

## Virtual Memory

### Proposed exercises

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**Exercise 1.** A processor has 32-bit virtual addresses and 2 KB pages. Indicate the format of the virtual address, as well as the maximum number of pages that a program can have running on this computer

**Exercise 2.** Consider a 32-bit computer with a virtual memory system that uses 8 KB pages and has 1 GB of main memory installed. Please indicate in a reasoned manner:

- The format of the virtual address.
- The maximum number of pages in this computer.
- What is a page frame?
- The number of page frames on this computer.
- The size of the block that is transferred between disk and main memory when a page fault occurs.

**Exercise 3.** A 20-bit computer has a virtual memory with pages of 1 KB and a total of 256 KB of physical memory. Answer:

- What is the format of the virtual address? Indicate the fields and the number of bits in them.
- What is the maximum number of entries in the page table (single level)?
- How many page frames does the main memory have?
- What are the fields included in an entry of the page table? Also indicate what each of the fields is used for.

**Exercise 4.** There is a computer that addresses the memory by bytes and uses 32-bit virtual addresses. The system uses pages of 4KB size. It is requested:

- What is the format of the address?
- If a single-level page table is used and 32 bits are required for each entry, what is the maximum table size? Express its size in bytes and justify the answer.
- Starting from the following virtual page table, indicate the physical address corresponding to the virtual address 0x000023F0. Assume that all pages are in main memory.

0	20
1	6
2	4
3	8
4	1
5	3
6	5
7	7

**Exercise 5.** A processor has 32-bit virtual addresses and 2 KB pages. Indicate the format of the virtual address, as well as the maximum number of pages that a program can have running on this computer.

**Exercise 6.** An 18-bit computer has a virtual memory with pages of 4 KB and a total of 512 KB of physical memory. Answer:

- What is the format of the virtual address? Indicate the fields and the number of bits in them.
- What is the maximum number of entries in the page table (single level)?
- How many page frames does the main memory have?
- What are the fields included in an entry of the page table? Also indicate what each of the fields is used for.

**Exercise 7.** If a computer works with 16-bit addresses, and has pages of 2 KB:

- What size of virtual memory will we be able to address?
- How many pages will the virtual memory have?
- What will be the size of the page frame?
- Assuming that the physical memory is 8 KB, how many frames will we have?
- How many bits of the virtual memory address are used to select entries in the page table if it is a single level?
- What will we use the remaining bits of the virtual memory address for?
- How many entries will the page table have?

**Exercise 8.** A computer uses 8 KB pages and addresses the memory by bytes. Given the virtual address 0x20018004, indicate the size of the virtual address as well as the page number and the displacement within the page they refer to.

**Exercise 9.** A computer has a virtual address space of 256 Kpages and pages of 8 KB. The computer has a physical memory of 128 MB. How many bits are in the virtual address?

**Exercise 10.** Consider a computer that uses 32-bit virtual addresses with 8 KB pages. Answer:

- What is the format of the virtual address?
- What is the maximum number of entries a single-level page table can have? Why?
- Given the following code fragment:

```
int a[1000000];
for (j = 1; j < 890000; j++) {
    a[j] = a[j-1] + 1;
}
```

and assuming that there is no page in physical memory and that data and instructions are stored on different pages, indicate the minimum number of page faults that occur when that fragment is executed.

**Exercise 11.** A computer has a virtual memory system with pages of 4 Kbyte. The computer provides a virtual memory space of  $2^{32}$  bytes and has  $2^{18}$  bytes of physical memory. If the page table corresponding to a program in execution is the following:

Present bit	Modified bit	Frame/ Block in de swap
1	0	1
0	0	7
1	1	9
1	0	14
1	0	8
1	1	3
0	0	25
0	1	16

Answer:

- Indicate the format of the virtual address.
- Indicate the physical address corresponding to the virtual address 0x00005B83
- What is the size of the virtual address space of this program?

**Exercise 12.** Given a system that uses paged virtual memory with the following characteristics:

- The total number of pages is 512 and the page size is 8KB.
- The memory is addressed by bytes.
- The physical memory space is 1MB.
- The system does not have cache memory, but TLB.

5. The page table is not paged or segmented. The access time for the hard disk is 12ms, for the main memory is 40ns and for the TLB is 20ns.

Answer:

- a) The format of the virtual addresses. Briefly define each of the fields and the number of bits they comprise. Also indicate the size of the virtual address space.
- b) Explain the size in bits that the page table occupies, assuming that there are 3 control bits in each table entry.
- c) Obtain the maximum and minimum access time to a memory data.