COMPUTER SCIENCE

Memory management

multilevel paging, segmentation

Lecture No:05

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Topics to be Covered

multilevel paging, segmentation

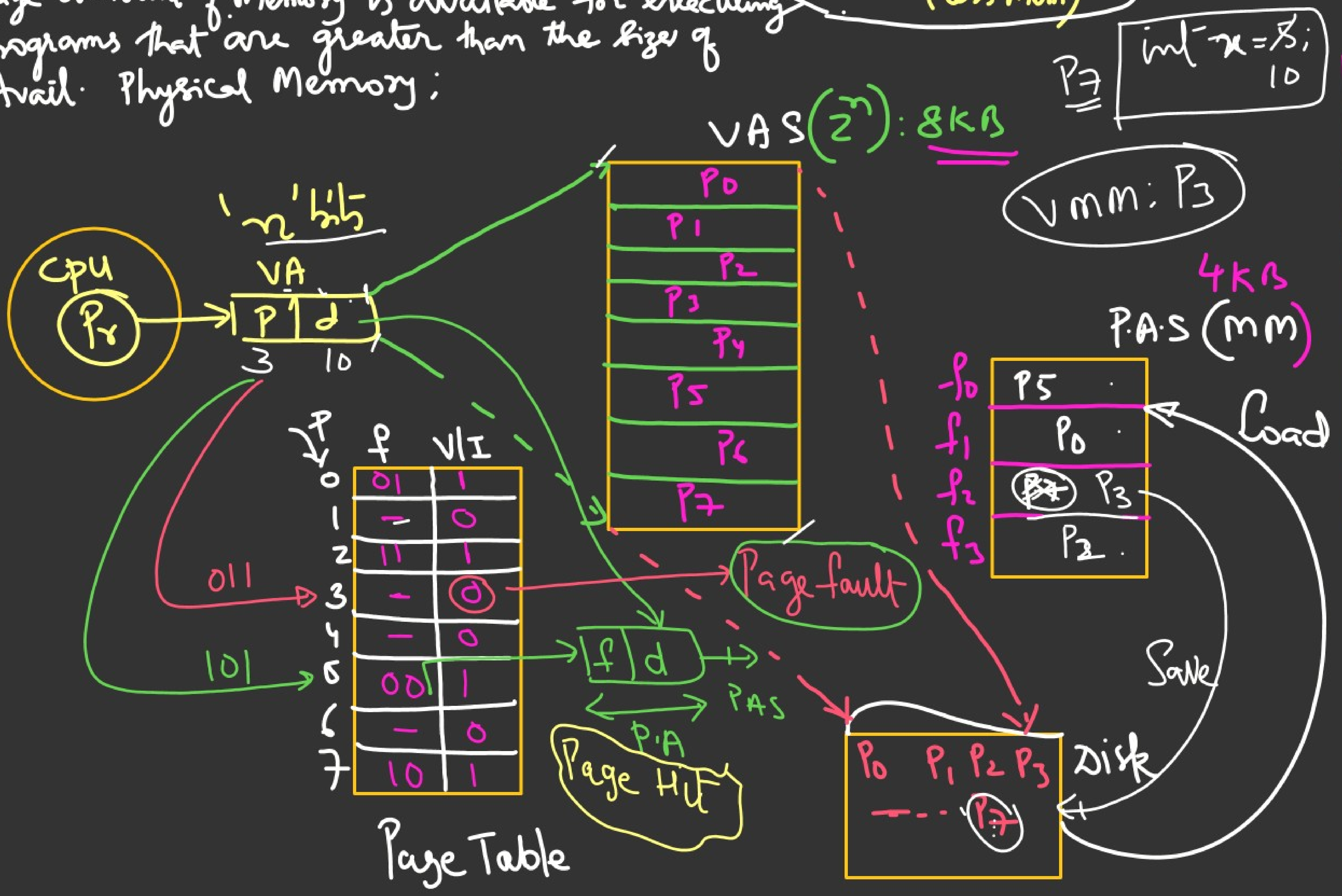
Virtual Memory (VM) [Manage execution of Larger Program in Small Memory Areas (less Mem)]

VM gives an illusion to the Programmer that a huge amount of Memory is available for executing Programs that are greater than the size of Avail. Physical Memory;

VAS = 8KB; PAS = 4KB;

VA = 13 bits (n)

P.S = 1KB



→ The Program (VAS) is Stored on disk in the form of Pages;

→ V|I : valid|Invalid bit

→ Page hit : The act of Referring to the Page which is in PAS;

→ Page fault : The event of referring to the Page that is not in Memory (PAS)

1. Process gets Blocked;
2. VMM takes the control (KM)
3. VMM ⟶ Disk Manager
4. DM ⟶ device driver
5. device driver Initiates disk I/O (DMA) direct Memory access
6. Page is read & Handed over to VMM
7. (i) Empty frame available (copy the Page)
   (ii) No Empty frame " : Page Replacement
8. update the PageTable
9. unblock the Process

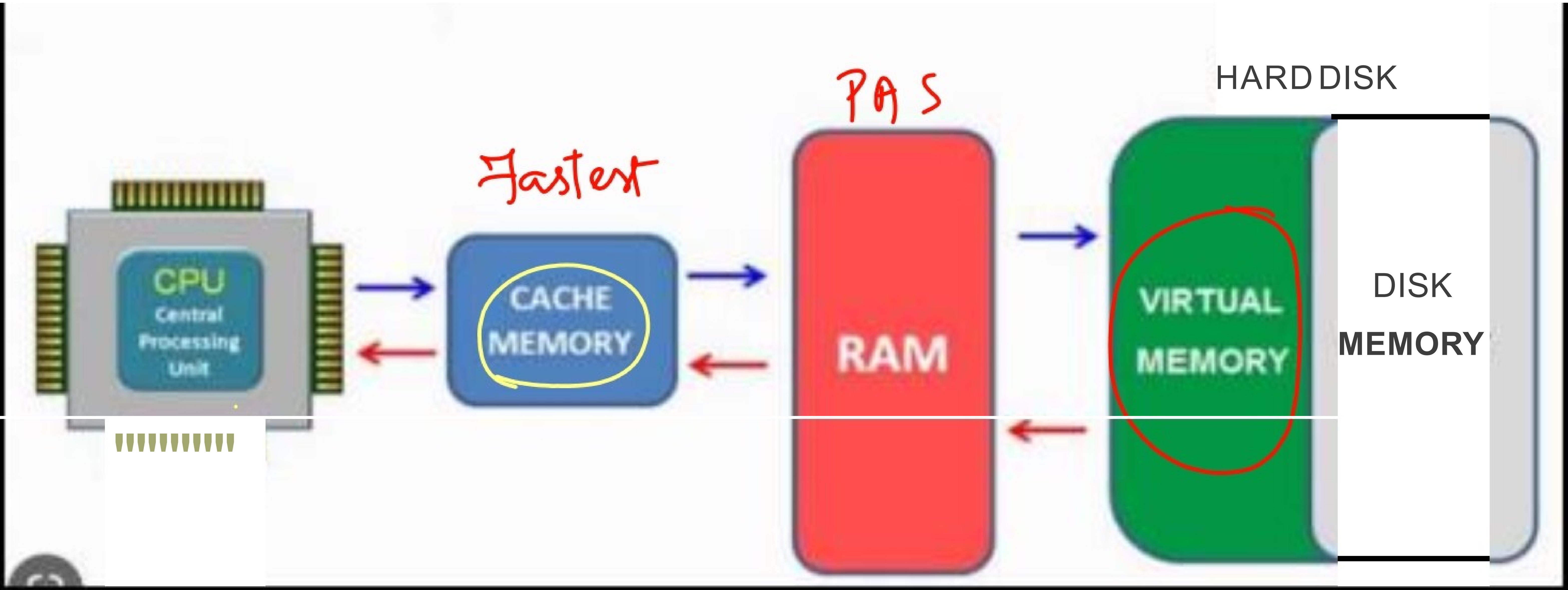
V.M is Implemented thru Demand Paging (DP)

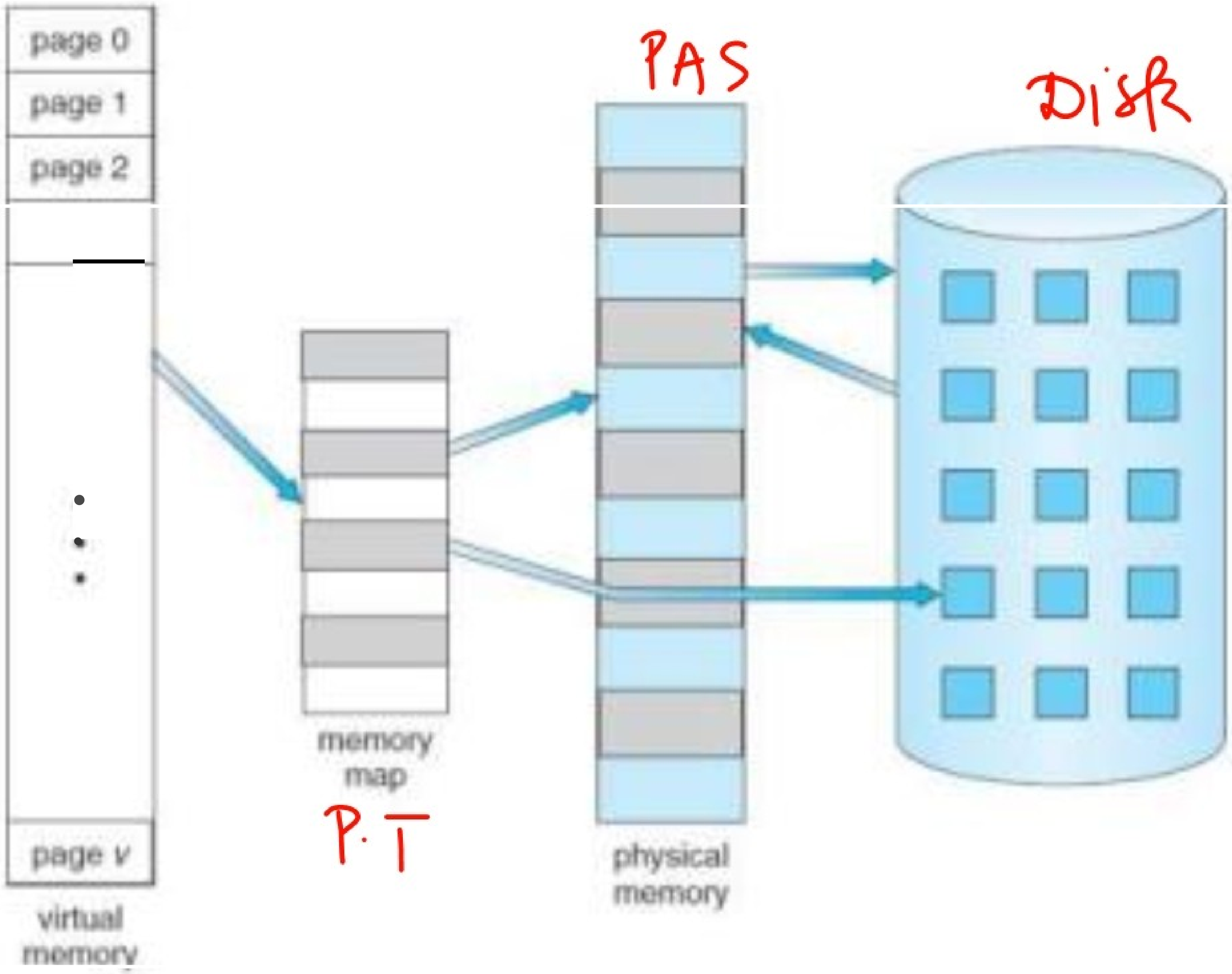
Pure D.P

Execution of the Program Starts with all Empty frames

Prefetched D.P

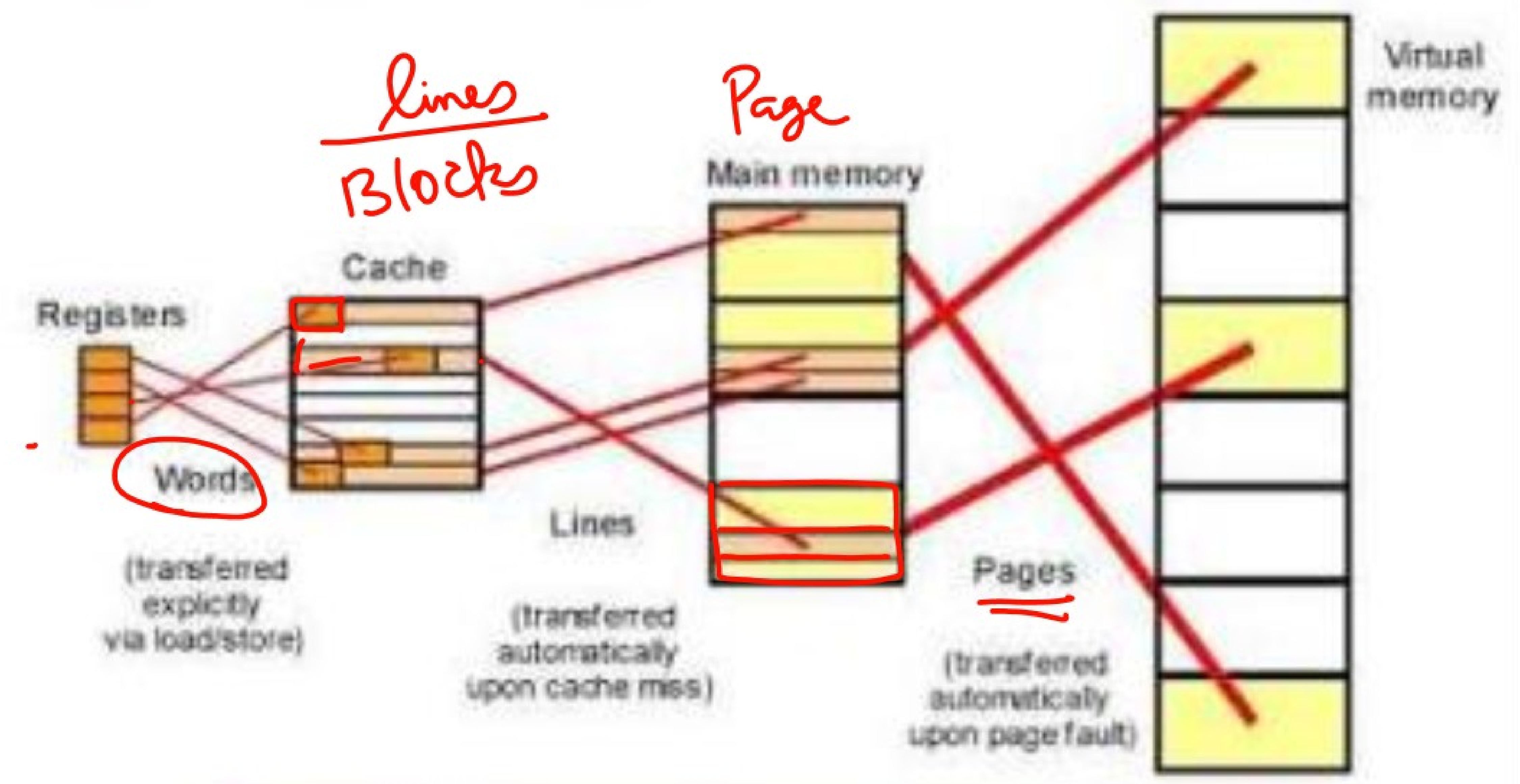
Execution Starts with Loaded Pages in frames


HARD DISK
PAS
Fastest
CPU
Central
Processing
Unit
CACHE
MEMORY
RAM
VIRTUAL
MEMORY
DISK
MEMORY



Figu 9.1 Diagram showing virtual memory that is larger than physical memory.

Memory Hierarchy: The Big Picture



Data movement in a memory hierarchy.

(TLB (Cache Memory) Can also be Used in V.M Implementation)

Pages → MM → Blocks in Cache → Words into Registers

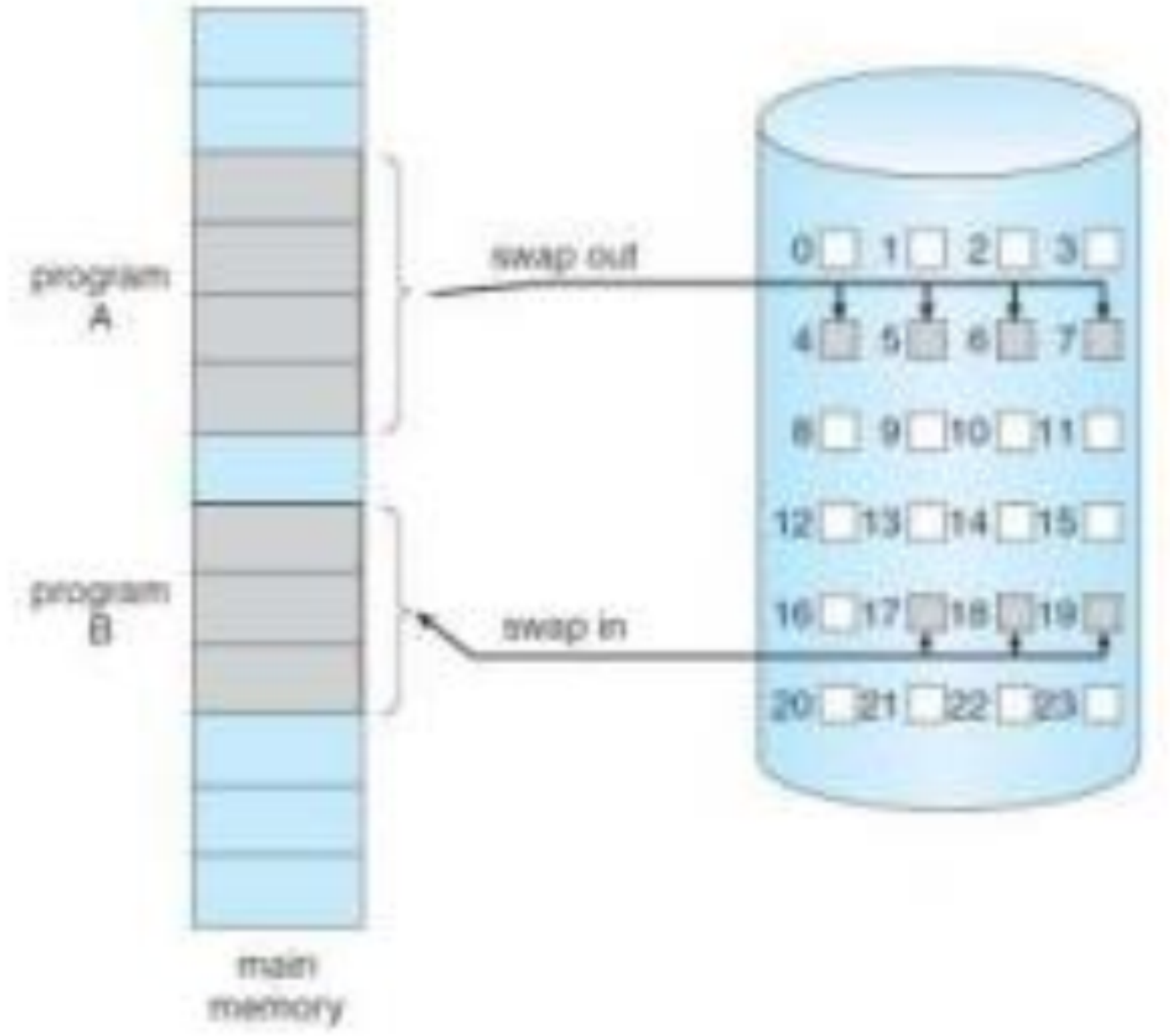


Figure 9.4 Transfer of a paged memory to contiguous disk space.

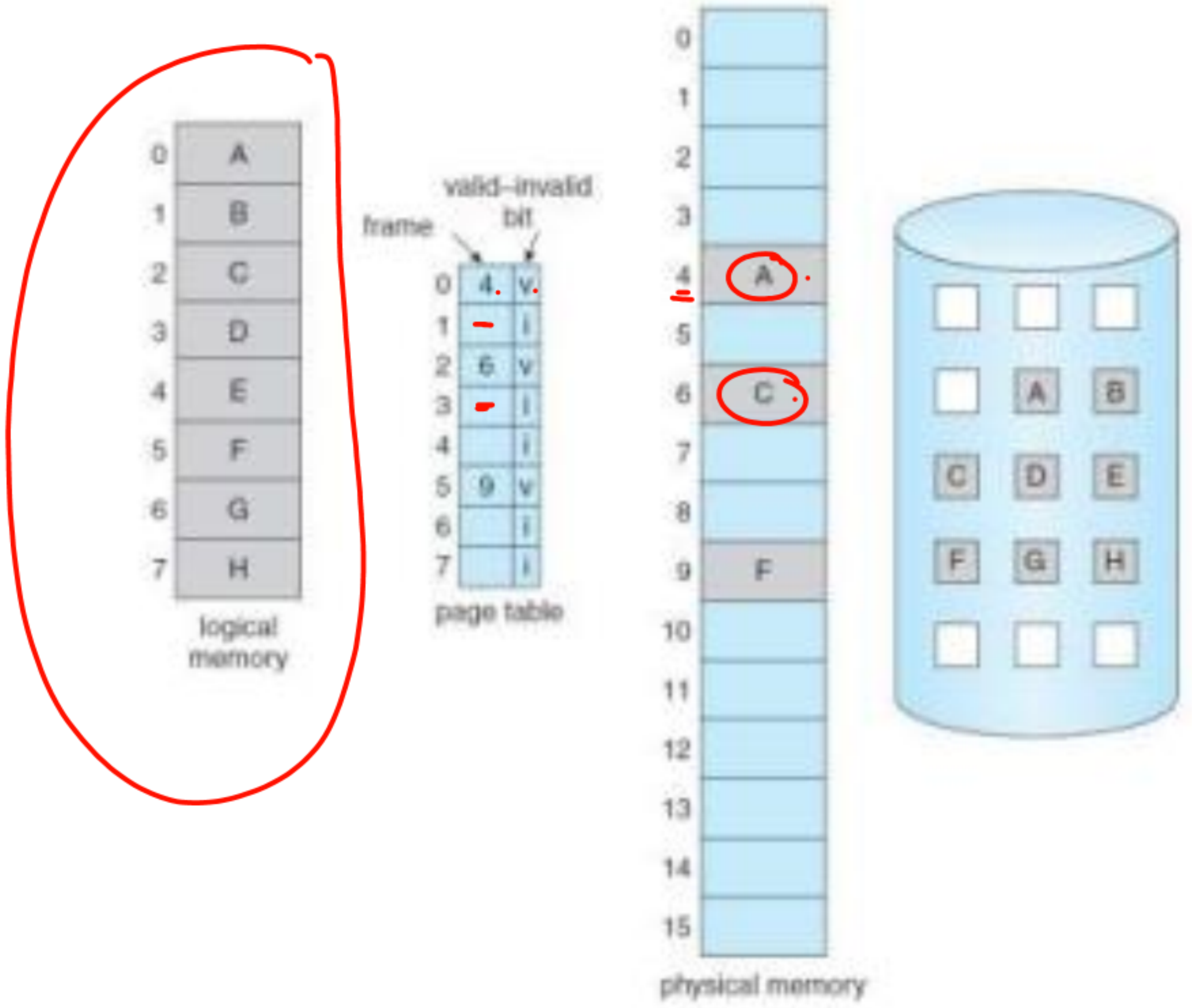


Figure 9.5 Page table when some pages are not in main memory.

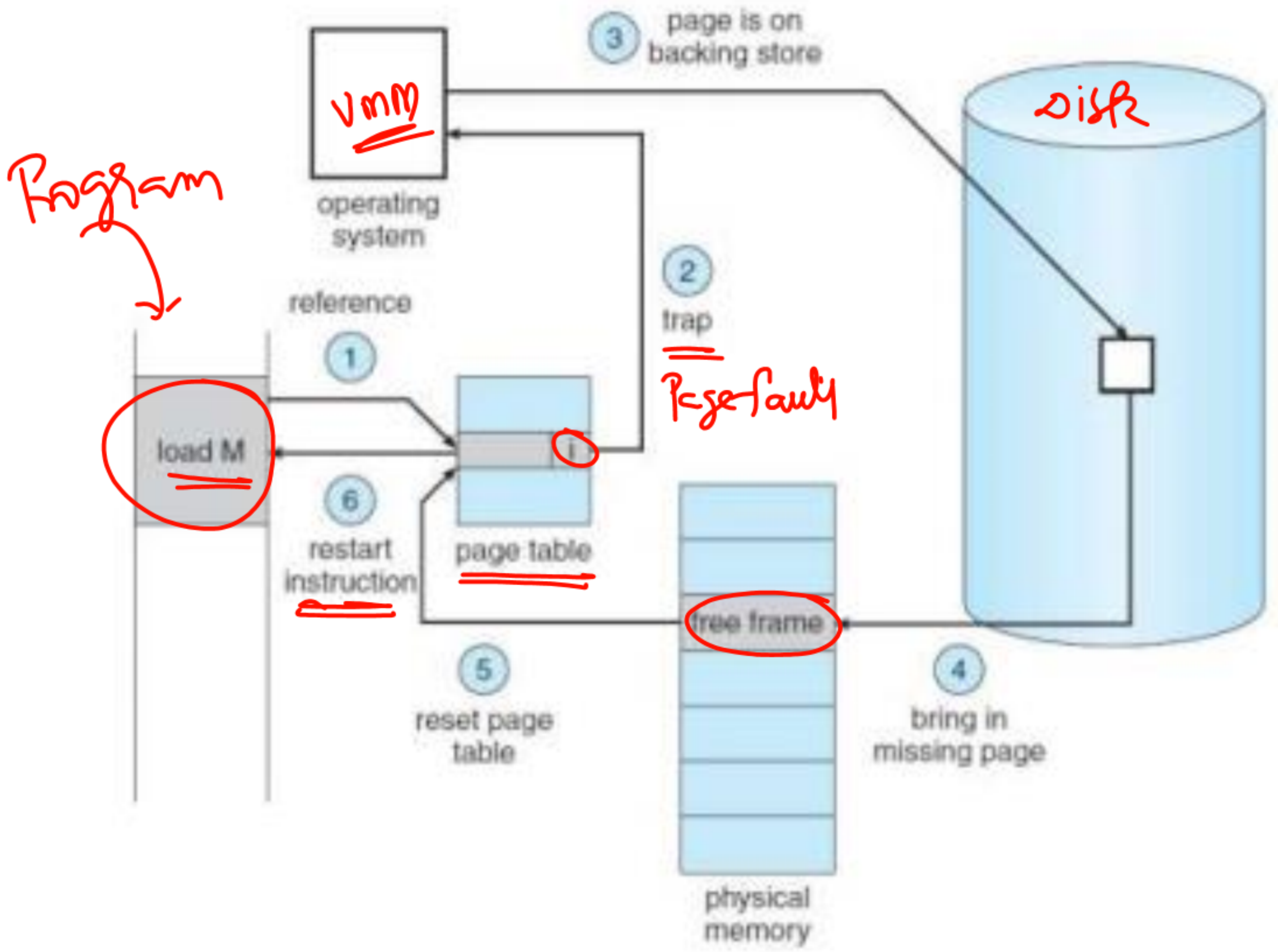
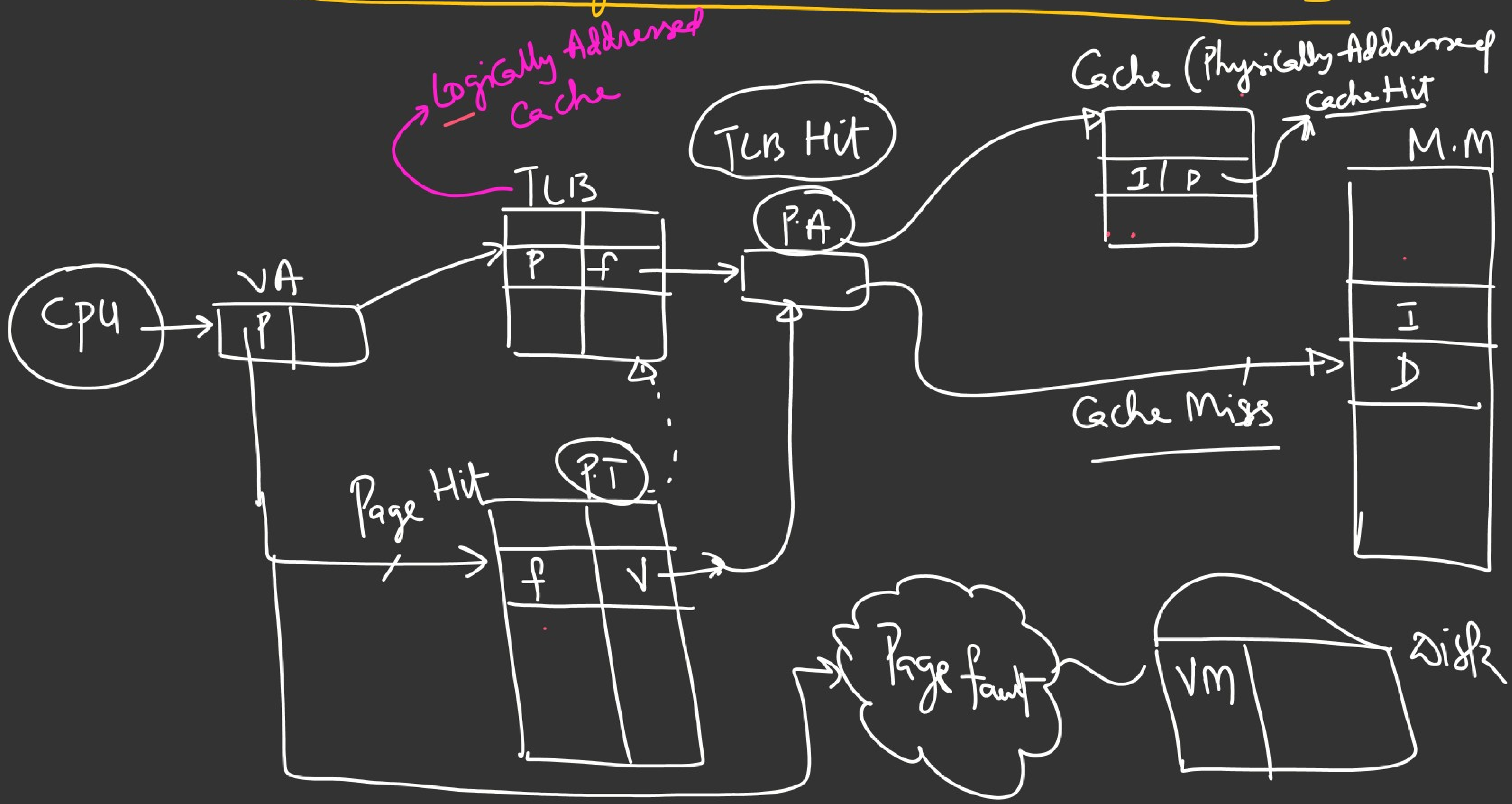
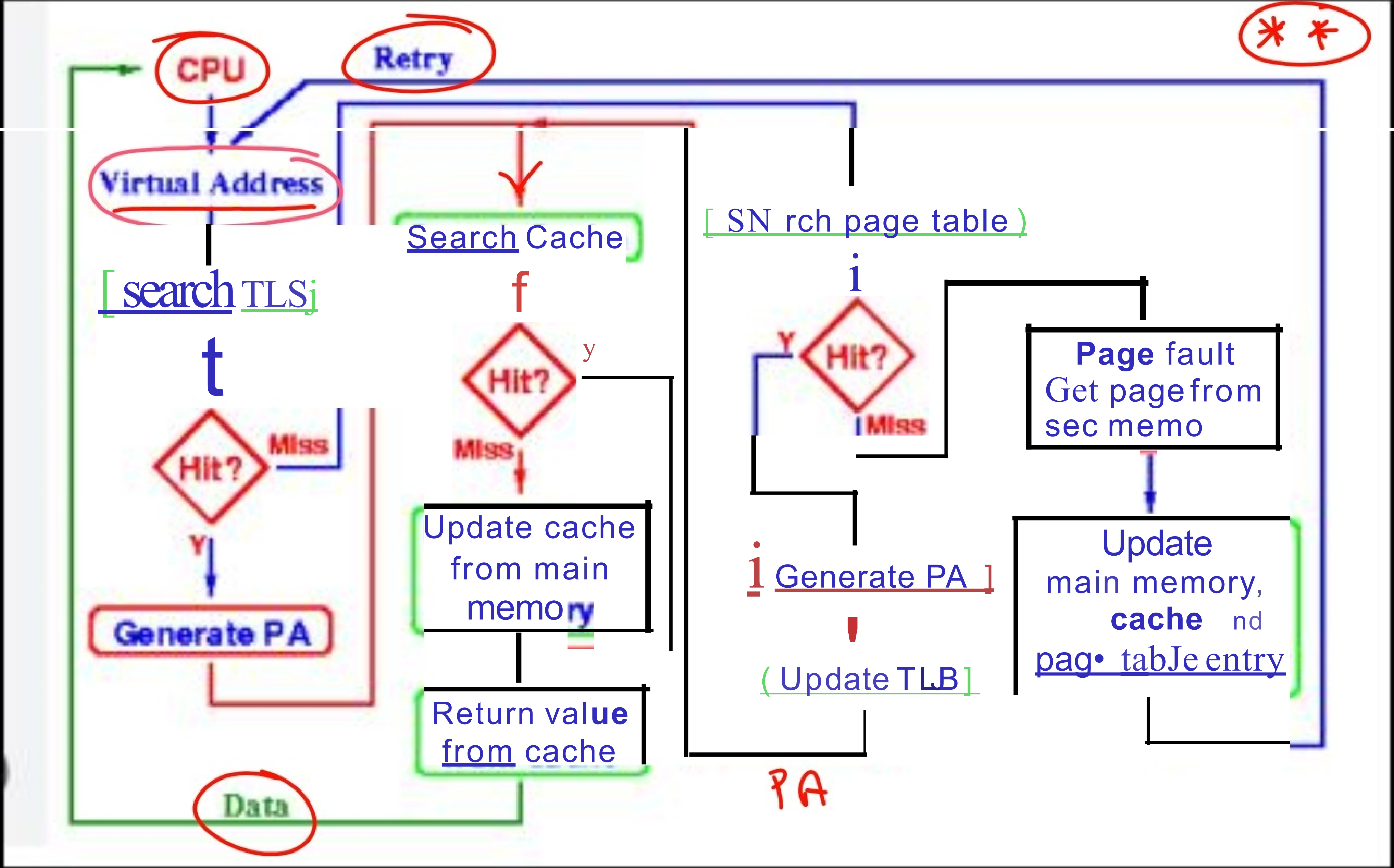


Figure 9.6 Steps in handling a page fault.

Architecture of V.M with TLB & Cache Memory





→ The amount of Time needed to Service a Page fault is known as Page fault Service Time (PFST) = 'S' (ms)

Disk Access

TLB|Cache AT ≪ MMAT ≪ PFST (disk time)

I. The Size of V.M is limited by (Disk Size).

II. $\boxed{\underline{\text{P.A.S}} \leq \underline{\text{V.A.S}} \leq \underline{\text{Disk A.S}}}$ (In Practice)

Q.1 In a virtual memory system the address space specified by the address lines of the CPU must be __greater__ than the physical memory size and __Smaller__ than the secondary storage size.

(A) Smaller, smaller

(B) Smaller, larger

(C) Larger, smaller ✓

(D) Larger, larger

Q.2 The total size of address space in a virtual memory system is limited by:

- (A) Length of MAR
- (B) Available secondary storage
- (C) Available main memory
- (D) None

Q.3 Where does the swap space reside?

- A RAM
- B Disk
- C ROM
- D On chip cache

II. Performance of V.M

a) Time Issue (Temporal): VM without TLB & Cache

→ Main Mem. Access Time (MMAT): 'm'

→ Page fault Service Time (PFST): 's' [$s \gg m$]

→ Page fault rate: 'P' [No. of Page faults / Total References]

$0 \le P \le 1$

→ Page hit rate $= (1-P)$

→ Effective Mem. Access Time (EMAT) $= (1-P)m + P * s$

(D.P)

Q.4 Suppose the time to service a Page fault is on the average 10 milliseconds, while a Memory Access takes 1 microsecond. Then a 99.99% Hit ratio results in Average Memory Access Time of ______.

$P = 0.01\%$

$s = 10\ ms$

$m = 1\ \mu s$

$1-P = 0.9999$

$P = 0.0001$

$P = 10\%$

$EMAT =$

$= 0.9 * 1\times10^{-6} + 0.1 * 10\times10^{-3}$

$= 0.9\times10^{-6} + 1\times\frac{10^{-3}\times10^{-3}}{10^{-3}}$

$= 1000.9\times10^{-6}\ s$

$= 1000.9\ \mu s = 1\ ms$

$EMAT = (1-P)m + P * s$

$= 0.9999\times1\times10^{-6}\ s + 0.0001\times10\times10^{-3}\ s$

$= 0.9999\times10^{-6}\ s + 1\times10^{-6}\ s$

$= 1.9999\times10^{-6}\ s$

$= 1.9999\ \mu s$ ✓

Q.5

If an Instruction takes 'i' microseconds and with a Page Fault takes an additional 'j' microsecond, the Effective Instruction Time if on the average a page fault occurs every 'k' instruction is ________.

'i' : without P.F

'i+j' : with P.F

(p) P.F rate $= \frac{1}{k}$

$(1-p) = 1 - \frac{1}{k}$

$$\underline{E.I.T}_{DP} = \frac{1}{k}(i+j) + \left(1-\frac{1}{k}\right)i$$

$$= \cancel{\frac{i}{k}} + \frac{j}{k} + i - \cancel{\frac{i}{k}}$$

$$= i + j/k$$

Q.6

Assume that we have a Demand-Paged memory. It takes 8 milliseconds to service a page fault if an empty frame is available or if the replaced page is not modified, and 20 milliseconds if the replaced page is modified. Memory-access time is 100 nanoseconds. Assume that the page to be replaced is modified 70 percent of the time. What is the acceptable pagefault rate for an effective access time of no more than 2000nanoseconds? 'P' = ?

* (PG)

S → 8 ms : Empty frame + clean Page

S → 20 m : Dirty Page

m = 100 ns

P { 70% : Modified ; 30% : clean + E.F

EMAT = 2000 ns

EMAT = P * S + (1 − P) m

2000 ns = (1 − P) * 100 ns + P (0.7 * 20 ms + 0.3 * 8 ms)

P = ?

Q.7 Consider a process executing on an operating system that uses demand paging. The average time for a memory access in the system is M units if the Corresponding memory page is available in memory, and D units if the memory Access causes a page fault. It has been experimentally measured that the average Time taken for a memory access in the process is X units. Which one of the Following is the correct expression for the page fault rate experienced by the Process?

PYQ

1M

$EMAT = P \times S + (1-P) M$

$X = P * D + (1-P) M$

$P =$

(A) (D – M)/(X – M)

(B) (X – M)/(D – M)

(C) (D – X)/(D – M)

(D) (X – M)/(D – X)

b) **Page Replacement**: is needed when a Page fault occurs and no Empty frame is available;

(a) Reference String: { Set of Successively unique Pages (P) referred in the given list of V.As }

Page

VA: | P | d |

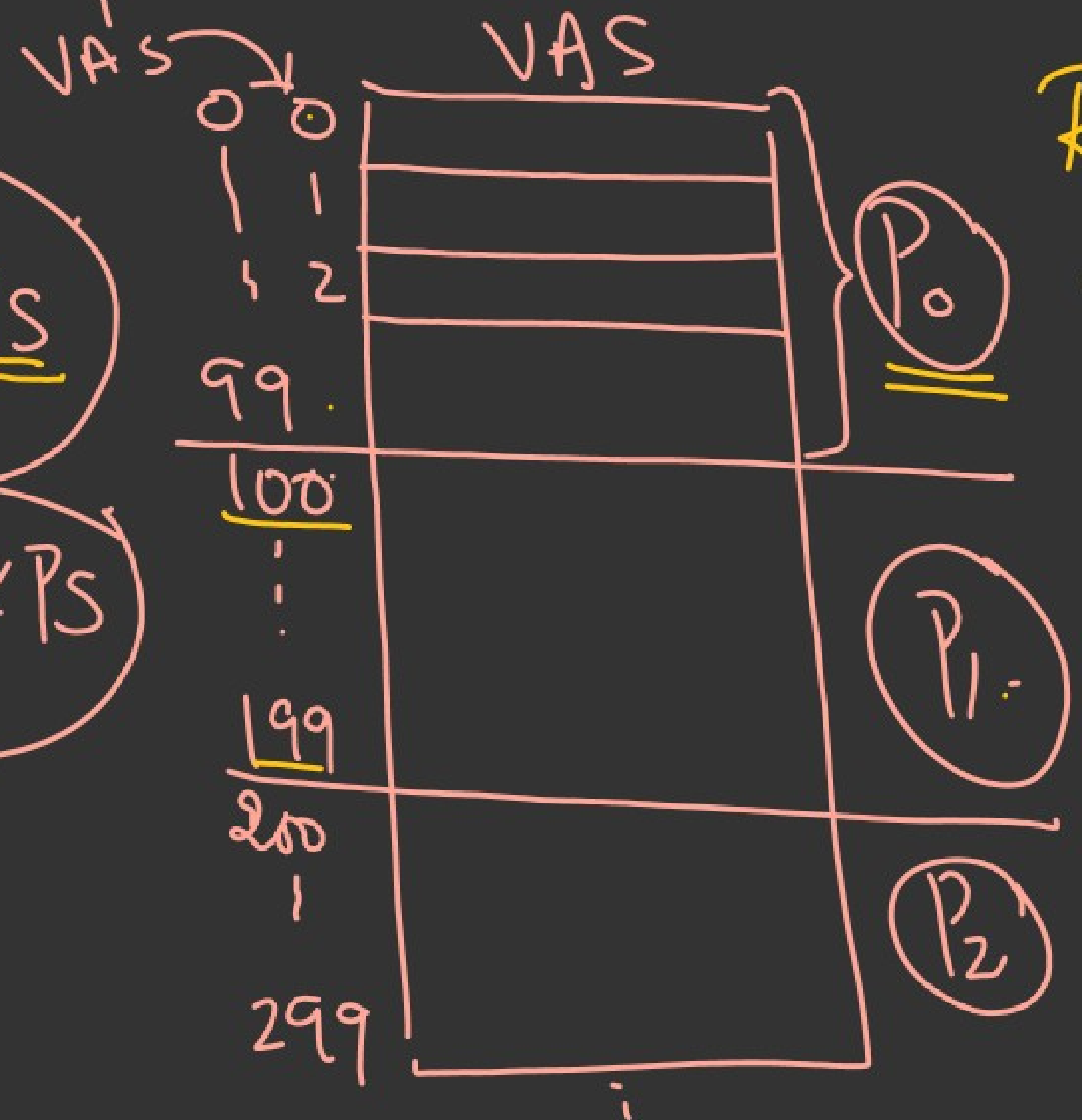
101 → 1, 1

P.S = 100 W

$P_{ri} \rightarrow$ V.A's = { 101, 222, 434, 404, 256, 12, 654, 655, 892, 934, 601 . . .

$P = VA / PS$

$d = VA \% PS$



Ref String: < 1, 2, 4, 2, 0, 6, 8, 9, 6 . . >

No. of unique Pages (n) = 7

Length of ref String (L) = 9

{1, 2, 4, 0, 6, 8, 9} = 7 Pages : 7 frames

$101 / 100$: P = 1, d = 1

$12 / 100$: P = 0, d = 12

THANK
YOU!