

Last name:

First name:

Student number:

Question 1)

Points:

Maximum points: $1+1+1+1+2=6$

- a) For which tasks is batch processing especially well suited

Batch processing is well suited for the execution of routine tasks.

- b) What is the purpose of memory protection?

A bug or crash of a single program does not affect the stability of other programs and the total system.

- c) What is the difference between 8 bit, 16 bit, 32 bit and 64 bit operating systems?

The bit number indicates the memory address length, with which the operating system works internally.

- d) Name the two types of real-time operating systems.

Hard real-time operating systems and soft real-time operating systems.

- e) Your colleague recommends you to relocate frequently used server daemons, such as web server, email server, SSH server and FTP server, from the user mode to the kernel mode. What is your opinion about this idea? Give reasons for your answer. Name at least one benefit and a drawback.

Last name:

First name:

Student number:

Question 2)

Points:

Maximum points: 2+3=5

- a) Explain the two file entries „.“ and „..“ in the output of `ls`?

```
$ mkdir new_directory
$ cd new_directory
$ ls -l --all --size --human-readable
insgesamt 8,0K
4,0K drwxr-xr-x  2 bnc users 4,0K Jul 12 11:03 .
4,0K drwxr-xr-x 119 bnc users 4,0K Jul 12 11:03 ..
```

„.“ is a hard link which points to the folder `new_directory` and „..“ is a hard link which points to the folder one layer above in the directory hirachy.

- b) Explain the permissions of the file `convert_script.py`.

```
$ ls -l --all --size --human-readable
insgesamt 16K
4,0K drwxr-xr-x  2 bnc users 4,0K Jul 12 09:14 .
4,0K drwxr-xr-x 119 bnc users 4,0K Jul 12 09:13 ..
8,0K -rwxr-xr--  1 bnc users 7,0K Jul 12 09:22 convert_script.py
```

(Note: Describe which operations the different users/groups are allowed to carry out with the file.)

The user `bnc` has the permission to carry out read and write operations on the file and to execute it.

All users, which are members of the group `users` have the permission to carry out read operations on the file and to execute it.

All other users have the permission to carry out read operations on the file.

Last name:

First name:

Student number:

Question 3)

Points:

Maximum points: $1+0.5+0.5+1+1+1+1=6$

- a) Name the two basic cache write policies.

Write-through und write-back.

- b) With which cache write policy of subtask a) may inconsistencies occur?

Write-back.

- c) With which cache write policy of subtask a) is the system performance lower?

Write-through.

- d) With which cache write policy of subtask a) are so called dirty bits used?

Write-back.

- e) For what reason are dirty bits used?

For each page inside the cache, a dirty bit specifies whether the page was modified.

- f) Which factors influence the access time of HDDs?

- *Average seek time*
- *Average rotational latency time*

- g) Describe the factors of subtask f).

- *The average seek time is the time that it takes for the arm to reach a desired track.*
- *The average rotational latency time is the delay of the rotational speed, until the required disk sector is located under the head. It depends entirely on the rotational speed of the disks.*

Last name:

First name:

Student number:

Question 4)

Points:

Maximum points: $1+1+1+1+1+1=6$

- a) Please comment the statement: „A RAID array can be used to replace the regular backup of important data“.

RAID is not a backup replacement. Wrong file operations or virus attacks take place on all drives.

- b) Why is it not useful to store all parity information on a single drive, but to distribute the parity information on all drives?

Each write operation on the RAID causes write operations on the dedicated parity drive \implies bottleneck.

- c) What is the net capacity of a RAID 0 array?

The net capacity is n , if n is the number of drives.

- d) What is the net capacity of a RAID 1 array?

The net capacity is the capacity of the smallest drive.

- e) What is the net capacity of a RAID 5 array?

The net capacity is $n - 1$, if n is the number of drives.

- f) How are the parity information of a RAID 5 array calculated?

$P(16-19) = \text{Block 16 XOR Block 17 XOR Block 18 XOR Block 19}.$

Last name:

First name:

Student number:

Question 5)

Points:

Maximum points: $3+1+1+1+1+0.5+0.5+1=9$

a) What is virtual memory?

Each process has a separate address space. This address space is an abstraction of the physical memory. It implements virtual memory. It consists of logical memory addresses, which are numbered from address 0 upwards. It is independent from the storage technology used and the existing expansion options.

b) Explain, why virtual memory helps to better utilize the main memory.

Processes do not need to be located in a row inside the main memory. External fragmentation occurs, but it is not a problem.

c) What is mapping?

The virtual memory is mapped to the physical memory.

d) What is swapping?

The process of relocating data from the main memory to the SDD/HDD and back.

e) Name the two different virtual memory concepts.

Segmentation and paging.

f) With which concept of subtask e) does internal fragmentation occur?

Paging. But it can only occur in the last page of each process.

g) With which concept of subtask e) does external fragmentation occur?

Segmentation.

h) What causes a page fault exception to occur?

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

Last name:

First name:

Student number:

Question 6)

Points:

Maximum points: $1+1+2+1+1+1=7$

a) What is an absolute path name?

It is a path name, which describes the complete path from the root to the file.

b) What is a relative path name?

It is a path name, which does not begin with the root.

c) What is the File Allocation Table (FAT) and what information does it store?

For each cluster in the file system, an entry exists in the FAT with the following information about the cluster:

- *Cluster is free or the storage medium is damaged at this point.*
- *Cluster is occupied by a file and it stores the address of the next cluster which belongs to the file or it is the last cluster of the file.*

d) What is the objective of the journal in journaling file systems?

In the journal, write operations are collected before being committed to the file system.

e) Name an advantage of journaling file systems compared with file systems without a journal.

After a crash, only the files (clusters) and metadata must be checked, for which a record exists in the journal.

f) What sort of data processing is maximum accelerated by defragmenting?

A continuous arrangement does maximum accelerate the continuous forward reading of data because no more seek times occur.

Last name:

First name:

Student number:

Question 7)

Points:

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

- a) Which three sorts of process context information stores the operating system?

User context, hardware context and system context.

- b) Which process context information are not stored in the process control block?

The user context, which is the allocated address space (virtual memory).

- c) Why does the process control block not store all process context information?

Depending of the architecture, the virtual memory of each process may be several GB in size. Therefore, the user context is just too big in size, to store it twice.

- d) What is the task of the dispatcher?

It carries out the state transitions of the processes.

- e) What is the task of the scheduler?

It specifies the execution order of the processes.

- f) What is the effect of calling the system call `fork()`?

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

- g) What is the effect of calling the system call `exec()`?

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

- h) What is a `cron` job?

A `cron` job specifies the time-based execution of a command or a process.

Last name:

First name:

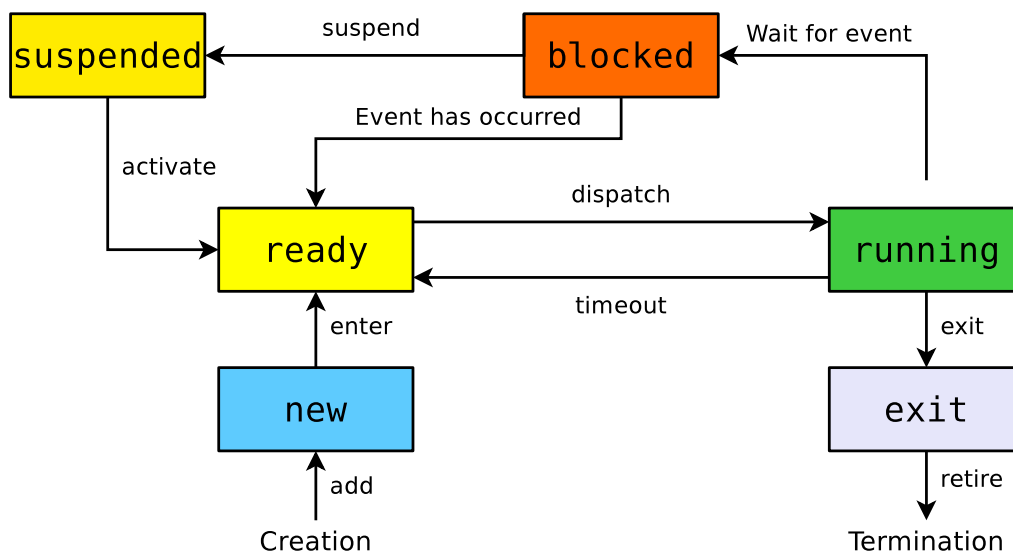
Student number:

Question 8)

Points:

Maximum points: 6+1=7

- a) Enter the names of the states in the diagram of the process state model with 6 states.



- b) What is a zombie process?

*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). It's PID still cannot assigned to another process.*

Last name:

First name:

Student number:

Question 9)

Points:

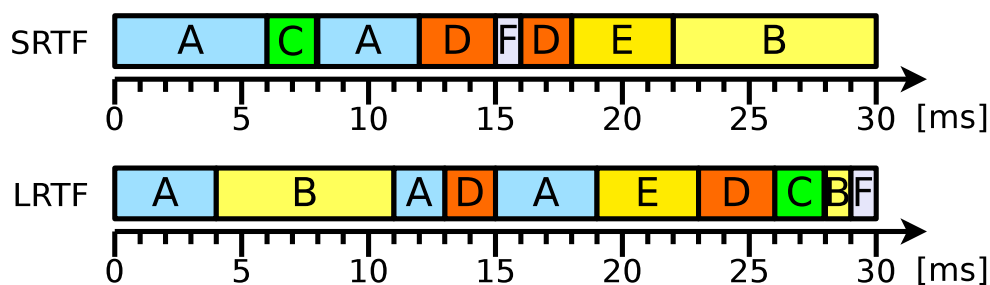
Maximum points: 5+5+2+2+2+2=18

a) Six processes with different creation times shall be executed on a single CPU system.

Process	CPU runtime [ms]	Creation time [ms]
A	10	0
B	8	4
C	2	6
D	5	11
E	4	13
F	1	15

Draw the execution order of the processes with a Gantt chart (timeline) for...

- Shortest Remaining Time First and
- Longest Remaining Time First.



b) Calculate the average runtimes of the processes.

$$\text{Shortest Remaining Time First} \quad \frac{12+26+2+7+9+1}{6} = 9.5 \text{ ms}$$

$$\text{Longest Remaining Time First} \quad \frac{19+25+22+15+10+15}{6} = 17.\bar{6} \text{ ms}$$

c) Calculate the average waiting times of the processes.

$$\text{Shortest Remaining Time First} \quad \frac{2+18+0+2+5+0}{6} = 4.5 \text{ ms}$$

$$\text{Longest Remaining Time First} \quad \frac{9+17+20+10+6+14}{6} = 12.\bar{6} \text{ ms}$$

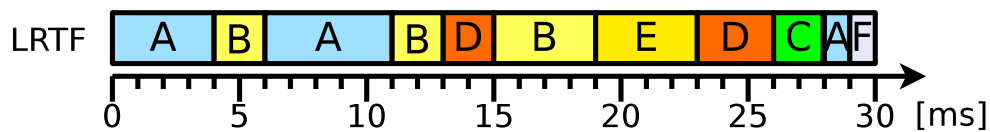
Last name:

First name:

Student number:

Question 9 – Continuation)

This solution for LRTF was graded as correct too. Here, if several processes have the same remaining CPU runtime during an event, always FIFO is used. On a single CPU system, this solution is more meaningful, because the running process must be interrupted in any case when an event occurs because the scheduler need the CPU for the review.



Average runtimes of the processes.

$$\text{Longest Remaining Time First } \frac{29+15+22+15+10+15}{6} = 17.\bar{6} \text{ ms}$$

Average waiting times of the processes.

$$\text{Longest Remaining Time First } \frac{19+7+20+10+6+14}{6} = 12.\bar{6} \text{ ms}$$

Last name:

First name:

Student number:

Question 10)

Points:

Maximum points: $1+1+1+2=5$

- a) What is the advantage of 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) What is a barrier?

A barrier synchronizes the involved processes at one point.

- c) Which two problems can arise from blocking?

Starvation and deadlock.

- d) What is 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.

Last name:

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Student number:

Question 11)

Points:

Maximum points: 13

In a warehouse, packages are delivered constantly by a supplier and picked up by two deliverers. The supplier and the deliverers need to pass through a gate. The gate can always be passed only by a single person. The supplier brings three packages with every shipment to the incoming goods section. One of the deliverers can pick two packages with every pickup from the outgoing goods section. The other deliverer can pick only a single package per pickup from the outgoing goods section. Exactly one process **Supplier**, one process **Deliverer_X** and one process **Deliverer_Y** exist.

For synchronizing the three processes, create the required semaphores, assign them values and insert semaphore operations. These conditions must be met:

- Only a single process can pass through the gate.
It is impossible that multiple processes pass through the gate simultaneously.
- Only one of both existing deliverers can access the outgoing goods section.
It is impossible that both deliverers access the outgoing goods section simultaneously.
- It should be possible that the supplier and one of the deliverers can simultaneously unload and pick goods.
- The capacity of the warehouse is 20 packages.
- No deadlocks are allowed.
- At the beginning, the warehouse contains no packets and the gate, as well as the incoming goods section and the outgoing goods section are free.

Source: TU-München, Übungen zur Einführung in die Informatik III, WS01/02

These semaphores are required:

- Boolean semaphore **gate** for the mutual exclusion of the gate with initial value 1. Initially, the gate is empty.
- Boolean semaphore **outgoing_goods_section** for the mutual exclusion of the outgoing goods section with initial value 1. Initially, the outgoing goods section is empty.
- Semaphore **free** for counting the free spaces in the warehouse with initial value 20. Initially all spaces are free.
- Semaphore **occupied** for counting the occupied spaces in the warehouse with initial value 0. Initially no space is occupied.

Last name:

First name:

Student number:

Question 11 – Continuation)

```
sema gate                = 1
sema outgoing_goods_section = 1
sema free                 = 20
sema occupied             = 0
```

```
Supplier                Deliverer_X                Deliverer_Y
{                        {                        {
  while (TRUE)          while (TRUE)          while (TRUE)
  {                    {                        {
    P(gate);            P(gate);            P(gate);
    <Pass through gate>; <Pass through gate>; <Pass through gate>;
    V(gate);            V(gate);            V(gate);

                        P(outgoing_goods_section); P(outgoing_goods_section);
    <Enter incoming    <Enter outgoing    <Enter outgoing
    goods section>;    goods section>;    goods section>;

                        P(occupied);
    P(free);            P(occupied);            P(occupied);
    P(free);            P(occupied);            <Pick 1 packet>;
    <Unload 3 packets>; <Pick 2 packets>;    V(free);
    V(occupied);        V(free);            V(free);
    V(occupied);        V(free);

                        <Leave outgoing
    <Leave incoming    <Leave outgoing    goods section>;
    goods section>;    goods section>;    V(outgoing_goods_section);
                        V(outgoing_goods_section);

    P(gate);            P(gate);            P(gate);
    <Pass through gate>; <Pass through gate>; <Pass through gate>;
    V(gate);            V(gate);            V(gate);
  }                    }                        }
}                      }                        }
```