Systems II

2020/21

Exam 1

Collaboration is not allowed during the exam. Each task from the computational part, which contributes 70 % towards the grade, is worth the same amount of points. Each task from the theoretical part, which contributes 30 % towards the grade, is worth the same amount of points. Literature and notes are not allowed. You may use a simple calculator. The exam takes 120 minutes.

Good luck and have fun!

Full name: _____

Enrollment ID: _____

Signature: _____

Task 1

A computer system has 6 page frames. The table below shows the time of loading, the time of last access, and the R and M bits for each page (the times are in clock ticks).

Frame	Loaded	Last access	R	M
0	180	310	1	0
1	25	275	1	1
2	15	300	1	1
3	190	225	1	0
4	120	215	0	1
5	90	200	0	1

The system has to load **two** new pages into RAM, so it has to remove two of those pages that are already loaded. For each of the algorithms below, determine which two pages are going to be replaced:

(a) not recently used (NRU);

(b) least recently used (LRU);

(c) first-in, first-out (FIFO);

(d) second chance.

All answers should be justified!

Task 2

Our system is using virtual memory and has 48-bit virtual address space and 32-bit physical address space. Page size is 16 KiB.

(a) How many entries are needed for a *single-level* page table?

What does the *two-level* page table look like if the part of the virtual address which identifies the page number is split into two fields of equal size?

(b) Our system also has the TLB (Translation Lookaside Buffer) with 128 entries. We run the following program which reads 32-bit integers from an array of size 200 000:

```
int[] t = new int[200000];

for (int i=399; i>=0; i--) {
    for (int j=0; j<500; j++) {
        // we access t[ i + 400 * j ]
    }
}
```

How efficient is the TLB in this case? More precisely, how many times will a TLB miss occur (resulting in page table lookup)? Assume that the TLB is initially empty.

Task 3

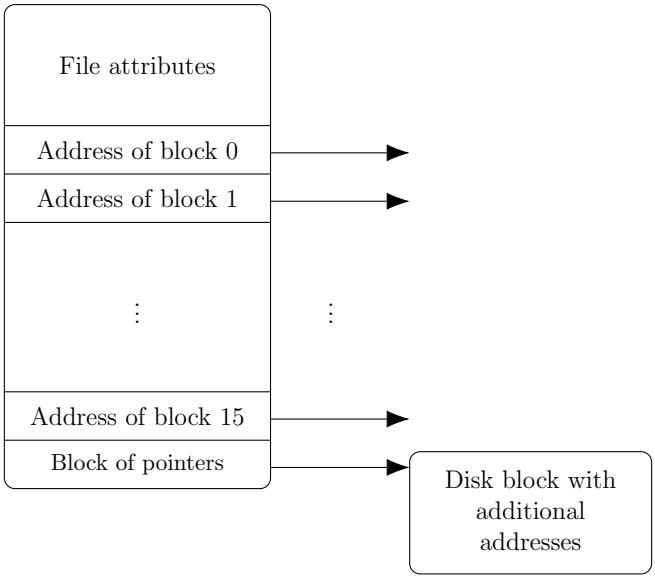
A system has 5 processes and 5 types of resources. The current state of the system is as follows:

Process	Allocated (C)	Requested (R)	Available (A)
Π_1	3 0 2 1 0	4 1 3 1 2	λ 1 2 2 1
Π_2	1 0 0 1 0	2 1 1 2 1	
Π_3	1 0 1 2 1	0 0 3 1 2	
Π_4	0 1 0 0 3	2 1 1 3 0	
Π_5	0 2 1 1 0	1 0 1 1 2	

What is the smallest values of λ for which the system is in a safe state? Justify your answer.

Task 4

The following figure depicts an i-node:



This i-node contains 16 direct addresses and a pointer to the block with additional addresses. Addresses take 16 B each and block size is 4 KiB = 4096 B.

(a) Draw a figure that depicts the i-node and the corresponding data blocks for a file of size 15 KiB.

(b) What is the largest possible file size if the block with additional addresses is not used? What if we also use the block with additional addresses (where the block with additional addresses cannot further be extended)?

(c) How much space on the disk is occupied by a file of size 75 KiB?

Theoretical part

(a) What are *system calls*? Give at least 5 particular examples of system calls.

(b) What is the *process hierarchy* and what is a *process group*?

(c) What are *semaphores* and what are they used for?

(d) What is a *page fault*? What should the operating system do if a page fault occurs?

(e) We listed the content of a folder which (among other items) includes the line:

```
-rwxr-xr--     1 nino  staff     6889 May 14 18:03 woodall.py
```

Explain the meaning of the string `-rwxr-xr--`.

(f) Briefly describe the two possible data structures that file systems use to keep track of free blocks. Which of the two structures is better in your opinion and why?