Most of the questions can be answered using the lecture slides and the recommended textbooks, but some may require additional sources. Some questions may have more than one possible answer or be more or less open for discussion. Note that we do not provide a sample solution, which is why we strongly recommend that students attend the exercise sessions and actively participate in the discussions. The concepts marked with yellow are important and should be fully understood. For solving numerical problems, a calculator should only be used as backup since calculators are not allowed in the exam.

Memory Management

1. What is the difference between a physical address and a virtual address?

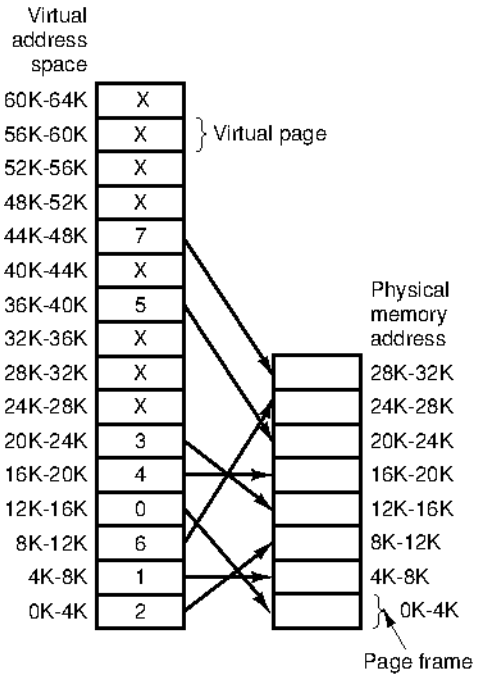

Figure 1: The relation between virtual addresses and physical memory addresses is given by the page table

2. Using the page table of Fig. 1, give the physical address corresponding to each of the following virtual addresses: *(Hint- The addressing scheme shown in the diagram is using the* 2^* *notation)*

   (a) 20

   (b) 4100

   (c) 8300

(d) 22300

3. Multi-level page tables:

   (a) Give an example for a two-level page table scheme to be used with 32 bit virtual addresses. Specify the amount and sizes of the page tables if the page size is 16KiB.

   (b) For 64 bit virtual addresses, so called inverted page tables are used instead of the previously discussed multi-level page tables. Why is that? Give an example for such a scheme using inverted page tables and 8 KiB pages!

   (c) Describe how the lookup times of inverted page tables can be improved using a hashed page table design.

4. A computer's main memory is divided into eight page frames. The current virtual CPU time is 290. The time of loading, time of last access, and the R and M bits for each page are as shown in the table (the times are in clock ticks). In case of WSClock, the "clock hand" is at "page 3" and τ is 12 clock ticks.

Page	Loaded	Last referenced	R	M
0	126	280	1	0
1	230	265	0	1
2	140	270	0	0
3	110	285	1	1
4	190	287	1	0
5	175	260	0	1
6	100	283	1	1
7	260	275	0	0

Table 1: Four page frames in a simple computer

   (a) Which page will **NRU** replace?

   (b) Which page will **FIFO** replace?

   (c) Which page will **LRU** replace?

   (d) Which page will **second chance** replace?

5. A computer provides each process with 65536 bytes of address space divided into pages of 4096 bytes. A particular program has a text size of 32768 bytes, a data size of 16386 bytes and a stack size of 15870 bytes. Will this program fit in the address space? What if the page size is 512 bytes? We assume that a page may not contain parts of two different segments. Why is that a valid assumption?

6. Segmentation is an addressing scheme that provides programmers with many independent address spaces. Describe the segmentation concept and its benefits over a one-dimensional address space.