## Solution of Exercise Sheet 5

# Exercise 1 (Memory Management)

1.	With which men	Vith which memory management methods do internal fragmentation occur?								
	<ul><li></li></ul>	titioning								
2.	Vith which memory management methods do external fragmentation occur									
	<ul> <li>□ Static partitioning</li> <li>⋈ Dynamic partitioning</li> <li>⋈ Buddy memory allocation</li> </ul>									
3.	How can extern	al fragmentation	be fixed?							
	By defragmenta	tion. For virtual memory, external fragmentation is irrelevant.								
4.	Which memory	management me	thod searches for	or the block, which fits best?						
	$\square$ First Fit	$\square$ Next Fit	$\boxtimes$ Best fit	$\square$ Random						
5.	*	hich memory management concept searches for a free block, starting from e beginning of the address space?								
	⊠ First Fit	□ Next Fit	$\square$ Best fit	$\square$ Random						
6.		management con l of the address s		quickly the large area of free						
	$\square$ First Fit	$\boxtimes$ Next Fit	$\square$ Best fit	Random						
7.	Which memory block?	management co	ncept selects ra	andom a free and appropriate						
	☐ First Fit	$\square$ Next Fit	$\square$ Best fit	⊠ Random						
8.	Which memory the latest alloca	_	ncept searches f	for a free block, starting from						
	☐ First Fit	$\boxtimes$ Next Fit	$\square$ Best fit	☐ Random						
9.	Which memory slow?	management co	ncept produces	many mini-fragments and is						
	☐ First Fit	$\square$ Next Fit	$\boxtimes$ Best fit	$\square$ Random						

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### Exercise 2 (Buddy Memory Allocation)

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

	1024 KB									
65 KB Anforderung => A	А	128 KB	256	КВ	512 KB					
30 KB Anforderung => B	А	B 32 64 KB	(B 256 KB		512 KB					
90 KB Anforderung => C	А	B 32 64 KB	C 128 KE		512 KB					
34 KB Anforderung => D	А	B 32 D	C 128 KB		512 KB					
130 KB Anforderung => E	А	B 32 D	С	128 KB	E	256 KB				
Freigabe C	А	B 32 D	128 KB	128 KB	E	256 KB				
	Α	B 32 D	256 KB		Е	256 KB				
Freigabe B	А	32 32 <b>D</b>	256 KB		Е	256 KB				
	А	64 KB D	256 KB		Е	256 KB				
275 KB Anforderung => F Nicht möglich, weil keine 275 kB am Stück frei	А	64 KB D	256 KB		Е	256 KB				
145 KB Anforderung => G	А	64 KB D	G		Е	256 KB				
Freigabe D	Α	64 KB 64 KB	G		Е	256 KB				
	Α	128 KB	(	j	Е	256 KB				
Freigabe A	128 KB	128 KB	G		E	256 KB				
	256 KB		G		E	256 KB				
Freigabe G	128 KB	128 KB	256 KB		Е	256 KB				
		512	КВ		Е	256 KB				
Freigabe E		512	КВ		256 KB	256 KB				
		512	КВ		512 KB					
	1024 KB									

### Exercise 3 (Real Mode and Protected Mode)

1. Describe the functioning of the real mode.

Each process can access the entire memory, which can be addressed.

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- 2. Why is it impossible to use real mode for multitasking operation mode?

  It provides no memory protection.
- 3. Describe the functioning of the protected mode.

Each process can only access its own virtual memory. Virtual memory addresses translates the CPU with the MMU into physical memory addresses.

4. 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 and it is independent from the storage technology used and the existing expansion options.

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

Processes do not need to be located in one piece inside the main memory. Therefore, the external fragmentation of the main memory is not a problem.

6. What is mapping?

The virtual memory is mapped to the physical memory.

7. What is swapping?

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

8. Which component of the CPU is used to implement virtual memory?

Memory Management Unit (MMU).

9. Describe the function of the component from subtask 8.

Virtual memory addresses are translated into physical memory addresses by the CPU using the MMU.

10. Name a virtual memory concept.

Paging.

11. What sort of fragmentation does occur with the concept of subtask 10?

Internal fragmentation. It can only occur in the last page of each process.

12. What causes a page fault exception to occur?

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

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13. What is the reaction of the operating system, when a page fault exception occurs?

The operating system handles the page fault exception by executing these steps:

- Allocate the page by using the controller and the device driver on the swap memory (SSD/HDD).
- Copy the page into a free page of the main memory.
- Update the page table.
- Return control to the process. The process next tries to execute again the instruction that caused the page fault.
- 14. What causes an access violation exception or general protection fault exception to occur?

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

15. What is the consequence (effect) of an access violation exception or general protection fault exception?

In some legacy Windows operating systems, segmentation faults often caused system crashes and resulted in a blue screen. In Linux, the signal **SIGSEGV** is returned as a result.

16. What contains the kernelspace?

The operating system kernel and kernel extensions (drivers).

17. What contains the userspace?

The currently running process, which is extended with swap memory (Windows: page file).

#### Exercise 4 (Memory Management)

Please mark for each one of the following statements, whether the statement is true or false.

1.	Real mode is suited for multitasking systems.								
	$\square$ True	$\boxtimes$ False							
2. In protected mode, each process is executed in its own copy of the physical address space, which is protected from other processes.									
	⊠ True	$\square$ False							

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პ.	When static partitioning is used, internal fragmentation occurs.						
	⊠ True	☐ False					
4.	When dynamic partitioning is used, external fragmentation cannot occur.						
	$\square$ True	⊠ False					
5.	With paging, all pages have the same length.						
	⊠ True	$\square$ False					
6.	One advantage of long pages is little internal fragmentation.						
	$\square$ True	⊠ False					
7.	A drawback o	f short pages is that the page table gets bigger.					
	⊠ True	☐ False					
8.	When paging physical memory	is used, the MMU translates the logical memory addresses into ory addresses.					
	⊠ True	$\square$ False					
9.	Modern operating systems (for x86) operate in protected mode and use onl paging.						
	⊠ True	☐ False					

### Exercise 5 (Page Replacement Strategies)

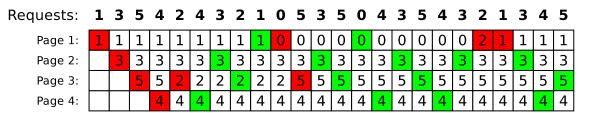
1. Why is it impossible to implement the optimal replacement strategy OPT?

Because it is not possible to predict the future and therefore the future request sequence is unknown.

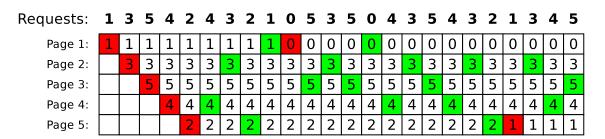
2. Perform the access sequence with the replacement strategies Optimal, LRU, LFU and FIFO once with a cache with a capacity of 4 pages and once with 5 pages. Also calculate the hit rate and the miss rate for all scenarios.

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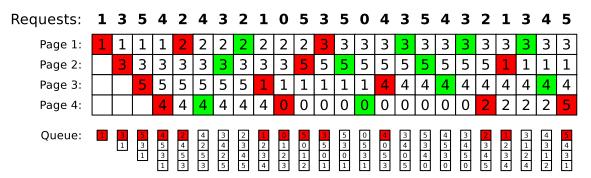
Optimal replacement strategy (OPT):



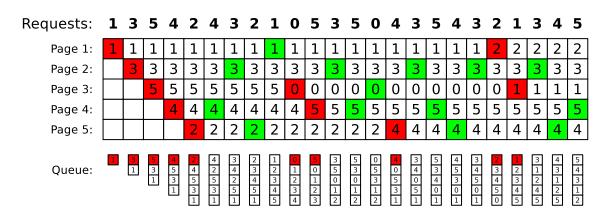
Hitrate: 15/24 = 0.625Missrate: 9/24 = 0.375



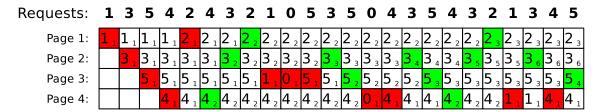
Hitrate: 17/24 = 0.7083333Missrate: 7/24 = 0.2916666 Replacement strategy Least Recently Used (LRU):



Hitrate: 11/24 = 0.4583333%Missrate: 13/24 = 0.5416666%



Hitrate: 14/24 = 0.583333%Missrate: 10/24 = 0.416666% Replacement strategy Least Frequently Used (LFU):



Hitrate: 12/24 = 0.5Missrate: 12/24 = 0.5

> Hitrate: 9/24 = 0.375Missrate: 15/24 = 0.625

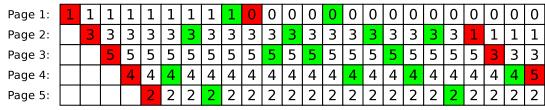
Replacement strategy FIFO:

Requests: 1 3 5 4 2 4 3 2 1 0 5 3 5 0 4 3 5 4 3 2 1 3 4 5 Page 1: Page 2: 

0 0 0 0 0 0 Page 3: Page 4: 

Hitrate: 11/24 = 0.4583333Missrate: 13/24 = 0.5416666

Requests: 1 3 5 4 2 4 3 2 1 0 5 3 5 0 4 3 5 4 3 2 1 3 4 5



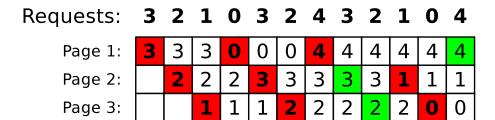
Hitrate: 15/24 = 0.625Missrate: 9/24 = 0.375

3. What is the key message of Laszlo Belady's anomaly?

FIFO result in worse results for certain access sequences with a bigger memory.

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4. 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.



Hitrate: 3/12 = 25%Missrate: 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	ო	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

Hitrate: 2/12 = 16.66%Missrate: 10/12 = 83.33%

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 for both scenarios the hit rate and miss rate.

# Exercise 6 (Time-based Command Execution, Sorting, Environment Variables)

1. Create in your home directory a directory NotImportant and write a cron job, which erases the content of the directory NotImportant every Tuesday at 1:25 clock am.

The output of the command should be appended to a file EraseLog.txt in your home directory.

- \$ mkdir ~/NotImportant
- \$ crontab -e

Insert these lines:

```
25 1 * * 2 rm -rfv /home/USERNAME/NotImportant/* >>
/home/USERNAME/EraseLog.txt
```

2. Write a cron job, which appends a line at a file Datum.txt with the following format (but with the current values) every 3 minutes between 14:00 to 15:00 clock on every Tuesday in the month of November:

\$ crontab -e

Insert these lines:

3. Write an at-job, which outputs at 17:23 today a list of the running processes.

```
$ at 1725 today
```

Insert these lines:

```
ps -r
```

4. Write an at-job, which outputs at December 24th at 8:15 am the text "It's christmas!"

```
$ at 0815 DEZ 25
```

Insert these lines:

```
echo "It's christmas!"
```

5. Create in your home directory a file Kanzler.txt with the following content:

```
Willy
          Brandt
                     1969
Angela
          Merkel
                     2005
Gerhard
          Schröder
                     1998
KurtGeorg Kiesinger 1966
          Kohl
Helmut
                     1982
Konrad
          Adenauer
                    1949
Helmut
          Schmidt
                     1974
                     1963
Ludwig
          Erhard
```

```
$ echo "Willy Brandt 1969" >> ~/Kanzler.txt
$ echo "Angela Merkel 2005" >> ~/Kanzler.txt
$ echo "Gerhard Schröder 1998" >> ~/Kanzler.txt
```

```
$ echo "KurtGeorg Kiesinger 1966" >> ~/Kanzler.txt
$ echo "Helmut Kohl 1982" >> ~/Kanzler.txt
$ echo "Konrad Adenauer 1949" >> ~/Kanzler.txt
$ echo "Helmut Schmidt 1974" >> ~/Kanzler.txt
$ echo "Ludwig Erhard 1963" >> ~/Kanzler.txt
```

6. Print out the file Kanzler.txt sorted by the first names.

```
$ sort ~/Kanzler.txt
```

7. Print out the file Kanzler.txt sorted by the third letter of the last names.

```
$ sort -k+2.4 ~/Kanzler.txt
```

8. Print out the file Kanzler.txt sorted by the year of the inauguration.

```
$ sort -k3 ~/Kanzler.txt
```

9. Print out the file Kanzler.txt backward reverse sorted by the year of the inauguration and redirect the output into a file Kanzlerdaten.txt.

```
$ sort -k3 -nr ~/Kanzler.txt > ~/Kanzlerdaten.txt
```

- 10. Create with the command export an environment variable VAR1 and assign it the value Testvariable.
  - \$ export VAR01=Testvariable
- 11. Print out the value of VAR1 in the shell.
  - \$ printenv VAR01
- 12. Erase the environment variable VAR1.
  - \$ unset VAR01