# Written examination in Operating Systems

*February 12th 2024*

**Last name:** ______________________________

**First name:** ______________________________

**Student number:** ______________________________

Mit dem Bearbeiten dieser schriftlichen Prüfung (Klausur) bestätigen Sie, dass Sie diese alleine bearbeiten und dass Sie sich gesund und prüfungsfähig fühlen. Mit dem Erhalt der Aufgabenstellung gilt die Klausur als angetreten und wird bewertet.

By attending this written exam, you confirm that you are working on it alone and feel healthy and capable to participate. Once you have received the examination paper, you are considered to have participated in the exam, and it will be graded.

- Use the provided sheets. Do *not* use own paper.
- You are allowed to use a *self prepared*, *single sided DIN-A4 sheet* in the exam. Only *handwritten originals* are allowed, but no copies.
- Do *not* use a red pen.
- Time limit: *90 minutes*
- Turn off your mobile phones!

**Grade:** ____________

| Questions: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | **Σ** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Points: | 10 | 6 | 8 | 7 | 7 | 7 | 8 | 8 | 4 | 7 | 6 | 7 | 5 | 90 |
| Achieved Points: | | | | | | | | | | | | | | |

**1.0**: 90.0-85.5, **1.3**: 85.0-81.0, **1.7**: 80.5-76.5, **2.0**: 76.0-72.0, **2.3**: 71.5-67.5,
**2.7**: 67.0-63.0, **3.0**: 62.5-58.5, **3.3**: 58.0-54.0, **3.7**: 53.5-49.5, **4.0**: 49.0-45.0, **5.0**: <45

# Question 1)

Points: ...................... of 10

1 Point (1) Describe what swapping is.

1 Point (2) Explain what singletasking is.

1 Point (3) Describe what half multi-user operating systems are.

1 Point (4) Describe the difference between 8 bit, 16 bit, 32 bit, and 64 bit operating systems.

½ Point (5) Give the maximum amount of memory, a 32-bit architecture can address.

2 Points (6) Explain why multi-level paging and not single-level paging is used in 32-bit and 64-bit systems.

1 Point (7) Explain the event that causes a page fault exception.

1 Point (8) Give the name of the best page replacement strategy and describe how it works.

1 Point (9) Describe the key message of Laszlo Belady's anomaly.

½ Point (10) Give the name of the page replacement strategy that is implemented by most modern operating systems (Hint: It is not OPT and not random).

# Question 2)

Points: ...................... of 6

Give a command that can be used to...

½ Point (1) modify the permissions of files or directories.

½ Point (2) print out the path of the present working directory in the shell.

½ Point (3) create a new directory.

½ Point (4) create an empty file.

½ Point (5) concatenate the content of different files or print out the content of a file.

½ Point (6) print out lines from the end of a file in the shell.

½ Point (7) print out lines from the beginning of a file in the shell.

½ Point (8) delete files or directories.

½ Point (9) place a string in the shell.

½ Point (10) create a link.

½ Point (11) search a file for lines, which contain a search pattern.

½ Point (12) terminate a process.

# Question 3)

Points: ...................... of 8

½ Point (1) Name <u>one</u> persistent data storage.

½ Point (2) Name <u>one</u> non-persistent data storage.

½ Point (3) The storage of computer systems is distinguished into the categories primary, secondary, and tertiary storage. Give the name of the category or categories the CPU can access directly.

1 Point (4) Give the name of the category or categories of subtask (3) the CPU can only access via a controller.

1½ Points (5) Name <u>one</u> example for each category of subtask (3).

1 Point (6) Describe what near-line storage is.

1 Point (7) Describe what off-line storage is.

2 Points (8) Name <u>one</u> advantage and <u>one</u> drawback of NAND memory compared with NOR memory.

# Question 4)

Points: ...................... of 7

1 Point (1) Explain the effect when executing this command in the command-line shell:

```
$ chmod 777 script.sh
```

1 Point (2) Explain the effect when executing this command in the command-line shell:

```
$ chmod 544 script.sh
```

1 Point (3) Explain the effect when executing this command in the command-line shell:

```
$ chmod 000 script.sh
```

1 Point (4) Explain the effect when executing this command in the command-line shell:

```
$ chmod u-x folder
```

½ Point (5) For executing a program written in the language C one requires a(n)...

□ Booster
□ Compiler
□ Interpreter
□ Mixer
□ All of them
□ None of them

½ Point (6) For executing a program written in the language Python one requires a(n)...

□ Booster
□ Compiler
□ Interpreter
□ Mixer
□ All of them
□ None of them

1 Point (7) Explain the purpose of the Page-Table Base Register (PTBS).

1 Point (8) Explain the purpose of the Page-Table Length Register (PTLR).

# Question 5)

Points: ...................... of 7

½ Point (1) Local variables of functions reside inside the...

□ Heap □ Stack □ Text Segment

½ Point (2) Call parameters and return addresses of functions reside inside the...

□ Heap □ Stack □ Text Segment

½ Point (3) Constants and variables which get values assigned in global declarations (outside of functions) reside inside the...

□ Heap □ Stack □ Text Segment

½ Point (4) Environment variables of a process reside inside the...

□ Heap □ Stack □ Text Segment

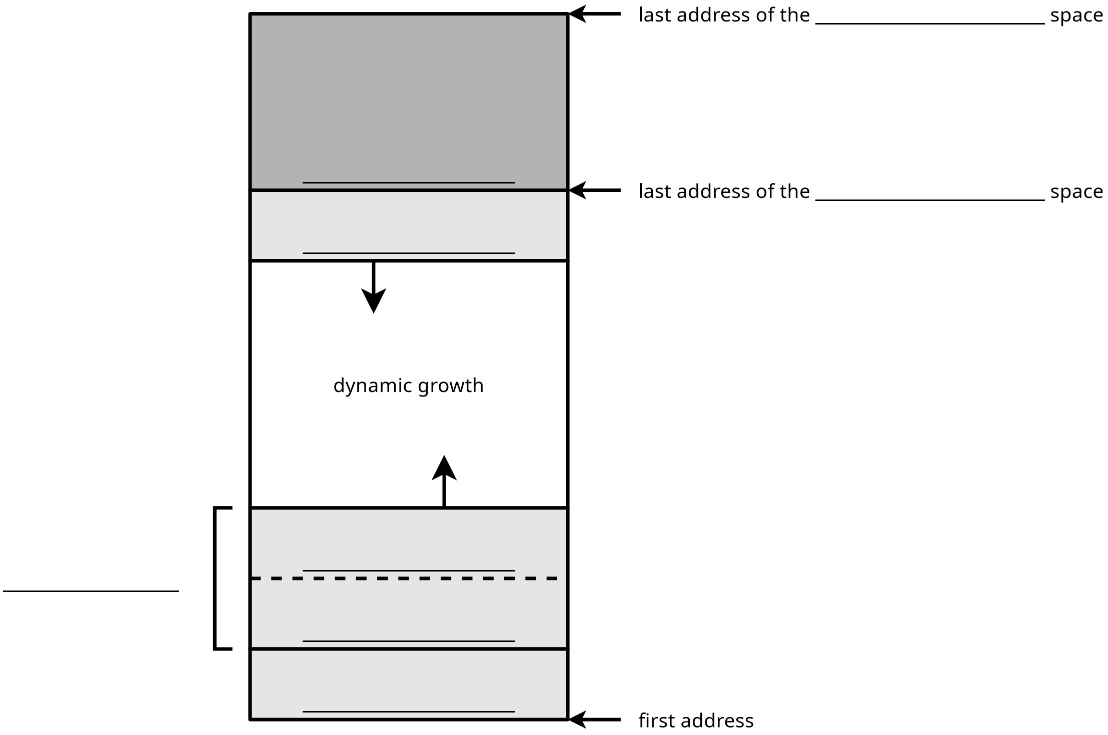
½ Point (5) The machine code of a process resides inside the...

□ Heap □ Stack □ Text Segment

½ Point (6) Command line arguments of a process reside inside the...

□ Heap □ Stack □ Text Segment

4 Points (7) The figure shows the structure of a UNIX process in memory. Fill in the missing labels (technical terms) of the process-related data and the missing information about the content of this data.


last address of the ____________ space
last address of the ____________ space
dynamic growth
____________
first address

# Question 6)

Points: ...................... of 7

1 Point (1) Describe which information inodes store.

1 Point (2) Describe what a cluster in the file system is.

½ Point (3) Give one example for an absolute path name.

½ Point (4) Name one Linux file system that implements block addressing.

½ Point (5) Name one Linux file system that implements journaling.

½ Point (6) Name one Linux file system that implements extents.

½ Point (7) Name one Windows file system that implements the file allocation table.

½ Point (8) Name one Windows file system that implements journaling.

½ Point (9) Name one Windows file system that implements extents.

½ Point (10) Name one file system that implements copy-on-write.

1 Point (11) Describe what the master file table is.

# Question 7)

Points: ....................... of 8

1 Point

(1) Explain what a zombie process is.

3 Points

(2) The following C source code creates a child process.

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

void main() {
  int returnvalue = fork();

  if (returnvalue < 0) {
    printf("Error.\n");
    exit(1);
  }
  else if (returnvalue > 0) {
    printf("Parent.\n");
    exit(0);
  }
  else {
    printf("Child.\n");
    exit(0);
  }
}
```

Give the value of the `returnvalue` variable for the child process and for the parent process. In your answer, explain the importance of the return value in the parent process.

2 Points

(3) Name two differences of a child process from the parent process shortly after its creation.

2 Points

(4) Describe the consequences if a parent process is terminated before the child process.

# Question 8)

Points: ...................... of 8

1 Point (1) Explain why fairness is a relevant criteria in scheduling.

2 Points (2) Explain the difference between preemptive and non-preemptive scheduling.

1 Point (3) Name the scheduling method that Windows operating systems implement.

4 Points (4) Explain how the scheduling method of Windows operating systems works.
(Hint: A schematic diagram may help here!)

# Question 9)

Points: ....................... of 4

4 Points

(1) Explain how the Completely Fair Scheduler of the Linux kernel (Kernel 2.6.23 until Kernel 6.5.13) works.
(Hint: A schematic diagram may help here!)

# Question 10)

Points: ...................... of 7

1 Point (1) Describe what a critical section is.

1 Point (2) Describe what a race condition is.

1 Point (3) Describe why race conditions are hard to locate and fix.

1 Point (4) Explain what a system call is.

1 Point (5) Explain what the standard library is and its purpose.

1 Point (6) Explain what a semaphore is.

1 Point (7) Explain what a mutex is.

# Question 11)

Points: ...................... of 6

6 Points

(1) Perform the deadlock detection with matrices and check if a deadlock occurs.

$$\text{Existing resource vector} = \begin{pmatrix} 10 & 5 & 7 \end{pmatrix}$$

$$\begin{matrix}\text{Current}\\\text{allocation}\\\text{matrix}\end{matrix} = \begin{bmatrix} 0 & 1 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 2 \\ 2 & 1 & 1 \\ 0 & 0 & 2 \end{bmatrix} \qquad \begin{matrix}\text{Request}\\\text{matrix}\end{matrix} = \begin{bmatrix} 7 & 4 & 3 \\ 1 & 2 & 2 \\ 6 & 5 & 0 \\ 4 & 1 & 1 \\ 4 & 3 & 5 \end{bmatrix}$$

# Question 12)

Points: ...................... of 7

½ Point

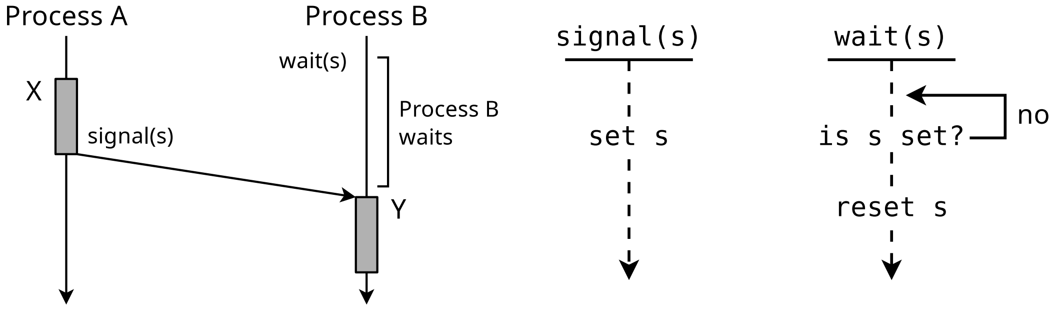
(1) Name <u>one</u> sort of inter-process communication that can only be used for processes that are closely related to each other.

½ Point

(2) Name <u>one</u> sort of inter-process communication that allows communication over computer system boundaries.

3 Points

(3) The figure shows the working principle of signaling, a technique that is used to specify an execution order of critical sections of processes.



Describe where you see room for improvement in terms of CPU utilization.

2 Points

(4) Explain <u>one</u> possible way of implementing the signaling technique shown in subtask (3) in Linux.

1 Point

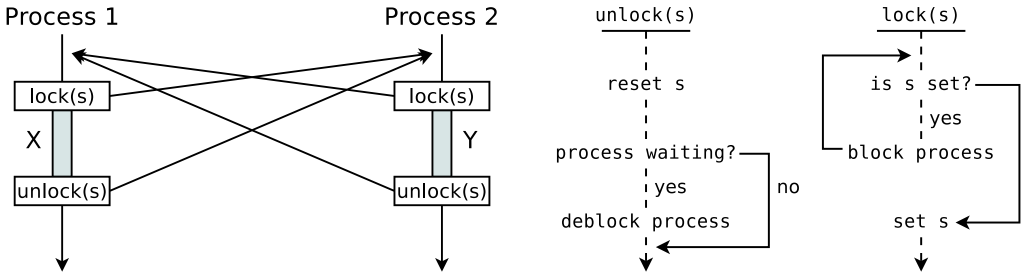
(5) Name a technique for process synchronisation, which has less drawbacks than signaling shown in subtask (3).

# Question 13)

Points: ...................... of 5

2 Points

(1) The figure shows the working principle of a synchronisation technique that ensures that the execution of critical sections does not overlap and does not specify the execution order of the critical sections.



Explain one possible way of implementing the signaling technique shown in this subtask in Linux

½ Point

(2) Name one sort of inter-process communication that operates bidirectional.

½ Point

(3) Name one sort of inter-process communication where the operating system does not guarantee the synchronization.

2 Points

(4) Explain the meaning of the lines and columns in the file `/proc/buddyinfo`.

```
$ cat /proc/buddyinfo
Node 0, zone      DMA      1      1      1      0      2      1      1      0      1      1      3
Node 0, zone    DMA32    208    124   1646    566    347    116    139    115     17      4    212
Node 0, zone   Normal     43     62    747    433    273    300    254    190     20      8    287
```