

VM Address Translation

■ Virtual Address Space

- $V = \{0, 1, \dots, N-1\}$

■ Physical Address Space

- $P = \{0, 1, \dots, M-1\}$

■ Address Translation

- $MAP: V \rightarrow P \cup \{\emptyset\}$

- For virtual address a

- $MAP(a) = a'$ if data at virtual address a is at physical address a' in P
- $MAP(a) = \emptyset$ if data at virtual address a is not in physical memory
 - Either invalid or stored on disk

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Summary of Address Translation Symbols

■ Basic Parameters

- $N = 2^n$: Number of addresses in virtual address space
- $M = 2^m$: Number of addresses in physical address space
- $P = 2^p$: Page size (bytes)

■ Components of the virtual address (VA)

- TLBI: TLB index
- TLBT: TLB tag
- VPO: Virtual page offset
- VPN: Virtual page number

■ Components of the physical address (PA)

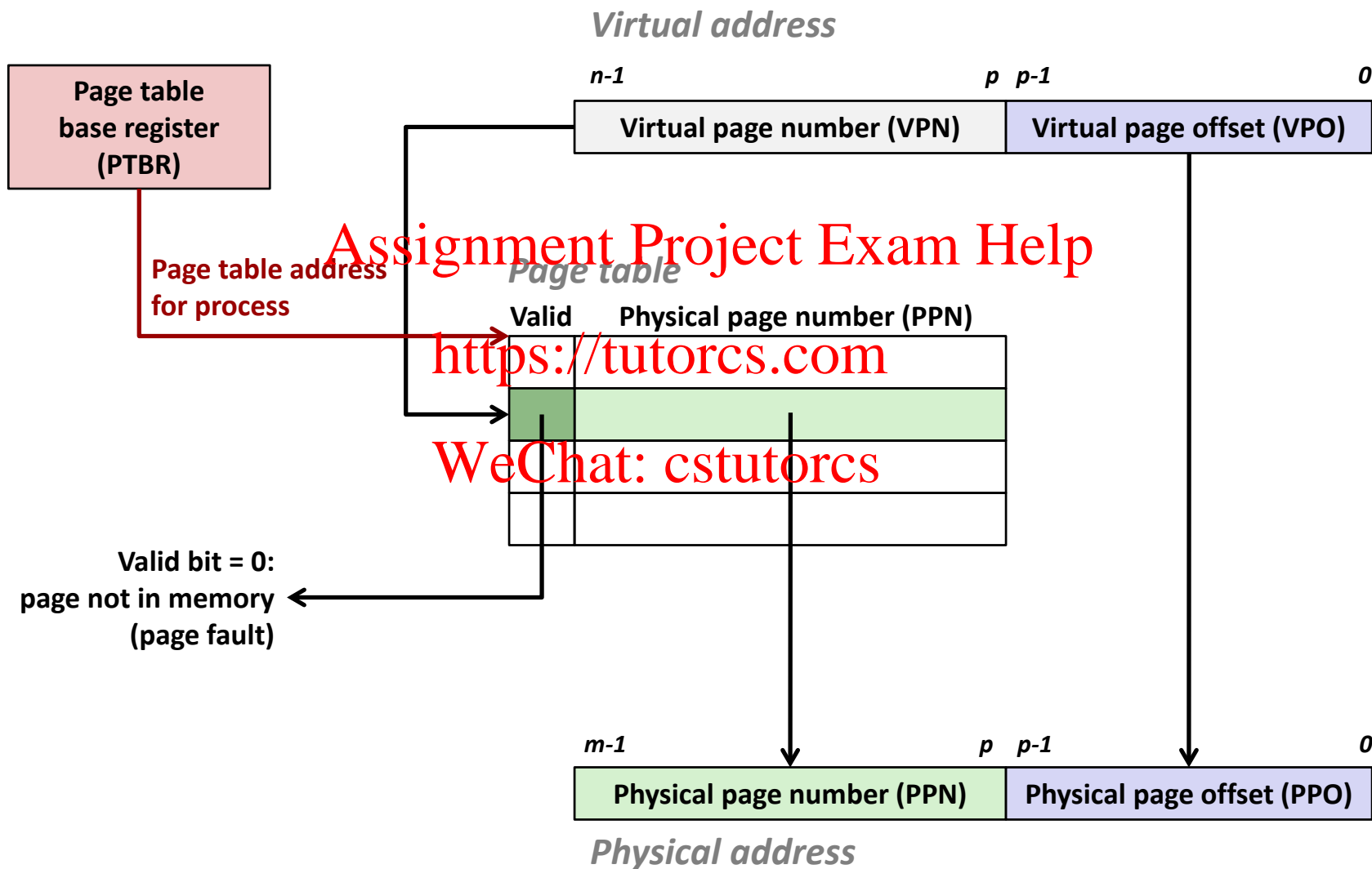
- PPO: Physical page offset (same as VPO)
- PPN: Physical page number
- CO: Byte offset within cache line
- CI: Cache index
- CT: Cache tag

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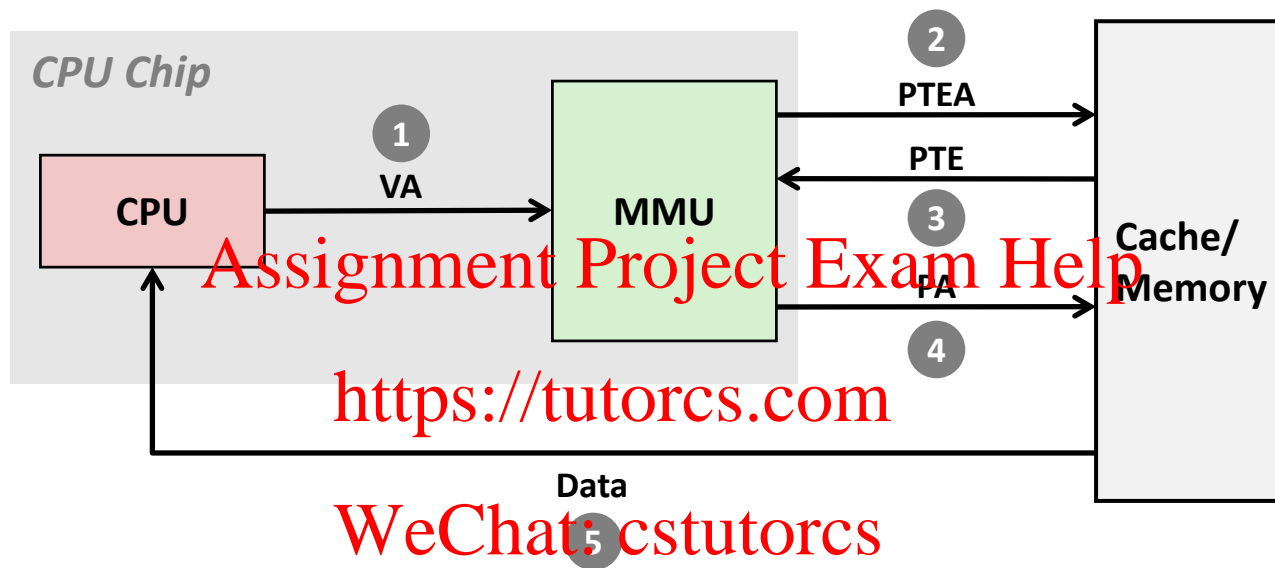
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Address Translation With a Page Table

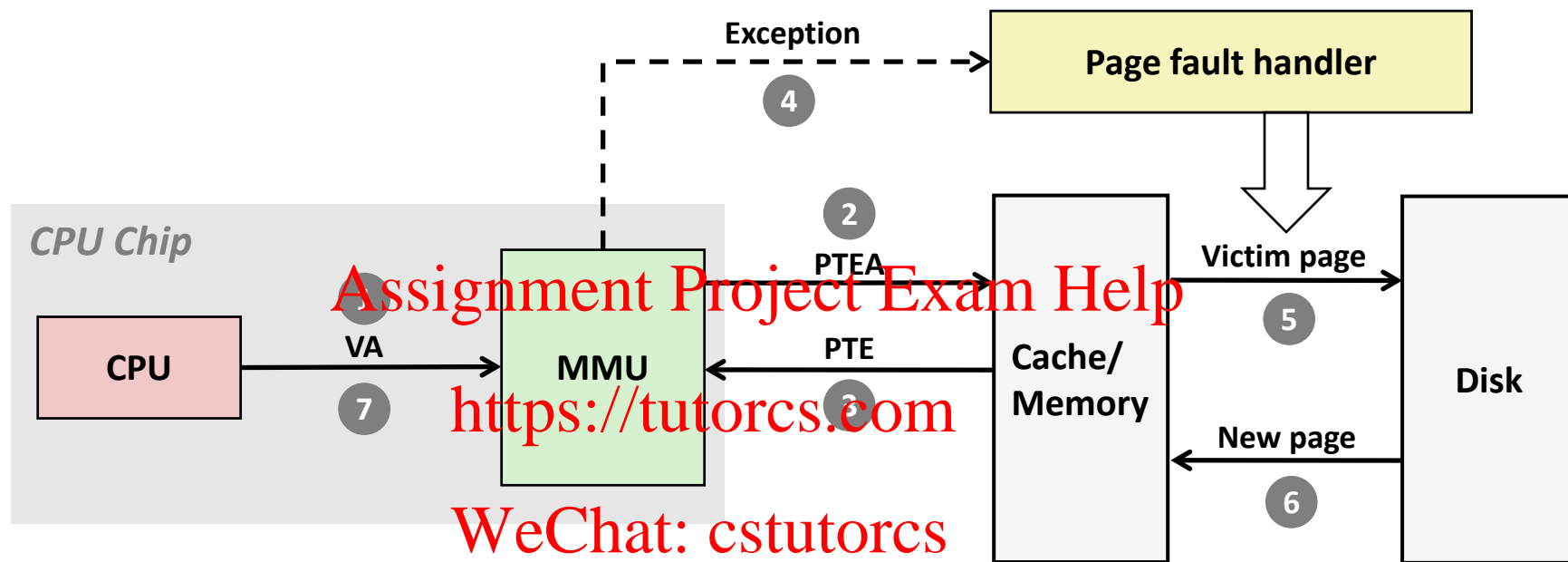


Address Translation: Page Hit



- 1) Processor sends virtual address to MMU
- 2-3) MMU fetches PTE from page table in memory
- 4) MMU sends physical address to cache/memory
- 5) Cache/memory sends data word to processor

Address Translation: Page Fault



- 1) Processor sends virtual address to MMU
- 2-3) MMU fetches PTE from page table in memory
- 4) Valid bit is zero, so MMU triggers page fault exception
- 5) Handler identifies victim (and, if dirty, pages it out to disk)
- 6) Handler pages in new page and updates PTE in memory
- 7) Handler returns to original process, restarting faulting instruction