

**NATIONAL UNIVERSITY OF SINGAPORE**

**CS2106 – INTRODUCTION TO OPERATING SYSTEMS**

(Semester 1: AY2018/19)

Time Allowed: 2 Hours

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**INSTRUCTIONS TO CANDIDATES**

1. This assessment paper consists of **TWENTY-FIVE (25)** questions and comprises **SIX (6)** printed pages on **THREE (3)** sheets of paper.
2. This is a **CLOSED BOOK** assessment. Two A4 reference sheets are allowed. Calculators are not allowed.
3. Answer all questions and write your answers in the **ANSWER BOOKLET** provided.
4. Fill in your Student Number with a pen, clearly on odd-numbered pages of your **ANSWER BOOKLET**.
5. You may use pencil to write your answers.
6. Marks allocated to each question are indicated. Total marks for the paper is **100**.
7. You are to submit only the ANSWER BOOKLET and no other document.

**Questions 1-8 [4 marks x 8 = 32 marks]:**

Give brief answer (**no more than 3 sentences**) to the following questions. You may state any assumption **only if necessary**.

1. If two tasks A and B **have to enter critical section in strict order**, i.e.  $A \rightarrow B \rightarrow A \rightarrow B \dots$ , use only **binary semaphore(s)** to show how this can be achieved. Note that you need to provide the critical section outline for both task A and task B.
2. If the solution from (1) above is used for a scenario where A and B **can enter critical section in any order**, which critical section criteria is/are violated? Explain with a simple example.
3. Is it possible that the execution of a simple "memory load" instruction causes the **currently running process** to enter **block state**? Briefly elaborate ("how" if possible, "why" if not possible).
4. Is it possible that the execution of a **file read** operation (on an opened file) **does not cause** the currently running process to enter **block state**? ("how" if possible, "why" if not possible).
5. For an OS employing 2-Level Paging, what is stored in the "memory context" of the Process Control Block (PCB) for each process?
6. If a **folder** (directory) has the **read and execute permission enabled** but NOT the **write permission**, give 2 **different file-related operations** that cannot be performed for files under that folder.
7. On a FAT16 system, what is the relationship between A: (**sum of file size of all files + current free space**) and B: (**total capacity of all data blocks**)? Relationship refers to magnitude comparison of the two expressions, you can write " $A > B$ ", etc. Briefly elaborate **why**.
8. On an **ext** file system, should the data blocks for a file come from the same block group? Briefly explain.

**Questions 9 – 11 [14 marks]:**

Consider the following 3 tasks on a remote controlled exploration vehicle **USLOL**:

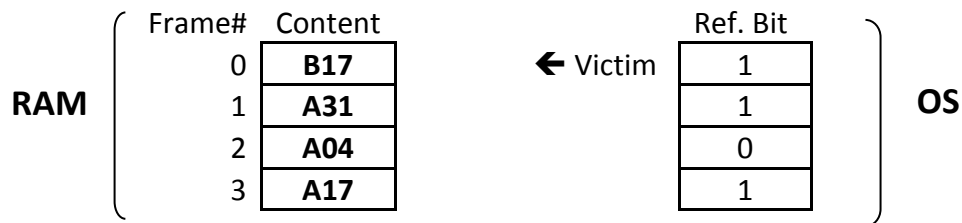
<b>TaskA( )</b> while (1) <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">A1</div> //Use Antenna to // receive control // commands from // base <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">A2</div>	<b>TaskB()</b> while(1) <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">B1</div> //Use sensors to // collect // environmental // data <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">B2</div>	<b>TaskC()</b> while(1) <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">C1</div> //Use Antenna to // send "still alive" // signal to base <div style="border: 1px solid black; padding: 2px; margin: 2px 0;">C2</div>
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**USLOL** is equipped with a single antenna for communication, a number of sensors (temperature, atmospheric pressure etc) for collecting environment data, and a few other equipment not relevant to this question. The operation base can communicate and control the **USLOL** via remote operation. In this question, you will be considering the execution of the 3 tasks on the on-board **single-core processor** of **USLOL**.

9. Use only binary semaphore(s) to synchronize the three tasks so that there is no race condition in using any of the on board equipment. You only need to decide the appropriate semaphore declaration, and give appropriate semaphore operations in the 6 slots (A1, A2, ..... C1, C2) in the answer sheet. **Write "NA" if you think there is no need for synchronization. [5 marks]**
  
10. Continuing from Q9, suppose priority scheduling is used on **USLOL** and you need to assign scheduling priority: {LOW, MEDIUM, HIGH} to the three tasks. Choose a set of priority assignment that can cause **priority inversion**. Note that the priority is not exclusive, i.e. more than one task can be assigned the same priority.  
  
Give the priority for the 3 tasks, then give a scenario where **priority inversion** can take place. **[5 marks]**
  
11. If we have to use priority scheduling and the priority assignment from above must be used, suggest a way to fix the priority inversion problem. There is **no need** to show the code, just a high level description will do. **[4 marks]**

**Questions 12 – 18 [26 marks]:**

Below is a snapshot of the memory frames in RAM on a system with virtual memory. The memory pages in the frame is shown as <Process><Page#>, e.g. B17 means Page 17 of Process B.



The OS maintains additional information shown on the right to perform **second chance** page replacement algorithm on the memory frames.

Suppose **Process A access Page 8** (i.e. A08) now, answer the following:

12. Which **memory frame** will be replaced? [2 marks]
13. Give the steps OS take to update the affected page table entries. Answer using a step-by-step point form format. [5 marks]

**Continuing from the above**, if **Process B access Page 13** (i.e B13) now, answer the following:

14. Which **memory frame** will be replaced? [2 marks]
15. If **OS** keeps an **inverted page table**, give the content of the inverted page table **after** the replacements (after Q12 and 14). [4 marks]
16. Give the steps OS take to update the affected page table entries **with the help of inverted page table**. Answer using a step-by-step point form format. [5 marks]

Based on your observations of this arrangement, answer the following:

17. Is the page replacement algorithm **global** or **local**? Briefly explain. [4 marks]
18. In this case, what is the relationship between the pages in the memory frames versus the **working set** of the processes? Briefly explain. [4 marks]

**Questions 19 – 22 [5 marks x 4 = 20 marks]:**

Below is a snapshot of a FAT file system. There are only 20 data blocks, each 1KiB (1,024 bytes) large.

	+00	+01	+02	+03	+04	+05	+06	+07	+08	+09
00	19	FREE	07	16	FREE	END	14	11	06	02
10	FREE	END	FREE	18	END	END	END	FREE	09	08

There are two folders on the system with the directory entries shown below. The root folder is located in data block 15.

name	IsDir?	start	size
TIS	0	13	5432
WHY	1	5	---
IHATE	0	3	1234

Root folder "/"

name	IsDir?	start	size
FAT08	0	0	4333

Folder "WHY/"

For the following file operations **[5 marks each]**:

- Show the modified FAT Table entries (if any).
- List disk logical blocks that are modified. Put "NA" if no disk block is modified.
- Show the modified directory entries (if any).

Note:

- Only show the **modified entries**, you can leave all unaffected entries blank in the answer sheet.
- If new logical block is needed, use the smallest available logical block in order.
- **The questions are independent**, i.e. each start from the same original state as shown above.

19. Delete /IHATE.

20. Rename /IHATE to /ILOVE

21. Copy /WHY/FAT08 to /TIS (i.e. overwrites the destination's content).

22. Append /IHATE to the end of /WHY/FAT08 (i.e. adding the content to the end).

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For your reference, below are the multiples of 1 KiB and their actual value:

1 KiB	1,024 Bytes
2 KiB	2,048 Bytes
3 KiB	3,072 Bytes
4 KiB	4,096 Bytes
5 KiB	5,120 Bytes

6 KiB	6,144 Bytes
7 KiB	7,168 Bytes
8 KiB	8,192 Bytes
9 KiB	9,216 Bytes
10 KiB	10,240 Bytes

**Questions 23 – 25 [8 marks]:**

These questions use the same FAT file system from previous page. The FAT file system is duplicated below for your reference:

	+00	+01	+02	+03	+04	+05	+06	+07	+08	+09
00	19	FREE	07	16	FREE	END	14	11	06	02
10	FREE	END	FREE	18	END	END	END	FREE	09	08

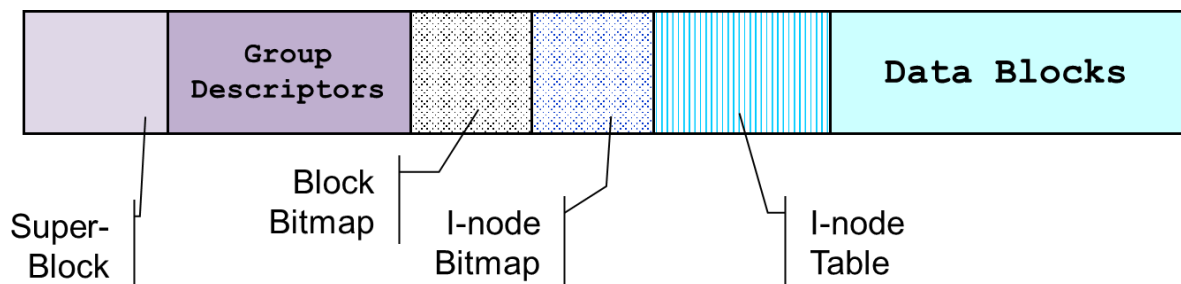
name	IsDir?	start	size
TIS	0	13	5432
WHY	1	5	---
IHATE	0	3	1234

Root folder "/" (at Data Sector 15)

name	IsDir?	start	size
FAT08	0	0	4333

Folder "WHY/"

Suppose the same set of folders and files are stored under **ext** file system instead. Below is an illustration of a **block group** in **ext** file system:



If we assume that the data blocks size used is the same (i.e. 1KiB), answer the following:

23. The number of '1's in the Block Bitmap. **[2 marks]**
24. The number of '1's in the Inode Bitmap. **[2 marks]**
25. Given that the data block pointers in an Inode is setup as {2 x Direct, 1 x Single Indirect points to 3 blocks, 1 x Double Indirect points to 3 single indirect blocks}. If we start the file access from scratch (i.e. no cached inode, file data etc), identify the block of which file cause the **most number of disk accesses to read** and **give the number of accesses**.

Disk access is incurred when **reading inode and file content**. Expected answer format is (  $N^{\text{th}}$  block of file "F", block starts from  $0^{\text{th}}$ ). Give only one answer if there are multiple possibilities. **[4 marks]**

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