There are 5 questions in this exam. You have 75 minutes to finish the questions. All the questions in this exam are mandatory (no optional question).

Please provide your solutions on the separate blank paper (please do not squeeze your solutions into this question sheet).

Student ID (the last three digits): ___________________

QUESTION #1 (15 minutes) – 20 points (4 points each)

(1) If a sufficient condition is not satisfied, what conclusion can we draw?

If a sufficient condition is not satisfied, there is nothing that can be concluded (since it means “may or may not”).

Note: the underlined concept should be emphasized, mentioned, or implied for full credit.

(2) What problem in “batch system” do “multi-programming (multitasking) OSes” fix and how?

Batch systems execute programs one at a time. This will result in a poor processor utilization (since whenever a process blocks, especially for I/O requests (e.g., inputs from a keyboard), such a process just stays blocked, wasting the CPU resource. In multi-tasking OS, whenever the currently running process blocks, the OS switches the unused processor to another ready process. Thus, wasting CPU resource will be reduced.

Note: the underlined concepts should be emphasized, mentioned, or implied for full credit.

(3) When the degree of multi-tasking is too high, the effectiveness in executing processes can decrease, which is called “thrashing”. Explain how can thrashing happen.

Thrashing means that the processor spends most of its resource for performing too many context-switching (since the long-term scheduler in a multi-tasking operating system loaded too many processes).

Note: the underlined concept should be emphasized, mentioned, or implied for full credit.
(4) Many operating systems use “system calls”. What are the reasons (purposes) for using system calls in operating systems? Mention two different reasons.

① To switch the processor mode from USER mode to SYSTEM mode (or to prevent user processes from directly accessing the hardware resources)

② To provide user processes with high-level abstraction of a computer system (user processes can manipulate hardware components using high-level system calls).

(5) What are the primary advantages in using “micro-kernel architecture”?

Advantages:

(a) Robustness: the modules running in the user mode will give less fatal impacts to the operating system than they would have been executed in the system mode.

(b) Easy bug fixes: Since each module exists as an independent program file in the microkernel architecture, fixing bugs in a module can be done by replacing its latest edition. No compiling the module is necessary. No compiling the operating system body is necessary either.

(c) Small OS footprint (flexibility): Users can add only the necessary modules to the OS, which will make the OS footprint smaller. The modules will be dynamically loaded to the memory based on the requests from user applications, which also reduce the memory requirement.
QUESTION #2 (15 minutes) – 20 points

The following table shows the current snapshot of a system where three processes (X, Y, and Z) compete for multiple instances of a resource type (as we discussed in the classroom). By applying Banker’s Algorithm, answer the following questions.

(1) (10 points) If Process X requests 2 more instances of the resource, select the best (only one) option from the following choices. Then, justify your choice (i.e., explain how you selected that choice).

(a) The system is already in the unsafe state even before X makes the request.

(b) The system will remain in the safe state even after X’s request is approved.

(c) The system will move to an unsafe state after X’s request is approved (this implies that the system is in the safe state before X makes the request).

(d) Can not tell (conclude) anything.

Note: Not much credit for this question will be earned if a correct (and clear) explanation is not provided, even if you selected the correct choice. It is assumed that it is your responsibility to convince Dr. Fujinoki that you had the correct idea(s).

<table>
<thead>
<tr>
<th>Process</th>
<th>Assigned</th>
<th>MAX. Need</th>
<th>Requests Pending</th>
<th>Process Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>RUNNING</td>
</tr>
<tr>
<td>Y</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>RUNNING</td>
</tr>
<tr>
<td>Z</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>RUNNING</td>
</tr>
</tbody>
</table>

(2) (10 points) Assume that the system has approved the request from X in (1) (it can be the correct or the wrong decision for (1)):

- After the request (2 more instances) by X in (1) (i.e., two more were given to X in (1)), Z changes its mind, and it releases the 2 instances Z currently holds.
- Then (after Z’s release of 2): X requests 2 more instances and it finishes.
- Then (after X’s completion): Y makes a request for one more instance of the resource.

Select the best (only one) option from the following choices. Then, justify your choice (i.e., explain how you selected that choice).

(a) The system is already in the unsafe state even before Y makes the request.

(b) The system will remain in the safe state even after Y’s request is approved.

(c) The system will move to an unsafe state after Y’s request is approved (this implies that it is in the safe state before Y makes the request).

(d) Can not tell (conclude) anything.
Note: Not much credit for this question will be earned if a correct (and clear) explanation is not provided, even if you selected the correct choice. It is assumed that it is your responsibility to convince Dr. Fujinoki that you had the correct idea(s).

QUESTION #3 (15 minutes) – 20 points

The following is another implementation of a circular FIFO queue for a producer and a consumer (shown below). Regarding the implementation, answer the following questions.

(1) (10 points) Is it necessary to have “wait(mutex)” and “signal(mutex)” in the producer and the consumer processes (assume only one producer and only one consumer)? If NO, explain why not. If YES, explain why we need them.

Note: Not much credit for this question will be earned if a correct (and clear) explanation is not provided, even if you selected correct “YES” or “NO”.

(2) (10 points) Is there any demerit(s) (disadvantage(s)) in using the mutex semaphore (assume only one producer and only one consumer)? If yes, describe what is (are) the demerit(s) (all possible demerits)? If not, why not?

Note: Not much credit for this question will be earned if a correct (and clear) explanation is not provided, even if you selected correct “YES” or “NO”.

```c
#define N 100 // the queue size

shared memory int CFG[N]; // the circular FIFO queue
shared memory int TOP = 0; // pointer to the top of the queue
shared memory int TAIL = 0; // pointer to the tail of the queue

semaphore mutex = 1; // a mutex semaphore
semaphore empty = N; // a counting semaphore
semaphore full = 0; // a counting semaphore
```

void producer (void)
{
    int new_item; // place holder for a new item to insert

    while (TRUE)
    {
        new_item = produce_new_item(); // generate a new item
        wait(empty); // make sure the queue is NOT full
        wait(mutex); // I should be the only one
        insert(CFG, TAIL, new_item); // insert the new item to the queue
        TAIL = (TAIL + 1) % N; // update the top pointer
        signal(mutex); // I am done!
        signal(full); // (full) = (full) + 1
    }
}

void consumer (void)
{
    int new_item; // place holder for a new item to insert

    while (TRUE)
    {
        wait(mutex); // I should be the only one
        wait(TOP); // make sure the queue has at least one slot
        new_item = remove(CFG, TOP); // remove one item from the queue
        TOP = (TOP + 1) % N; // update the top pointer
        signal(mutex); // I am done!
        signal(EMPTY); // (empty) = (empty) + 1
        use_the_new_item(new_item); // use the new item
    }
}

Note 1: “demerit” means any negative effect for the execution speed of the two processes.

Note 2: Assume a multi-core processor in the computer system.
Note 3: The important idea(s) should be emphasized in your solution. Lack of adequate emphasis on such important idea(s) may prevent full credit for this question.

Note 4: It is assumed that clearly explain the idea(s) is your responsivity.

**QUESTION #4 (15 minutes) – 20 points**

Any counting semaphore can be implemented using only binary semaphores. Implement a counting semaphore using only binary semaphore(s).

Assumptions and requirements:

- No spin-wait (no busy wait) should be used in your implementation.
- More than one binary semaphore can be used (each binary semaphore should be initialized by “1”).
- Deadlock should not happen.
- Starvation should not happen.
- As a counting semaphore would do, only the first N processes should be let in.

Implement wait and signal operations for a counting semaphore. Assume it is your responsibility to make your idea(s) clear. Provide your solution using the following space holders (note: if you need more space, you can provide your solutions on separate piece of paper).
QUESTION #5 (10 minutes) – 20 points

With regards to the throughput of the SJF and the SRTF short-term process scheduling algorithms, answer the following questions:

(1) Select the best option from the following options for representing the relation between the throughput of the SJF and that of the SRTF (select one):

(a) SJF > SRTF  
(b) SRTF > SJF  
(c) SJF >= SRTF  
(d) SRTF >= SJF  
(e) SJF = SRTF  
(f) no relation between them

Where:
- “A > B” means “A’s throughput is always better than that of B”
- “A >= B” means “A’s throughput is either better than that of B or equal to that of B”
- “A = B” means “A’s throughput is always equal to that of B”

(2) For your choice for the above (i.e., question (1)), justify* (explain) your choice.

Note 1: If you do not provide a correct/clear justification (explanation), your will not earn much credit for QUESTION #5 even if you selected the correct choice for (1).

Note 2: Your solution for (2) will be graded based on how clearly the correct idea(s) is presented (“how well (or “how clearly”) your explanation justifies your choice for (1)). It is your responsibility to convince Dr. Fujinoki that you have the correct idea(s)).