Sample solution of the written examination

Operating Systems

March 5th 2021

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.
- You are allowed to use a non-programmable calculator.
- Do *not* use a red pen.
- Time limit: *90 minutes*
- Turn off your mobile phones!

Result:

Question:	1	2	3	4	5	6	7	8	9	10	11	**Σ**	Grade
Maximum points:	6	12	10	6	10	8	5	8	9	6	10	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

Last name: First name: Student number:

Question 1)

Points: .....

Maximum points: 6

Give a command that can be used to...

a) print out the path of the present working directory in the shell.

`pwd`

b) create a new directory.

`mkdir`

c) create an empty file.

`touch`

d) concatenate the content of different files or print out the content of a file.

`cat`

e) print out lines from the end of a file in the shell.

`tail`

f) print out lines from the beginning of a file in the shell.

`head`

g) delete files or directories.

`rm`

h) place a string in the shell.

`echo`

i) create a link.

`ln`

j) search a file for lines, which contain a search pattern.

`grep`

k) modify the permissions of files or directories.

`chmod`

l) terminate a process.

`kill`

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Question 2)

Points: .....

Maximum points: 5+5+1+0.5+0.5=12

a) Specify for each storage the access method.

Storage	**Access method**	
CD-ROM/DVD-ROM	☐ sequential	☒ random access
Flash memory	☐ sequential	☒ random access
Punched tape	☒ sequential	☐ random access
Hard disk drive (HDD)	☐ sequential	☒ random access
Main memory (DRAM)	☐ sequential	☒ random access
CD-R/CD-RW/DVD-R	☐ sequential	☒ random access
Punch card	☒ sequential	☐ random access
Magnetic-core memory	☐ sequential	☒ random access
Magnetic tape	☒ sequential	☐ random access
Floppy disk	☐ sequential	☒ random access

b) Specify for each storage how read operations are carried out.

Storage	**Read operation**			
CD-R/CD-RW/DVD-R	☐ electric	☐ mechanic	☐ magnetic	☒ optical
CD-ROM/DVD-ROM	☐ electric	☐ mechanic	☐ magnetic	☒ optical
Floppy disk	☐ electric	☐ mechanic	☒ magnetic	☐ optical
Hard disk drive (HDD)	☐ electric	☐ mechanic	☒ magnetic	☐ optical
Flash memory	☒ electric	☐ mechanic	☐ magnetic	☐ optical
Main memory (DRAM)	☒ electric	☐ mechanic	☐ magnetic	☐ optical
Magnetic-core memory	☐ electric	☐ mechanic	☒ magnetic	☐ optical
Punch card	☐ electric	☒ mechanic	☐ magnetic	☐ optical
Punched tape	☐ electric	☒ mechanic	☐ magnetic	☐ optical
Magnetic tape	☐ electric	☐ mechanic	☒ magnetic	☐ optical

c) Name the two basic cache write policies.

Write-through and write-back.

d) Name the cache write policy of question c) that may cause inconsistencies.

Write-back.

e) Name the cache write policy of question c) that causes a lower system performance.

Write-through.

Last name: First name: Student number:

Question 3)

Points: .....

Maximum points: 1+3+1.5+1.5+1+1+1=10

a) Explain why it is impossible to implement the optimal replacement strategy OPT.

Because it is impossible to predict the future and therefore the future request sequence is unknown.

b) Mark the memory management method that...

- produces many mini-fragments and works most slowly.
  ☐ First Fit ☐ Next Fit ☒ Best fit ☐ Random
- searches for the free block, which fits best.
  ☐ First Fit ☐ Next Fit ☒ Best fit ☐ Random
- fragments quickly the large area of free space at the end of the address space.
  ☐ First Fit ☒ Next Fit ☐ Best fit ☐ Random
- selects randomly a free block.
  ☐ First Fit ☐ Next Fit ☐ Best fit ☒ Random
- searches for a free block, starting from the latest allocation.
  ☐ First Fit ☒ Next Fit ☐ Best fit ☐ Random
- searches for a free block, starting from the beginning of the address space.
  ☒ First Fit ☐ Next Fit ☐ Best fit ☐ Random

c) Name the three components the CPU contains.

Arithmetic logic unit, control unit, memory.

d) Name the three digital bus systems each computer system contains according to the Von Neumann architecture.

Control bus, address bus, data bus.

e) Explain the tasks of the Southbridge.

The Southbridge is used for „slow“ connections like Ethernet, SATA and USB.

f) Explain what a page fault exception causes to occur.

A process tries to access a page, which is not located in the physical main memory.

g) Explain what an access violation exception or general protection fault exception causes to occur.

A process tried to access a virtual memory address, which it is not allowed to access.

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Question 4)

Points: .....

Maximum points: 6

a) Specify the net capacity of a RAID 0 array.
The net capacity is n, if n is the number of drives.

b) Specify the net capacity of a RAID 1 array.
The net capacity is the capacity of the smallest drive.

c) Specify the net capacity of a RAID 5 array.
The net capacity is $n - 1$, if n is the number of drives.

d) Specify the net capacity of a RAID 6 array.
The net capacity is $n - 2$, if n is the number of drives.

e) Name <u>one</u> RAID level, which improves the data transfer rate for write.
RAID-0 or RAID-5.

f) Name <u>one</u> RAID level, which improves the reliability.
RAID-1 or RAID-5.

g) Give the number of drives that can fail in a RAID 0 array without data loss.
None.

h) Give the number of drives that can fail in a RAID 1 array without data loss.
At least a single drive must work properly.

i) Give the number of drives that can fail in a RAID 5 array without data loss.
A single drive maximum is allowed to fail.

j) Give the number of drives that can fail in a RAID 6 array without data loss.
Two drives maximum are allowed to fail.

k) Name <u>one</u> advantage of software RAID compared with hardware RAID.
Benefit: No cost for additional hardware.

l) Name <u>one</u> drawback of software RAID compared with hardware RAID.
Drawback(s): Operating system dependent, additional CPU load.

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Question 5)

Points: .....

Maximum points: 8+1+1=10

a) Show Belady's anomaly by performing the access sequence with the replacement strategy FIFO once with a cache with a capacity of 3 pages and once with 4 pages. Also calculate the hit rate and the miss rate for both scenarios.

Requests:	**3**	**2**	**1**	**0**	**3**	**2**	**4**	**3**	**2**	**1**	**0**	**4**
Page 1:	**3**	3	3	**0**	0	0	**4**	4	4	4	4	4
Page 2:		**2**	2	2	**3**	3	3	3	3	**1**	1	1
Page 3:			**1**	1	1	**2**	2	2	2	2	**0**	0

Hit rate: 3/12 = 25%

Miss rate: 9/12 = 75%

Requests:	**3**	**2**	**1**	**0**	**3**	**2**	**4**	**3**	**2**	**1**	**0**	**4**
Page 1:	**3**	3	3	3	3	3	**4**	4	4	4	**0**	0
Page 2:		**2**	2	2	2	2	2	**3**	3	3	3	**4**
Page 3:			**1**	1	1	1	1	1	**2**	2	2	2
Page 4:				**0**	0	0	0	0	0	**1**	1	1

Hit rate: 2/12 = 16.66%

Miss rate: 10/12 = 83.33%

b) Mark the replacement strategy that is implemented by most modern operating systems.

☐ FIFO ☐ Optimal ☐ LRU ☒ Clock ☐ LFU ☐ TTL

c) Explain why fragmentation in memory management is irrelevant for modern operating systems.

Because of the virtual memory concept.

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Question 6)

Points: .....

Maximum points: 1.5+0.5+0.5+1+0.5+0.5+0.5+1+1+1=8

a) Name the three sorts of process context information the operating system stores.

User context, hardware context and system context.

b) Explain the task of the dispatcher.

It carries out the state transitions of the processes.

c) Explain the task of the scheduler.

It specifies the execution order of the processes.

d) Explain what a zombie process is.

A zombie process has completed execution (via the system call `exit`*) but its entry in the process table exists until the parent process has fetched (via the system call* `wait`*) the exit status (return code). Its PID can not yet be assigned to a new process.*

e) Explain what the PID is.

the process identifier (PID) is an integer number used to uniquely identify a process.

f) Explain what the PPID is.

The parent process identifier (PPID) is an integer number too. It is the process ID of a parent process of a process.

g) Explain what the UID is.

The user identifier (UID) is an integer number used to uniquely identify an operating system user.

h) Describe the effect of calling the system call `fork`.

If a process calls `fork`*, an identical copy is started as a new process.*

i) Describe the effect of calling the system call `exec`.

The system call `exec` *replaces a process with another one.*

j) Explain why some operating systems have one or more system idle processes.

If no process is in the state `ready`*, the system idle process gets the CPU assigned. The system idle process is always active and has the lowest priority. Due to the system idle process, the scheduler must never consider the case that no active process exists.*

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Question 7)

Points: .....

Maximum points: 5

a) Call parameters and return addresses of functions contains the...

☐ Heap ☒ Stack ☐ Text Segment

b) Constants and variables which get values assigned in global declarations (outside of functions) contains the...

☒ Heap ☐ Stack ☐ Text Segment

c) Environment variables of a process contains the...

☐ Heap ☒ Stack ☐ Text Segment

d) The program code (machine code) of a process contains the...

☐ Heap ☐ Stack ☒ Text Segment

e) Command line arguments of a process contains the...

☐ Heap ☒ Stack ☐ Text Segment

f) Local variables of functions contains the...

☐ Heap ☒ Stack ☐ Text Segment

g) Describe what a critical section is.

Processes carry out read and write operations on common data. Critical sections may not be processed by multiple processes at the same time.

h) Describe what a race condition is.

It is an unintended race condition of two processes, which want to modify the value of the same record.

i) Describe why race conditions are hard to locate and fix.

The result of a process depends on the order or timing of other events. The occurrence of the symptoms depends on different events. The symptoms may be different or disappear with each test run.

j) Describe how to avoid race conditions.

Race conditions can be avoided with the semaphore concept.

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Question 8)

Points: .....

Maximum points: 1+1+1+0.5+0.5+1+1+1+1=8

a) Explain the advantage of using the operations signal and wait compared with busy waiting.

When using busy waiting, computing time of the CPU is wasted because it is again and again occupied by the waiting process. Using signal and wait causes lesser CPU workload because the waiting process is blocked and later deblocked.

b) Name two problems that can arise from blocking.

Starvation and deadlock.

c) Explain the difference between signaling and blocking.

Signaling specifies the execution order of the critical sections of processes.

Blocking secures critical sections. The execution order of the critical sections of the processes is not specified. It is just ensured that the execution of critical sections does not overlap.

d) Mark the scheduling method that is implemented by message queues.

☐ Round Robin ☐ LIFO ☐ SJF ☒ FIFO ☐ LJF

e) Specify how many processes can communicate with each other via a pipe.

2

f) Explain the effect, when a process tries to write data into a pipe without free capacity.

The process that tries to write into the pipe is blocked.

g) Explain the effect, when a process tries to read data from an empty pipe.

The process that tries to read from the pipe is blocked.

h) Name the two different types of pipes.

Anonymous pipes and named pipes.

i) Name the two different types of sockets.

Connection-less sockets (also called: datagram sockets) and connection-oriented sockets (also called: stream sockets).

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Question 9)

Points: .....

Maximum points: 9

a) Mark <u>one</u> sort of inter-process communication, which allows communication over computer boundaries.

☐ Anonymous Pipes ☒ Sockets ☐ Shared Memory ☐ Message Queues

b) Mark <u>one</u> sort of inter-process communication, which can only be used for processes, which are closely related to each other.

☒ Anonymous Pipes ☐ Sockets ☐ Shared Memory ☐ Message Queues

c) Mark <u>one</u> sort of inter-process communication, where synchronization is <u>not</u> done by the operating system. It is a task of the developer.

☐ Anonymous Pipes ☐ Sockets ☒ Shared Memory ☐ Message Queues

d) Mark <u>one</u> sort of inter-process communication, where the data remains intact without a bound process.

☐ Anonymous Pipes ☐ Sockets ☒ Shared Memory ☒ Message Queues

e) Explain the functioning of the `P` access operation of a semaphore.

The access operation `P` tries to reduce (decrement) the value of the counter variable.

f) Explain the functioning of the `V` access operation of a semaphore.

The access operation `V` increments the value of the counter variable.

g) Explain the difference between Semaphores versus blocking/locking.

In contrast to semaphores, can locks only be used to allow a single process entering the critical section at the same time.

h) Explain what a binary semaphore is.

Binary semaphores are initialized with value 1 and ensure that 2 or more processes cannot simultaneously enter their critical sections.

i) Name the Linux/UNIX command that returns information about existing shared memory segments, message queues and semaphores.

`ipcs`

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Question 10)

Points: .....

Maximum points: 6

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

$$\text{Existing resource vector} = \begin{pmatrix} 9 & 6 & 8 & 7 & 6 & 7 \end{pmatrix}$$

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

The existing resource vector and the current allocation matrix are used to calculate the available resource vector.

$$\textit{Available resource vector} = \begin{pmatrix} 1 & 1 & 2 & 2 & 3 & 2 \end{pmatrix}$$

Only process 1 can run with this available resource vector. The following available resource vector results when process 1 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 3 & 1 & 4 & 5 & 5 & 2 \end{pmatrix}$$

Only process 3 can run with this available resource vector. The following available resource vector results when process 3 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 4 & 4 & 6 & 6 & 5 & 3 \end{pmatrix}$$

Only process 4 can run with this available resource vector. The following available resource vector results when process 4 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 7 & 5 & 6 & 7 & 6 & 4 \end{pmatrix}$$

Process 2 is not blocked.

No deadlock occurs.

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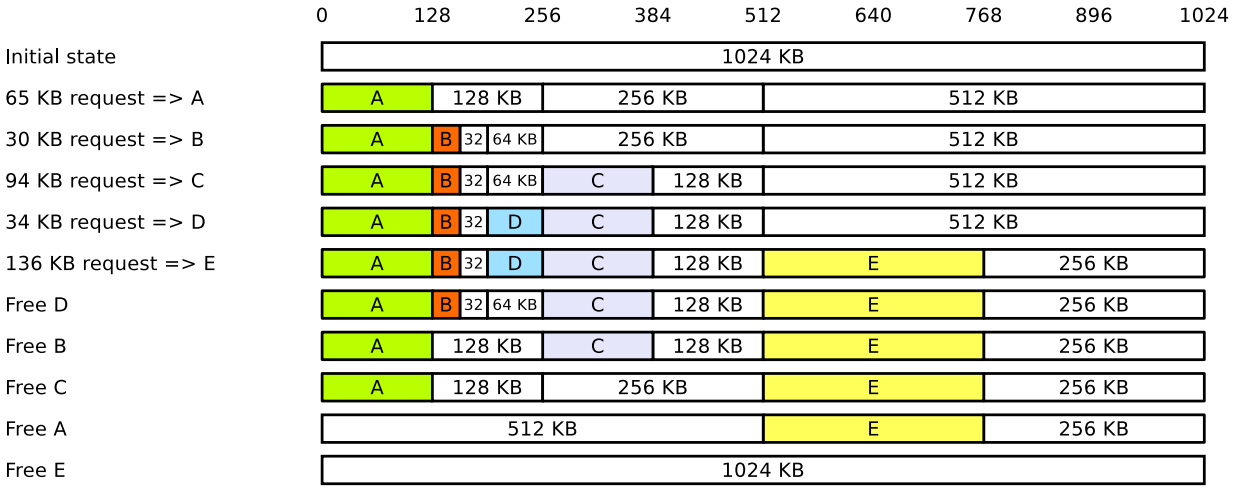
Question 11)

Points: .....

Maximum points: 10

The Buddy method for allocating memory to processes shall be used for a memory with a capacity of 1024 kB. Perform the provided operations and give the occupancy state of the memory after each operation.



(*!!! CAUTION !!! With the second template you can save time, if you want to try it all over again. Mark clearly which one of your solutions shall be considered during the correction!*)