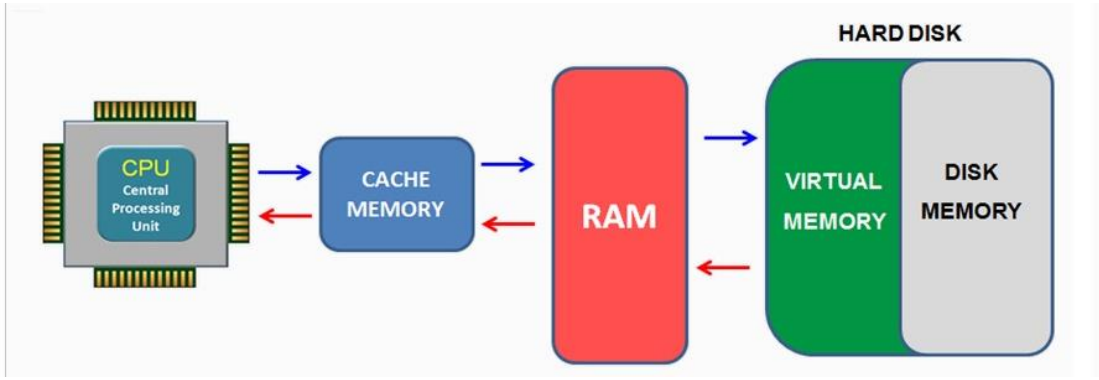
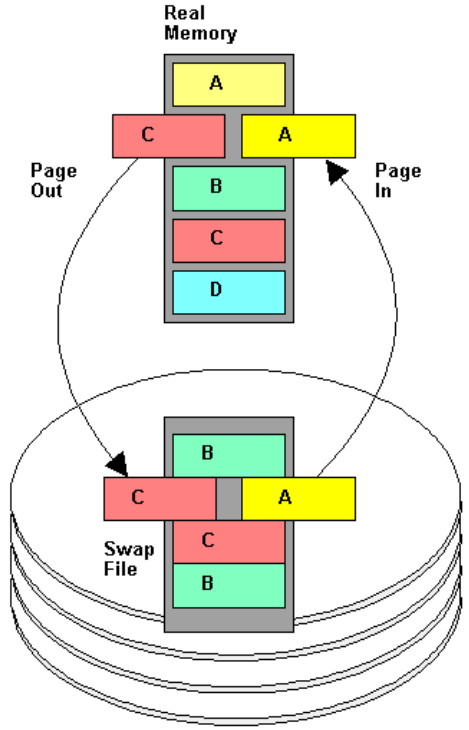
Virtual Memory

COMPUTER SYSTEMS ORGANIZATION 2021

What does it mean ?

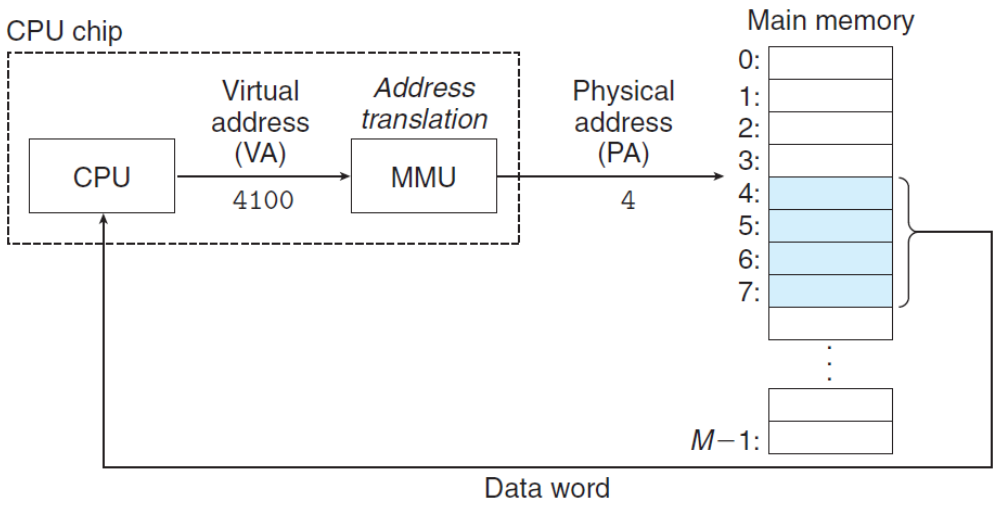
- Virtual memory is an elegant interaction of hardware exceptions, hardware address translation, main memory, disk files, and kernel software that provides each process with a large, uniform, and private address space. Virtual memory is one of the great ideas in computer systems.





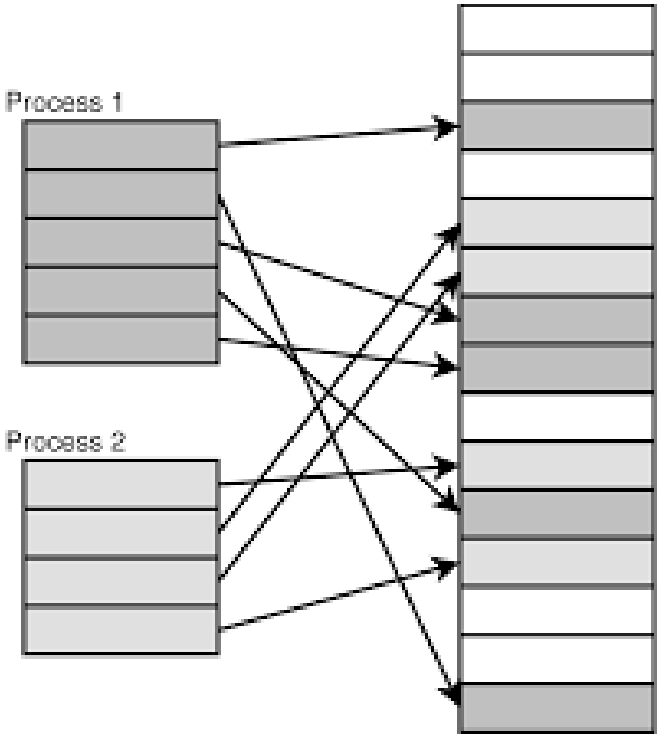
Physical and Virtual Addressing

- The main memory of a computer system is organized as an array of M contiguous byte-sized cells.
- Each byte has a unique physical address (PA).
- With virtual addressing, the CPU accesses main memory by generating a virtual address (VA).
- The VA is converted to the appropriate PA before being sent to the memory.
- The task of converting a virtual address to a physical one is known as address translation.



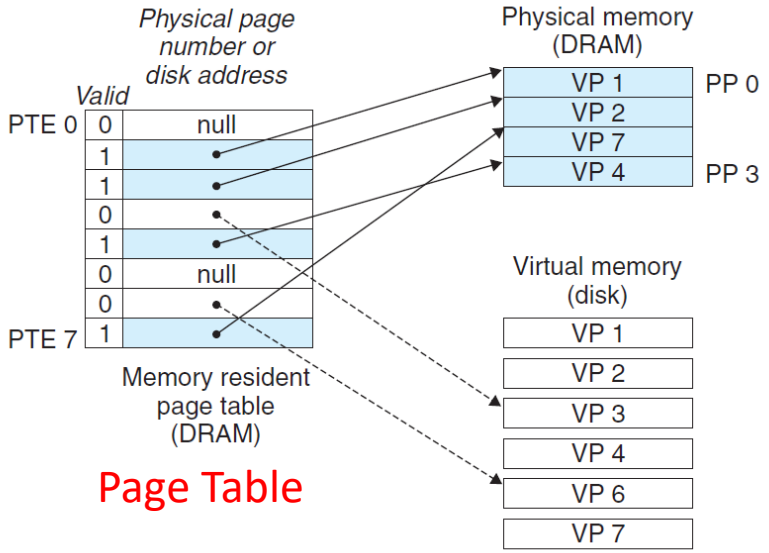
Address Spaces

- An address space is an ordered set of n nonnegative integer addresses.
- In a system with virtual memory, the CPU generates virtual addresses from an address space of N = 2^n addresses called the virtual address space.
- A virtual address space with N = 2^n addresses is called an n-bit address space. Modern systems typically support either 32-bit or 64-bit virtual address spaces.
- A system also has a physical address space that corresponds to the M bytes of physical memory in the system.
- Each byte of main memory has a virtual address chosen from the virtual address space and a physical address chosen from the physical address space.



Pages and Paging

- As with any other cache in the memory hierarchy, the data on disk (the lower level) is partitioned into blocks called pages that serve as the transfer units between the disk and the main memory (the upper level).
- Virtual pages of size P are mapped to physical pages (**page frames**) of same size.

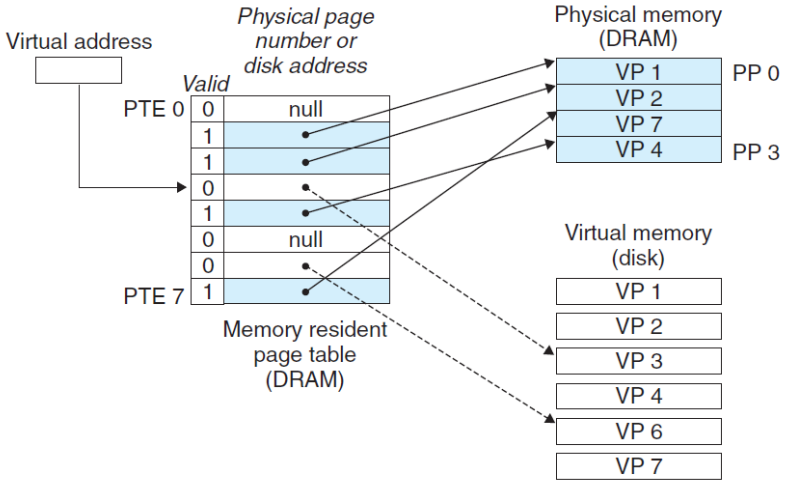


At any point in time, the set of virtual pages is partitioned into.

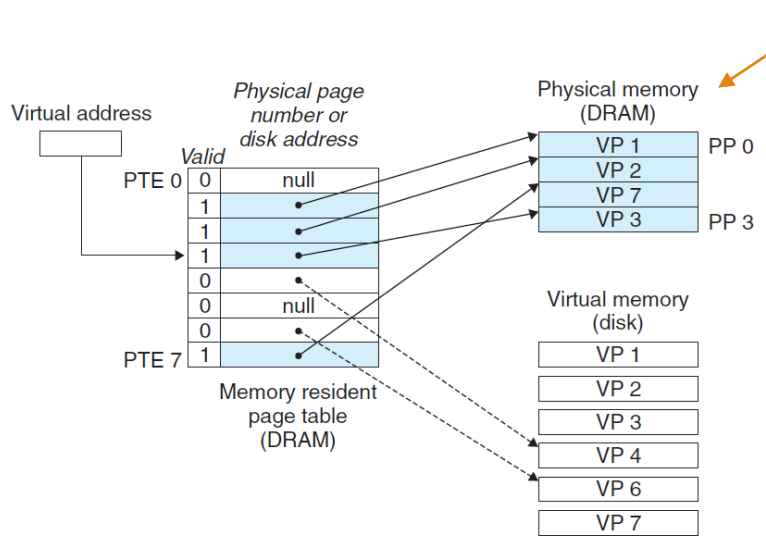
- Un-allocated
- Caches
- Un-cached

A page table is an array of page table entries (PTEs)

Page Tables, Hits and Misses



VM page fault (before).
The reference to a word in VP 3 is a miss and triggers a page fault.

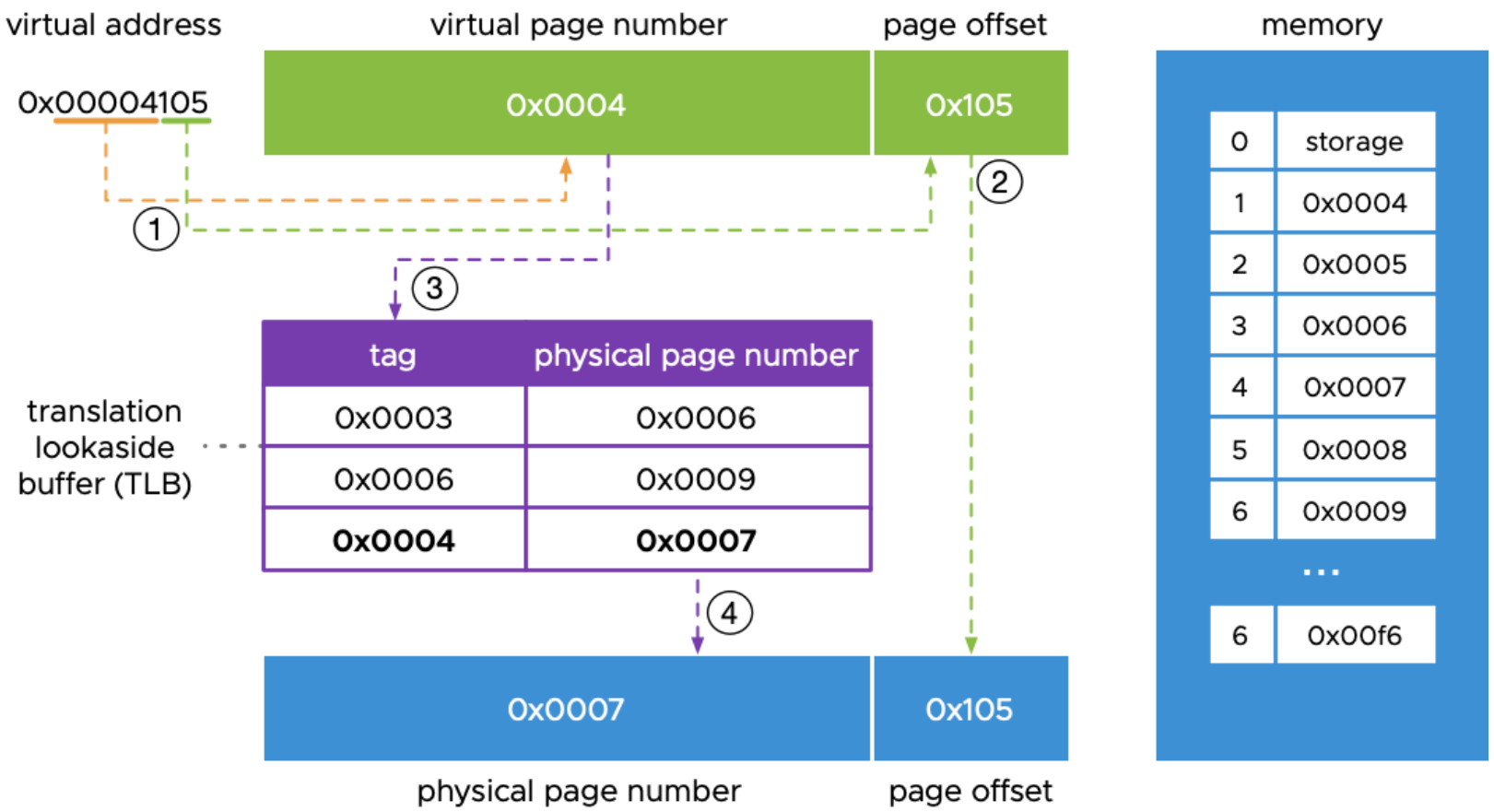


The page fault handler selects VP 4 as the victim and replaces it with a copy of VP 3 from disk. After the page fault handler restarts the faulting instruction, it will read the word from memory normally, without generating an exception.

EVICTION!!!!!

OS allocates a new page of virtual memory, for example, as a result of calling malloc.

Address Translation



Problem1

- Consider a machine with 64 MB physical memory and a 32-bit virtual address space. If the page size is 4KB, what is the approximate size of the page table?

Problem 2

- In a virtual memory system, size of virtual address is 32-bit, size of physical address is 30-bit, page size is 4 Kbyte and size of each page table entry is 32-bit. The main memory is byte addressable. Which one of the following is the maximum number of bits that can be used for storing protection and other information in each page table entry?