

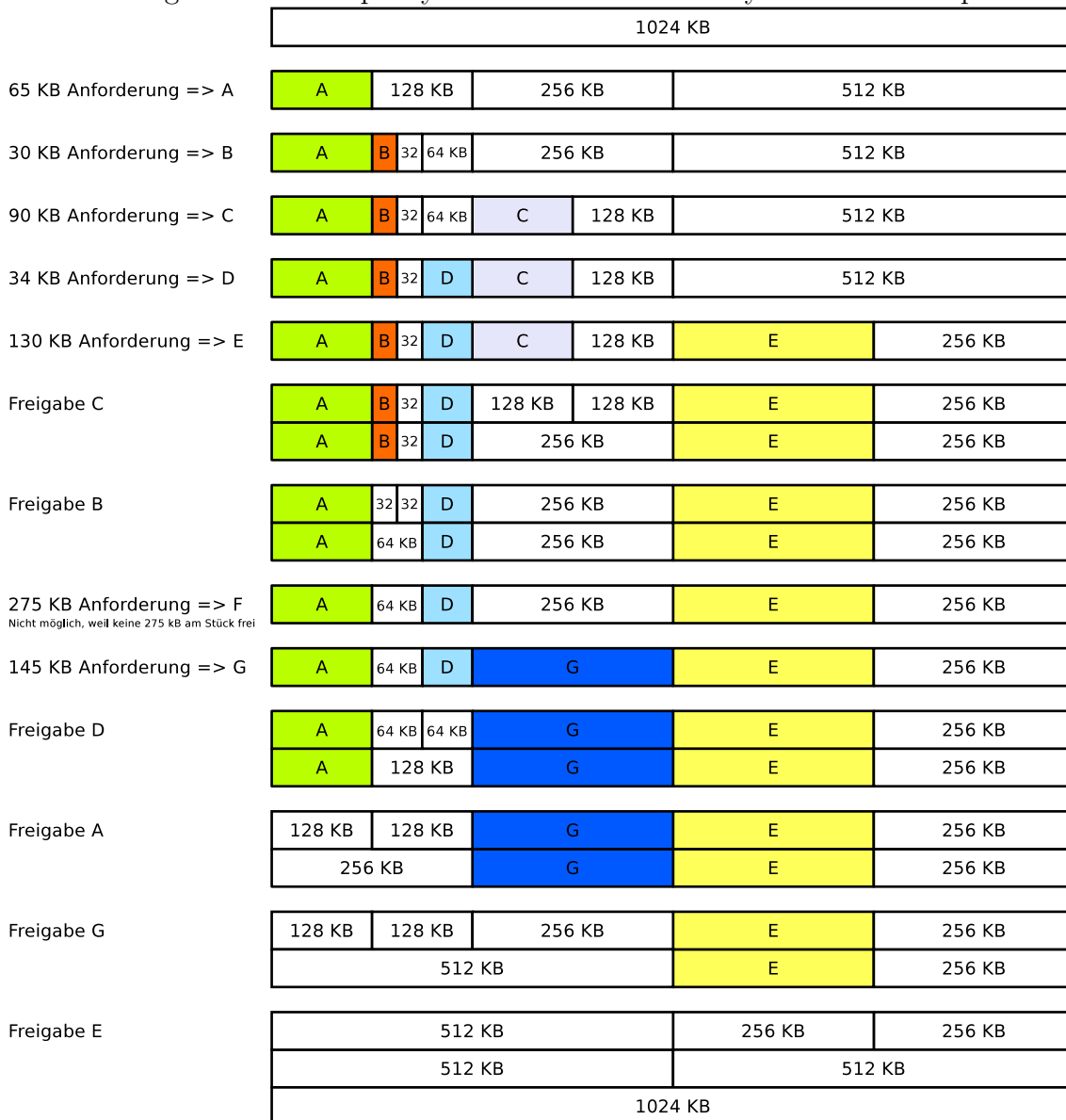
Exercise Sheet 7

Exercise 1 (Memory Management)

1. With which memory management methods do internal fragmentation occur?
 Static partitioning
 Dynamic partitioning
 Buddy memory allocation
2. With which memory management methods do external fragmentation occur?
 Static partitioning
 Dynamic partitioning
 Buddy memory allocation
3. How can external fragmentation be fixed?
By defragmentation. For virtual memory, external fragmentation is irrelevant.
4. Which memory management method searches for the block, which fits best?
 First Fit Next Fit Best fit Random
5. Which memory management concept searches for a free block, starting from the beginning of the address space?
 First Fit Next Fit Best fit Random
6. Which memory management concept fragments quickly the large area of free space at the end of the address space?
 First Fit Next Fit Best fit Random
7. Which memory management concept selects random a free and appropriate block?
 First Fit Next Fit Best fit Random
8. Which memory management concept searches for a free block, starting from the latest allocation?
 First Fit Next Fit Best fit Random
9. Which memory management concept produces many mini-fragments and is slow?
 First Fit Next Fit Best fit Random

Exercise 2 (Buddy Memory Allocation)

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



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.
2. Why is it difficult 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 SD-D/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.
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.
 True 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 False
3. When static partitioning is used, internal fragmentation occurs.
 True False
4. When dynamic partitioning is used, external fragmentation cannot occur.
 True False
5. With paging, all pages have the same length.
 True False
6. One advantage of long pages is little internal fragmentation.
 True False
7. A drawback of short pages is that the page table gets bigger.
 True False
8. When paging is used, the MMU translates the logical memory addresses into physical memory addresses.
 True False
9. Modern operating systems (for x86) operate in protected mode and use only paging.
 True False

Exercise 5 (Page Replacement Strategies)

- 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.
- 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.

Optimal replacement strategy (OPT):

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

Hitrate: $15/24 = 0.625$

Missrate: $9/24 = 0.375$

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

Hitrate: $17/24 = 0.7083333$

Missrate: $7/24 = 0.2916666$

Replacement strategy Least Recently Used (LRU):

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

Queue:

1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3	4	5
	1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3	4
		1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3
			1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1
				1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2
					1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3
						1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4
							1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5

Hitrate: $11/24 = 0.4583333\%$

Missrate: $13/24 = 0.5416666\%$

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

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

Queue:

1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3	4	5
	1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3	4
		1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1	3
			1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2	1
				1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3	2
					1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4	3
						1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5	4
							1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3	5
								1	3	5	4	2	4	3	2	1	0	5	3	5	0	4	3	5	4	3

Hitrate: $14/24 = 0.5833333\%$

Missrate: $10/24 = 0.4166666\%$

Replacement strategy Least Frequently Used (LFU):

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:	1 ₁	1 ₁	1 ₁	1 ₁	2 ₁	2 ₁	2 ₁	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₃	2 ₃	2 ₃	2 ₃	2 ₃
Page 2:		3 ₁	3 ₁	3 ₁	3 ₁	3 ₁	3 ₂	3 ₂	3 ₂	3 ₂	3 ₂	3 ₂	3 ₃	3 ₃	3 ₃	3 ₃	3 ₄	3 ₄	3 ₄	3 ₅	3 ₅	3 ₅	3 ₆	3 ₆	3 ₆	3 ₆	3 ₆
Page 3:			5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	0 ₁	5 ₁	5 ₂	5 ₂	5 ₂	5 ₂	5 ₂	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₄
Page 4:				4 ₁	4 ₁	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	0 ₁	4 ₁	4 ₁	4 ₁	4 ₂	4 ₂	4 ₂	4 ₂	1 ₁	1 ₁	4 ₁	4 ₁

Hirate: 12/24 = 0.5
Missrate: 12/24 = 0.5

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:	1 ₁	1 ₁	1 ₁	1 ₁	1 ₁	1 ₁	1 ₁	1 ₁	1 ₂	1 ₂	1 ₂	1 ₂	1 ₂	0 ₁	0 ₁	0 ₁	0 ₁	0 ₁	0 ₁	0 ₁	0 ₁	1 ₁	1 ₁	1 ₁	1 ₁	1 ₁	
Page 2:		3 ₁	3 ₁	3 ₁	3 ₁	3 ₁	3 ₂	3 ₂	3 ₂	3 ₂	3 ₂	3 ₃	3 ₃	3 ₃	3 ₃	3 ₃	3 ₄	3 ₄	3 ₅	3 ₅	3 ₅	3 ₆	3 ₆	3 ₆	3 ₆	3 ₆	
Page 3:			5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	5 ₁	0 ₁	5 ₁	5 ₂	5 ₂	5 ₂	5 ₂	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₃	5 ₄	
Page 4:				4 ₁	4 ₁	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₂	4 ₃	4 ₃	4 ₃	4 ₄	4 ₄	4 ₄	4 ₄	4 ₄	4 ₄	4 ₄	4 ₄	4 ₅	4 ₅
Page 5:				2 ₁	2 ₁	2 ₁	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₂	2 ₃	2 ₃	2 ₃	2 ₃	2 ₃

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

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

Hitrate: $11/24 = 0.4583333$

Missrate: $13/24 = 0.5416666$

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**

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

Hitrate: $15/24 = 0.625$

Missrate: $9/24 = 0.375$

3. What is the key message of Laszlo Belady's anomaly?
FIFO produces worse results for certain access patterns with increased memory.
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.

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

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	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

Hitrate: $2/12 = 16.66\%$

Missrate: $10/12 = 83.33\%$