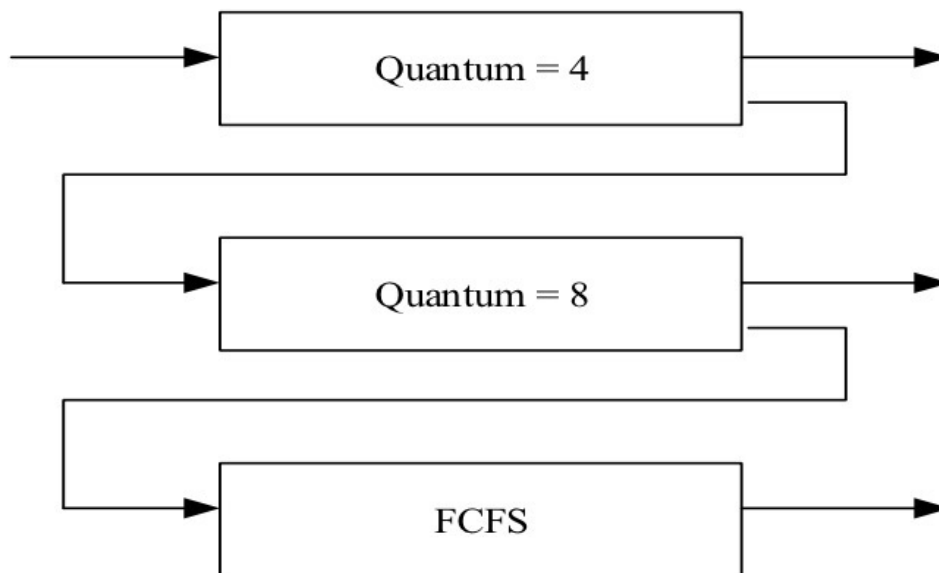
2) Consider the following single-thread process, arrival times, burst time and the following three queues:

Q0 - RR with time quantum 4 milliseconds

Q1 - RR with time quantum 8 milliseconds

Q2 - FCFS

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	6
P <sub>2</sub>	3	16
P <sub>3</sub>	9	5
P <sub>4</sub>	11	3
P <sub>5</sub>	17	14
P <sub>6</sub>	22	6



a) (6 points) Draw the Gantt chart depicting the scheduling procedures for these processes.

b) (4 points) Calculate the average waiting time.

3) (10 points) Consider the following single-thread process, executing times, deadlines and periods. Assume all processes arrive at timeslot 0. Fill in the table with the ID of the process that is running on the CPU with Rate-Monotonic (RM) scheduling and Earliest Deadline First (EDF) scheduling in the first 16 timeslots, and show how many deadlines are missed in each scheduler.

Process	Processing Time	Deadline	Period
P <sub>1</sub>	1	2	4
P <sub>2</sub>	2	5	6
P <sub>3</sub>	3	7	9

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RM																
EDF																

### 3. [15 points] Synchronization

Consider the following C code, we use `test_and_set` to emulate locks:

- Please note that this program will not always give the same output
- The final output is dependent on the execution sequence of the threads

```
#include <stdio.h>
#include <unistd.h>
#include <pthread.h>
// boolean is used in our lecture notes. Here, we use int
int test_and_set(int *value) {
    int result = *value;
    *value = 1;
    return result;
}
int value = 0;
int hello = 0;
void thread1_hello() {
    while (test_and_set(&value));
    hello += 1;
    printf("Thread 1: %d\n", hello);
    value = 0;
    pthread_exit(0);
}
void thread2_hello() {
    while (test_and_set(&value));
    hello += 1;
    printf("Thread 2: %d\n", hello);
    value = 0;
    pthread_exit(0);
}
int main() {
    pthread_t thread1, thread2;
    pthread_create(&thread2, NULL, (void*)&thread2_hello, NULL);
    usleep(1); // sleep for a very short period of time
    pthread_create(&thread1, NULL, (void*)&thread1_hello, NULL);
    while (test_and_set(&value));
    printf("Parent thread: %d\n", hello);
    value = 0;
    usleep(1); // sleep for a very short period of time
    return 0;
}
```

Assume the following sequence of execution:

In this program, we have 3 threads: MainThread, Thread1, and Thread2

1. MainThread starts and creates 2 threads, then MainThread is interrupted
2. Thread2 starts and run it increments hello, then Thread2 is interrupted
3. Thread1 starts, until it is interrupted
4. MainThread resumes, until it is interrupted
5. Thread2 runs to completion
6. MainThread runs to completion, but it is not yet exit
7. Thread1 runs to completion

1) (4 points) Is the given sequence of execution possible? Write Yes/No and briefly explain:

2) (4 points) Fill in the table of the return value of test\_and\_set(&value)

The execution steps	Return value of test_and_set(&value)
Step 3: Thread1 starts, until it is interrupted	
Step 6: MainThread runs to completion, but it is not yet exit	

3) (4 points) Given the execution sequence in the question, what will the program print?

4) (3 points) Is this implementation better than using locks? Write Yes/No and briefly justify your answer.

**== End of the Exam ==**



**Rough work sheet 1 (tear it off, if needed)**

**Rough work sheet 2 (tear it off, if needed)**