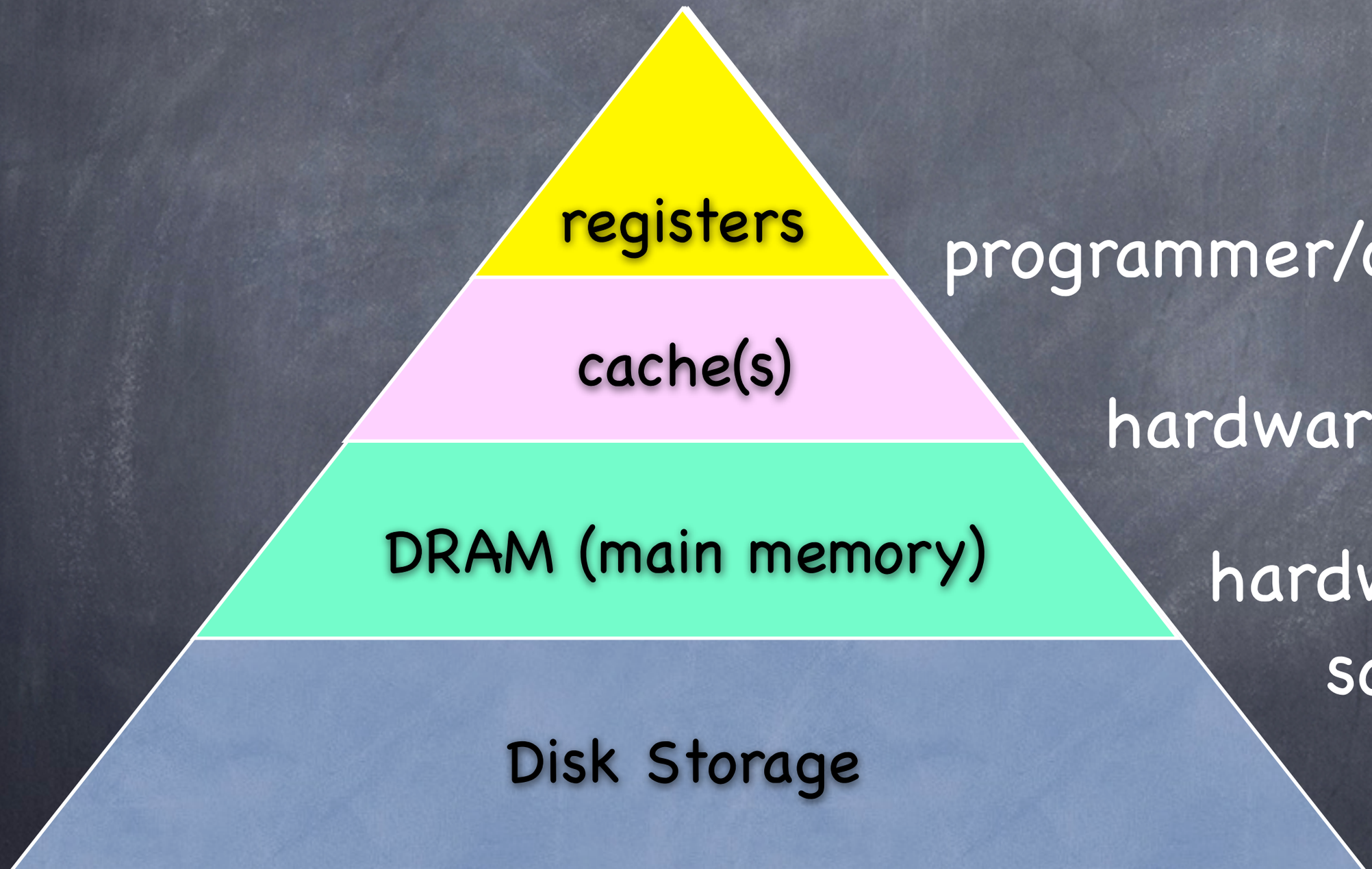
Announcements

(No longer optional) ARM Reading linked off labs page (Look at D.7 and D.8)


registers
cache(s)
DRAM (main memory)
Disk Storage
programmer/compiler
hardware
hardware + O.S.
software

Traps / Exceptions

- Divide by zero
- Invalid operation code
- Segmentation fault
- Reference to invalid page table entry
- Syscall

Exception Handling Approaches

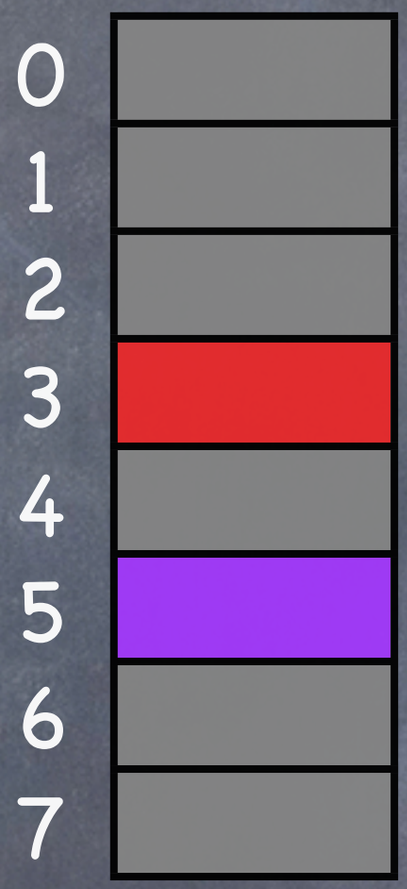
- Branch to "fixed" address
  - Actually fixed
  - Address stored in fixed address (typically low or high addresses in memory).
  - Address stored in special register
- Save information including PC where error occurred (like bal saves return address).
- Enter supervisor mode!

Privileged Modes

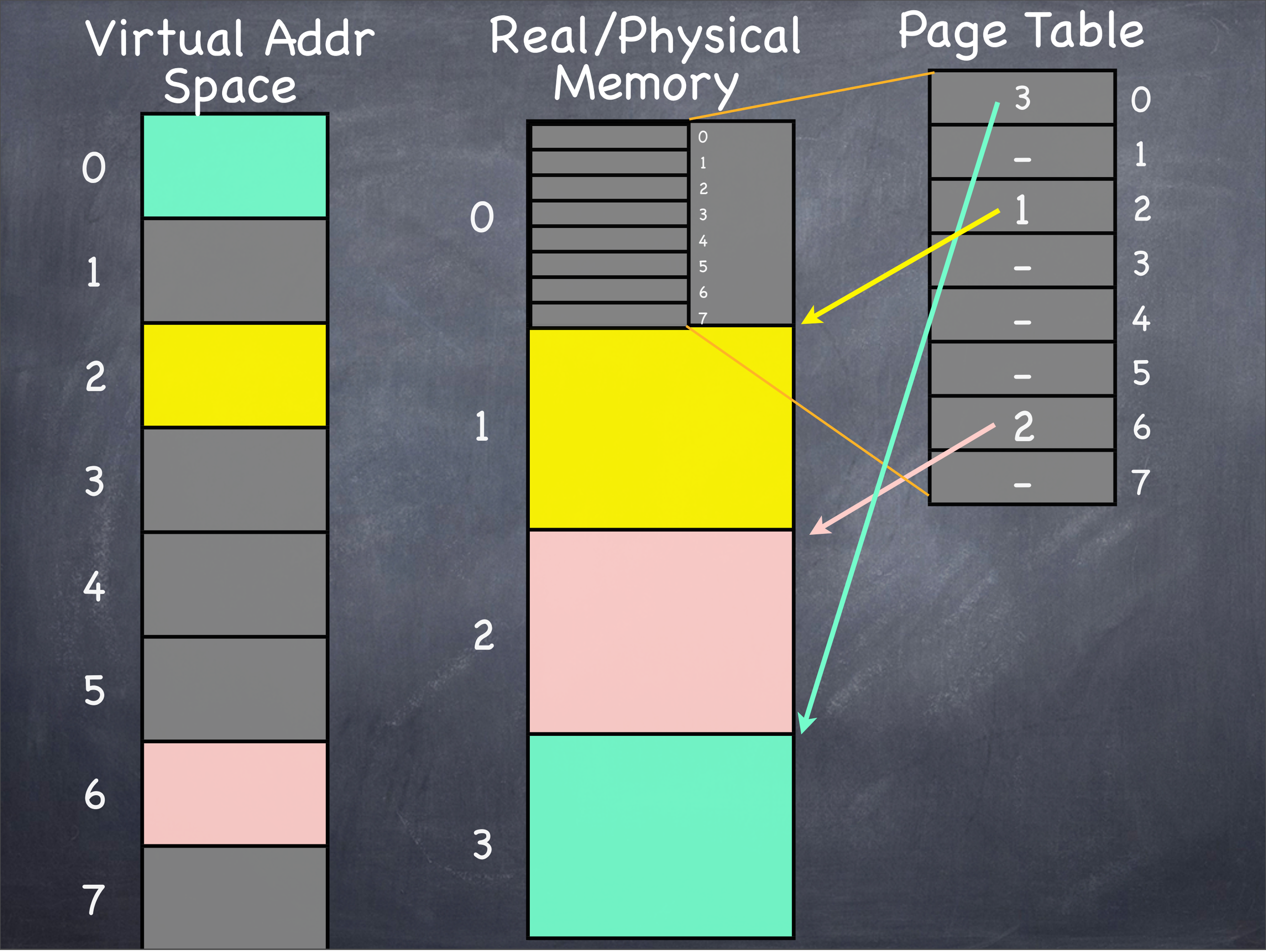
- Most processors have a register indicating current mode:
  - user mode
  - supervisor mode
- Can only set page table address register in supervisor mode ==> memory protection
- Can only set mode register in supervisor mode!

Program 1's Virtual Addr Space

Program 2's Virtual Addr Space

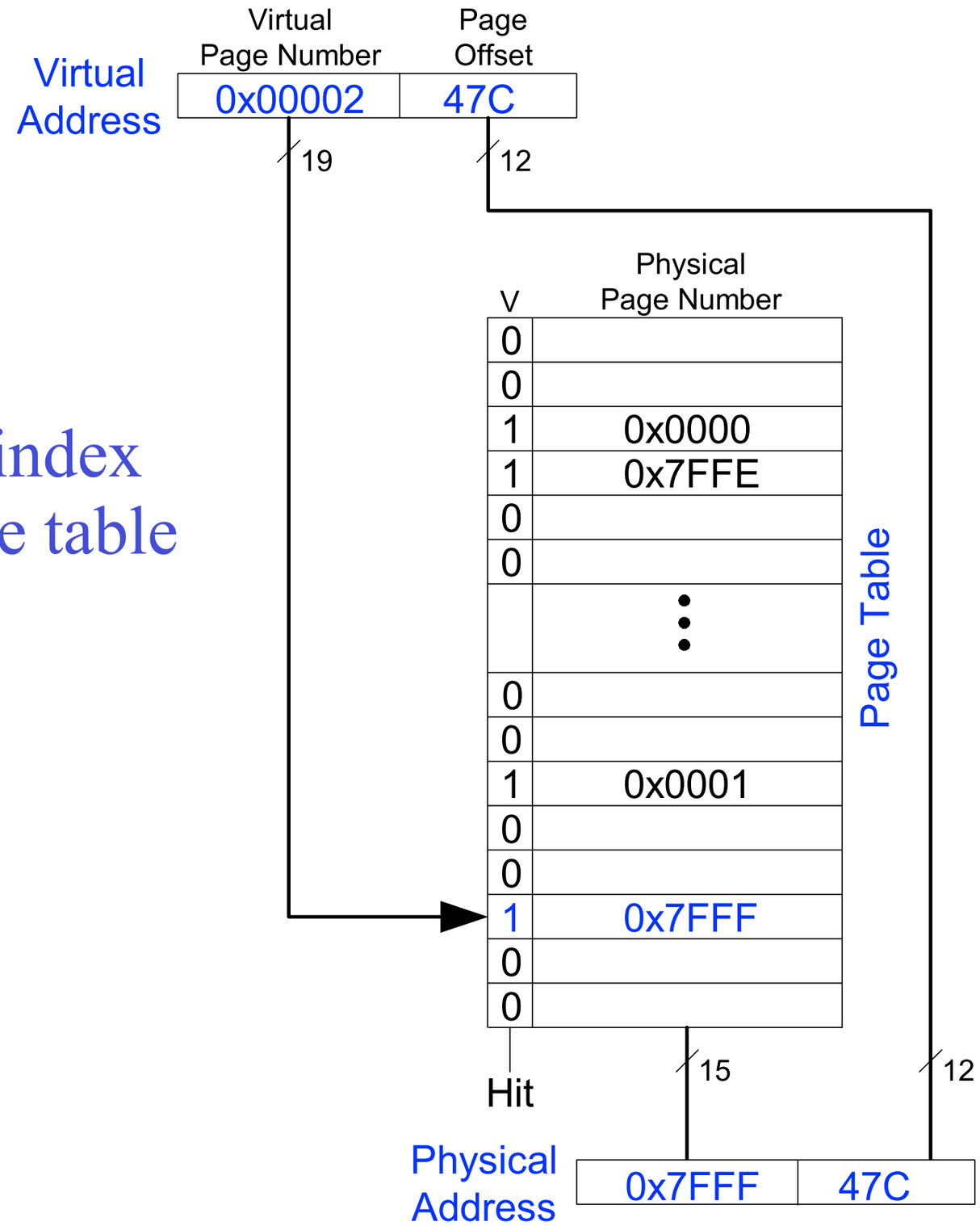


Real/Physical Memory


Virtual Addr Space
0
1
2
3
4
5
6
7
Real/Physical Memory
0
1
2
3
0
1
2
3
4
5
6
7
Page Table
3
–
1
–
–
–
2
–
0
1
2
3
4
5
6
7

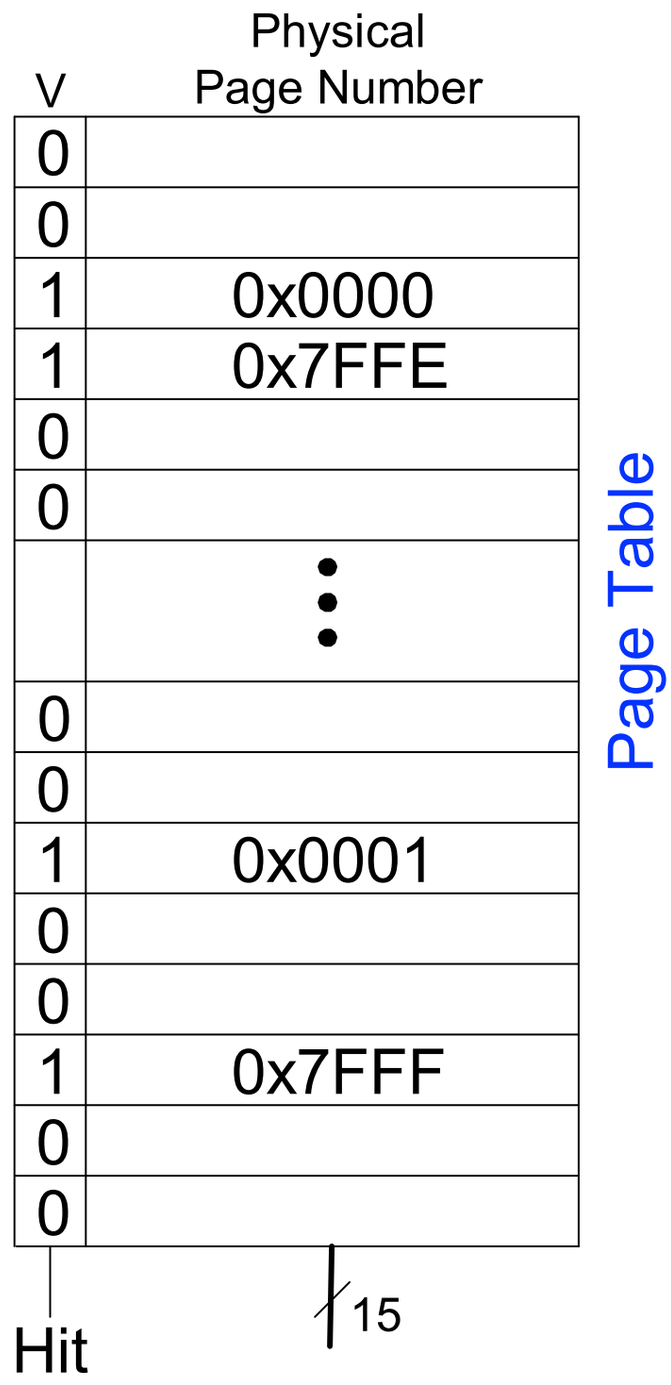
Page Table Example

VPN is index into page table



Page Table Example 1

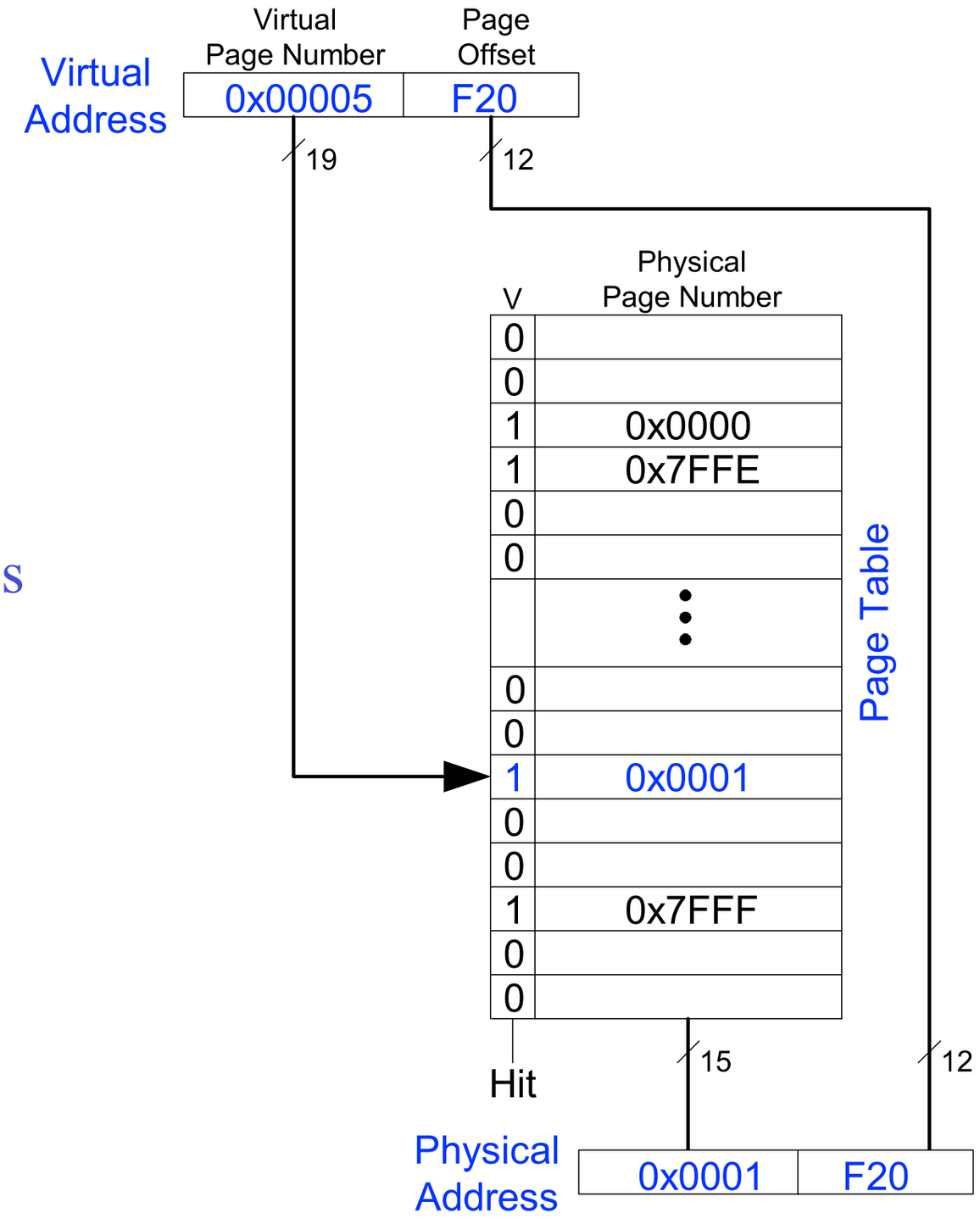
What is the physical address of virtual address **0x5F20**?



Page Table Example 1

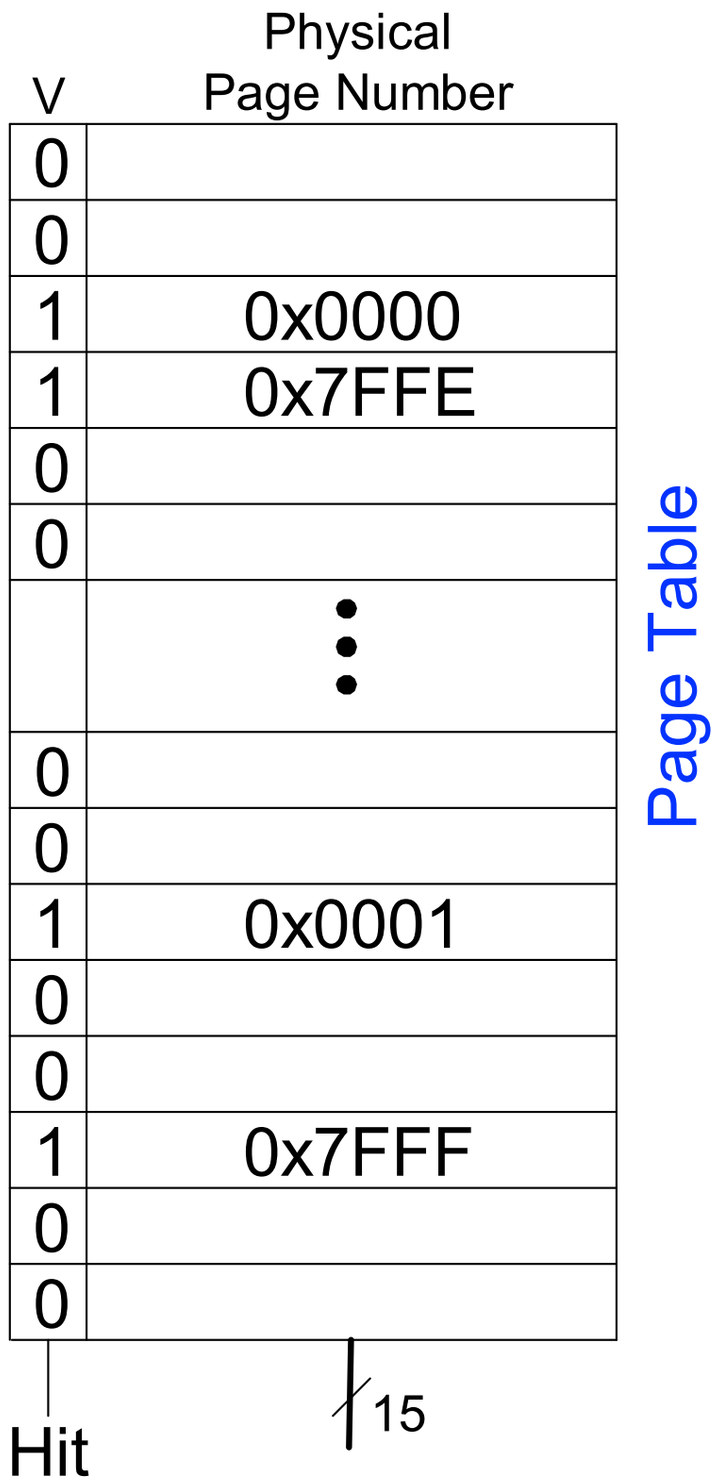
What is the physical address of virtual address **0x5F20**?

- VPN = **5**
- Entry 5 in page table indicates VPN 5 is in physical page **1**
- Physical address is **0x1F20**



Page Table Example 2

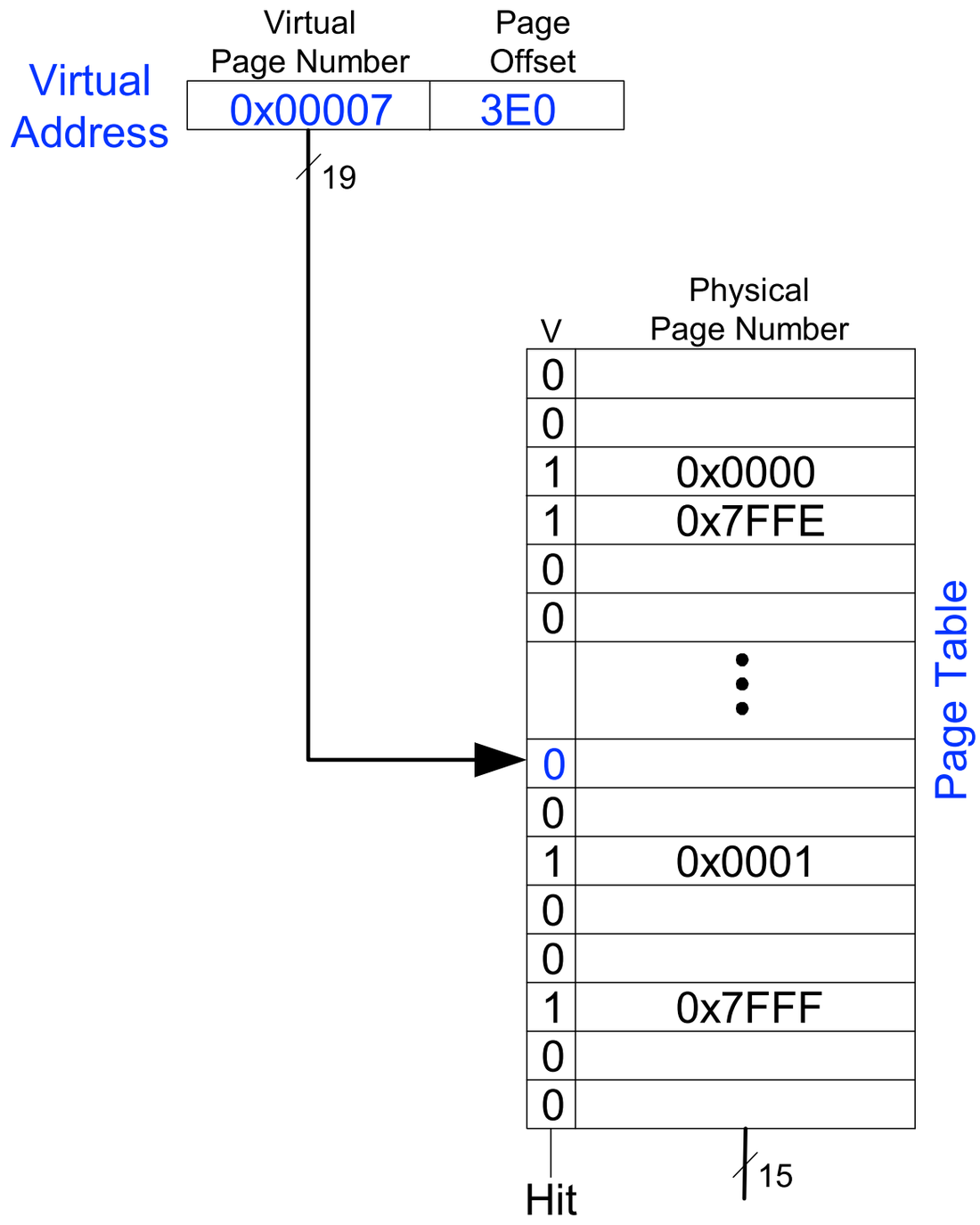
What is the physical address of virtual address **0x73E0**?



Page Table Example 2

What is the physical address of virtual address **0x73E0**?

- VPN = 7
- Entry 7 in page table is invalid, so the page is not in physical memory
- The virtual page must be ***swapped*** into physical memory from disk



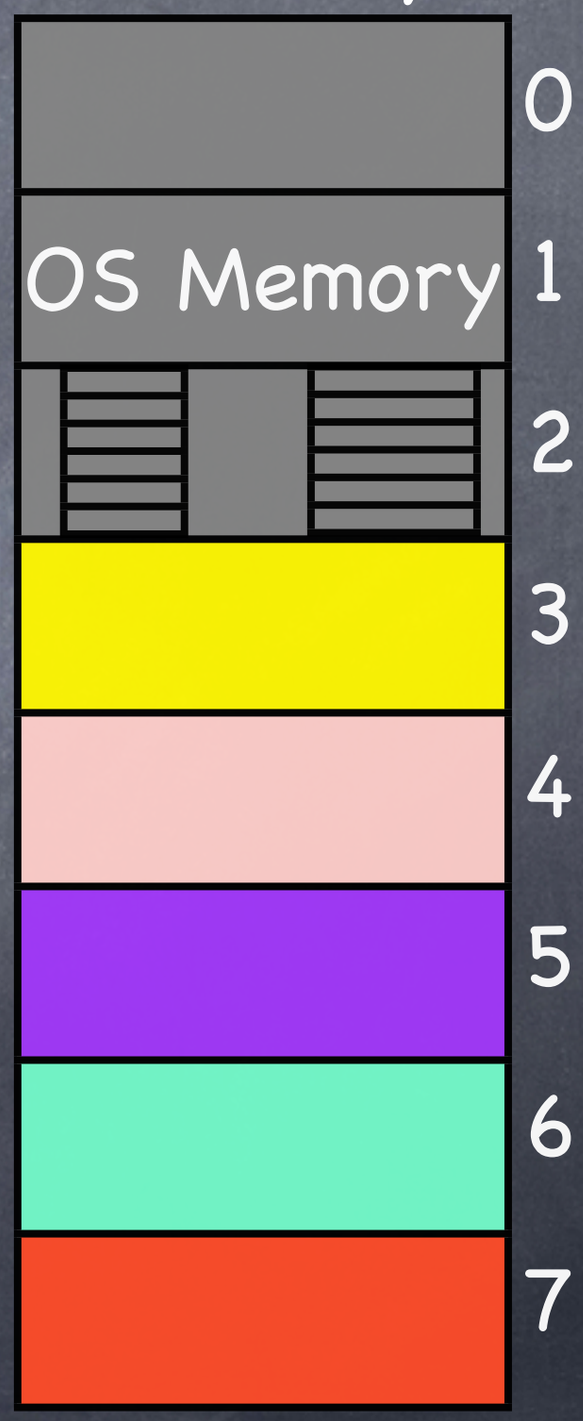
ELSEVIER

O.S. / HARDWARE INTERFACE

Program 1's Virtual Addr Space

Program 2's Virtual Addr Space

Real/Physical Memory



Page Table Address Register

Program 1's page table

6	0
–	1
3	2
–	3
–	4
–	5
4	6
–	7

Program 2's page table

–	0
–	1
–	2
7	3
–	4
5	5
–	6
–	7

Real/Physical Memory

Program 1's Virtual Addr Space

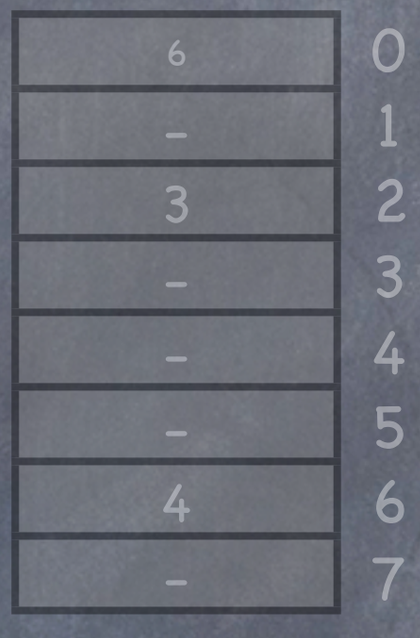
Program 2's Virtual Addr Space

Page Table Address Register

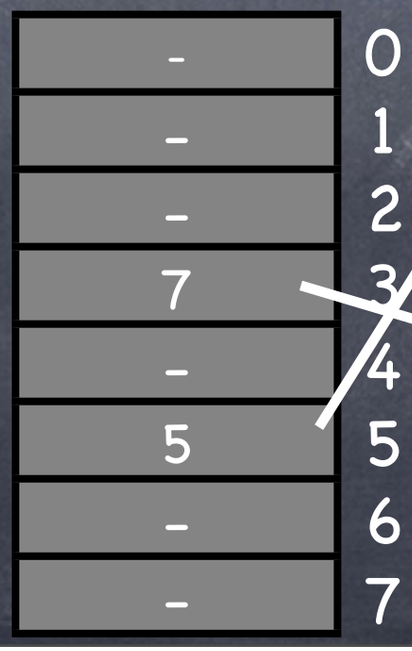
Program 1's Virtual Addr Space

Program 2's Virtual Addr Space

Program 1's page table

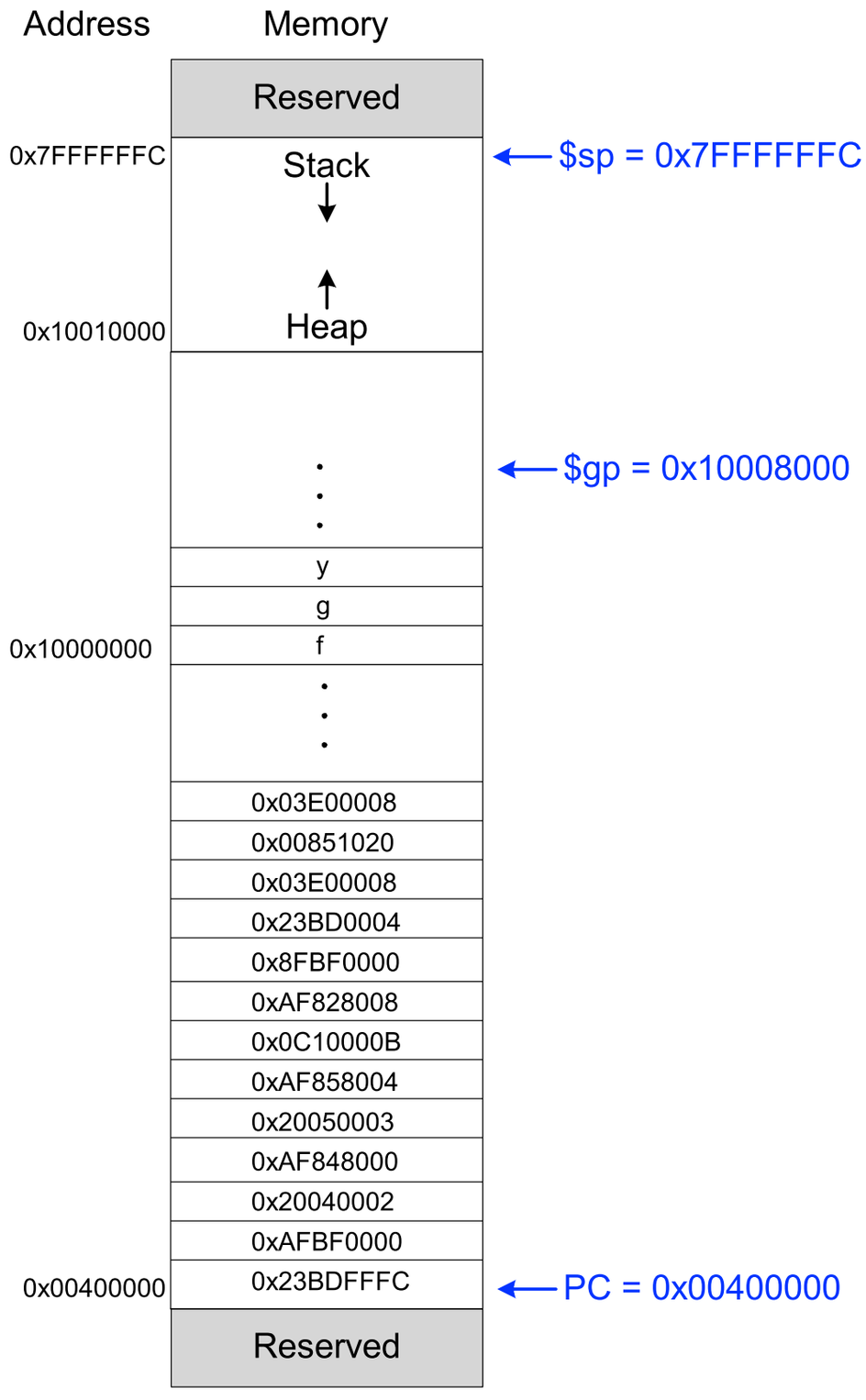


Program 2's page table

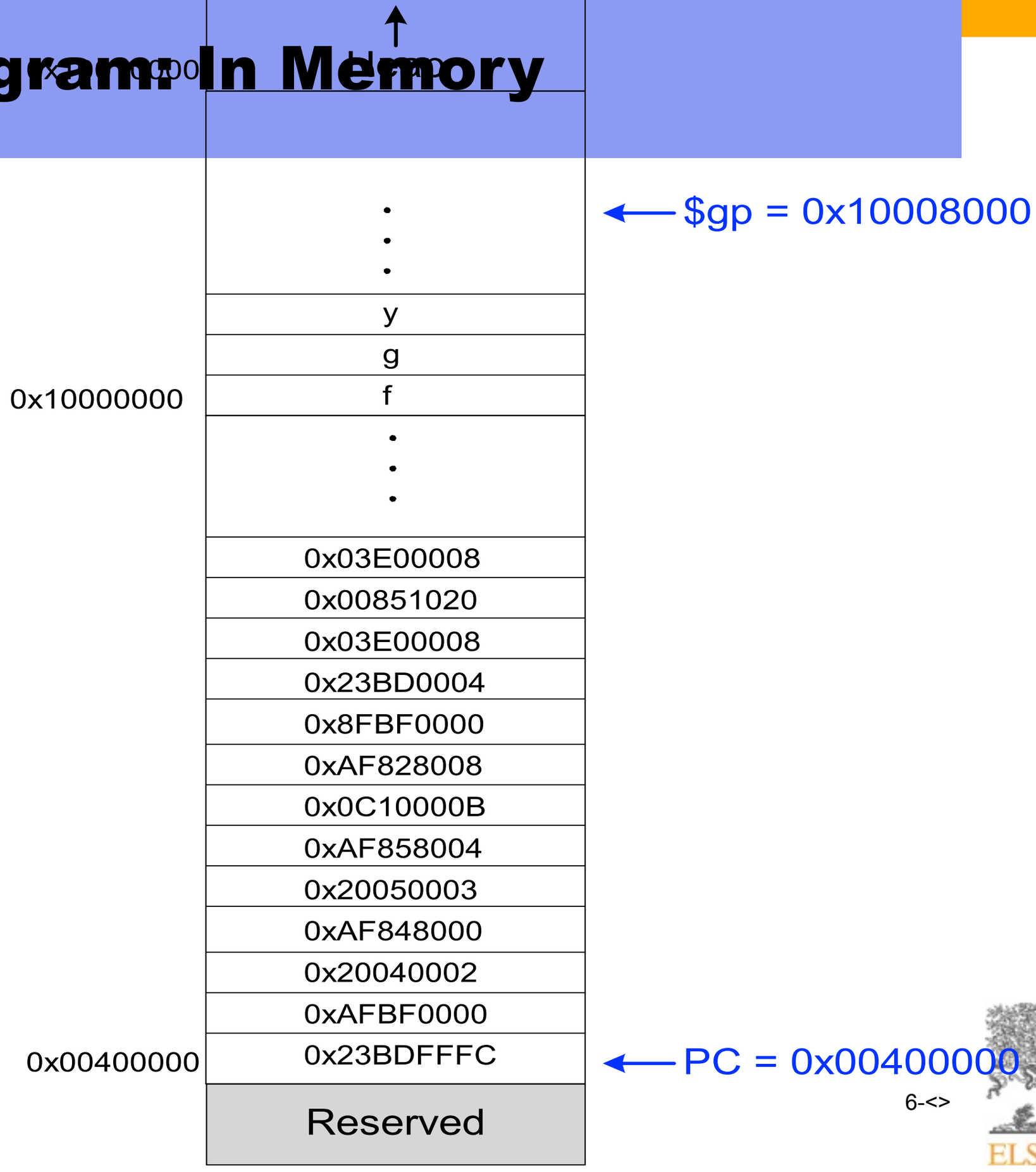


Real/Physical Memory

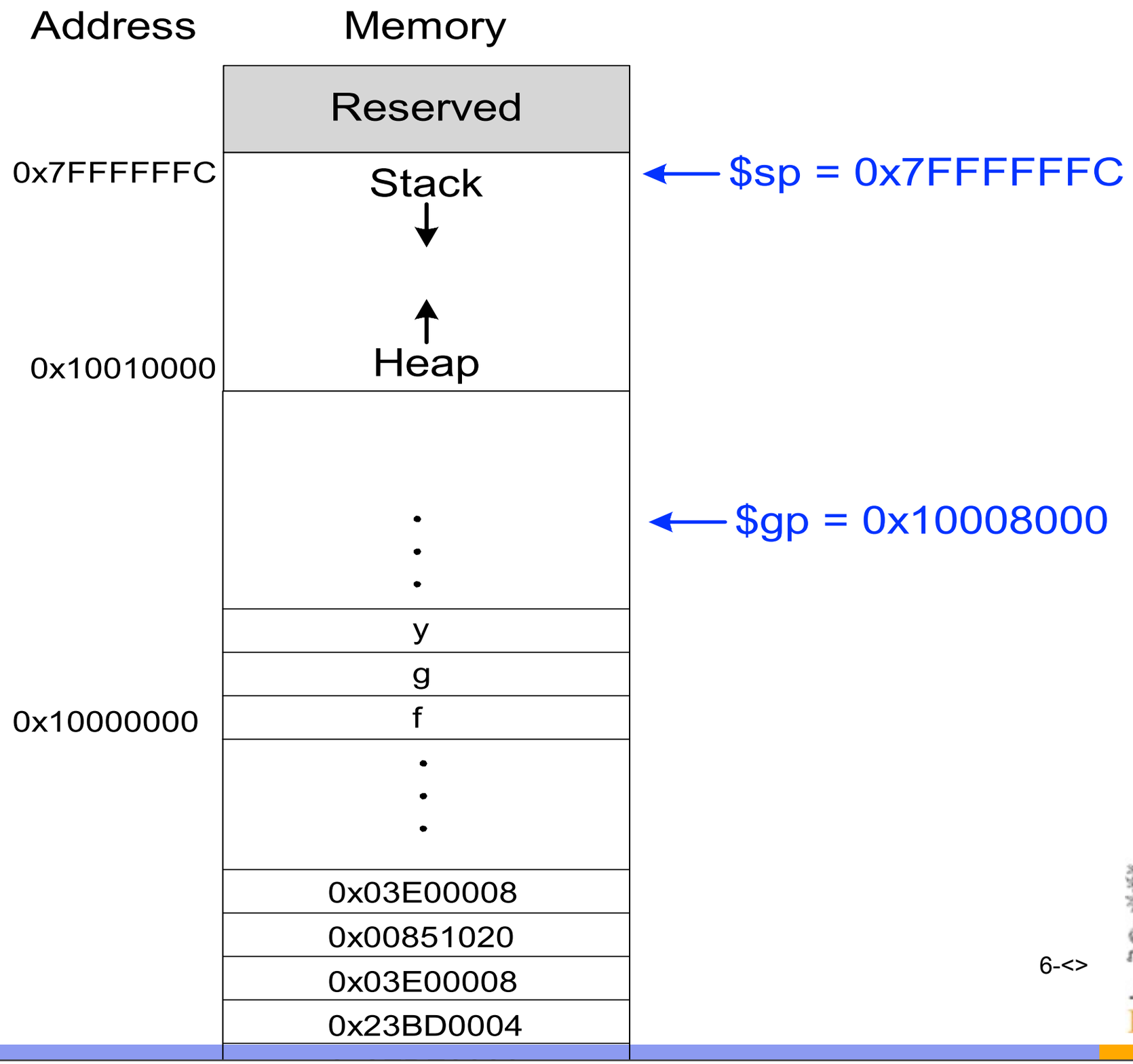
Example Program: In Memory



Example Program In Memory



Example Program: In Memory



Memory Management

$$\begin{array}{r} 7FFFFFFC \\ -\ \underline{10010000} \\ 6FFFFFFC \end{array}$$

$= 7 \times 16^7 - 4$

= about 2 Gigs

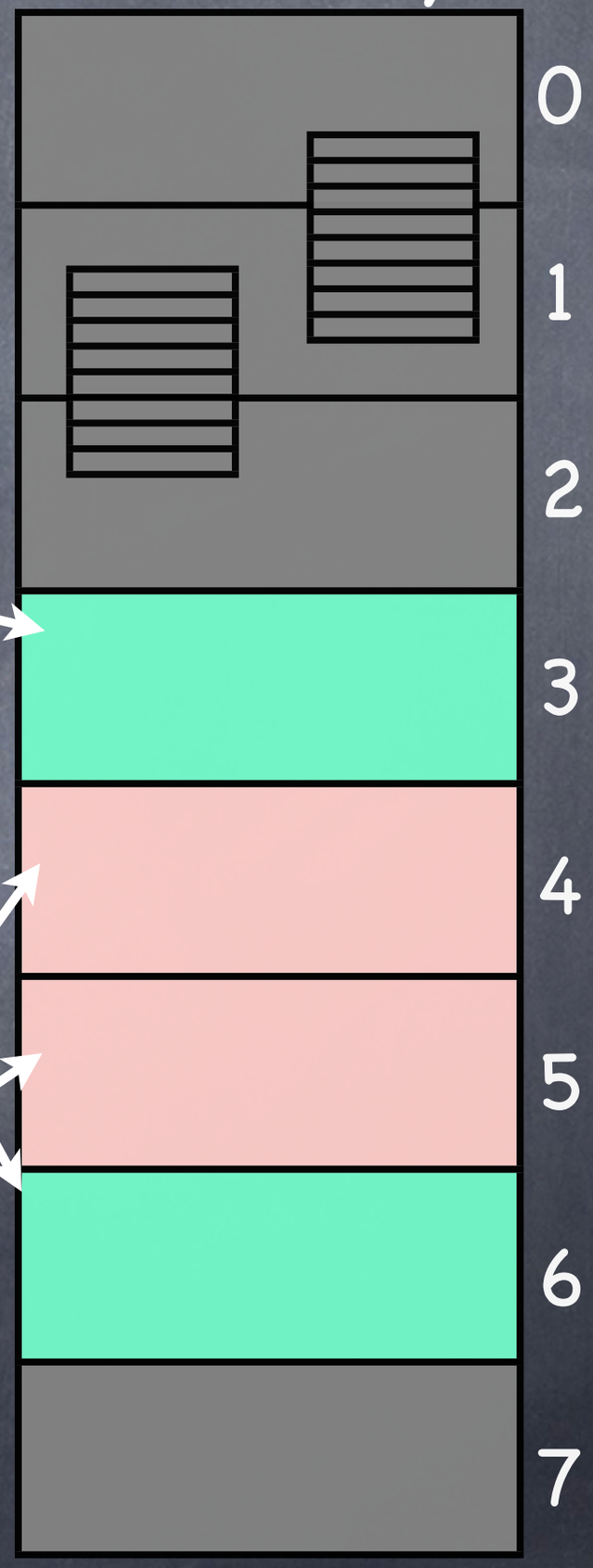
Program 1's Virtual Addr Space

11	stack
10	
9	
8	
7	
6	
5	
4	
3	
2	
1	
0	heap

Program 1's page table

3	0
6	1
-	2
-	3
-	4
-	5
-	6
-	7
-	8
-	9
5	10
4	11

Real/Physical Memory



Program 1's Virtual Addr Space

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Program 1's page table

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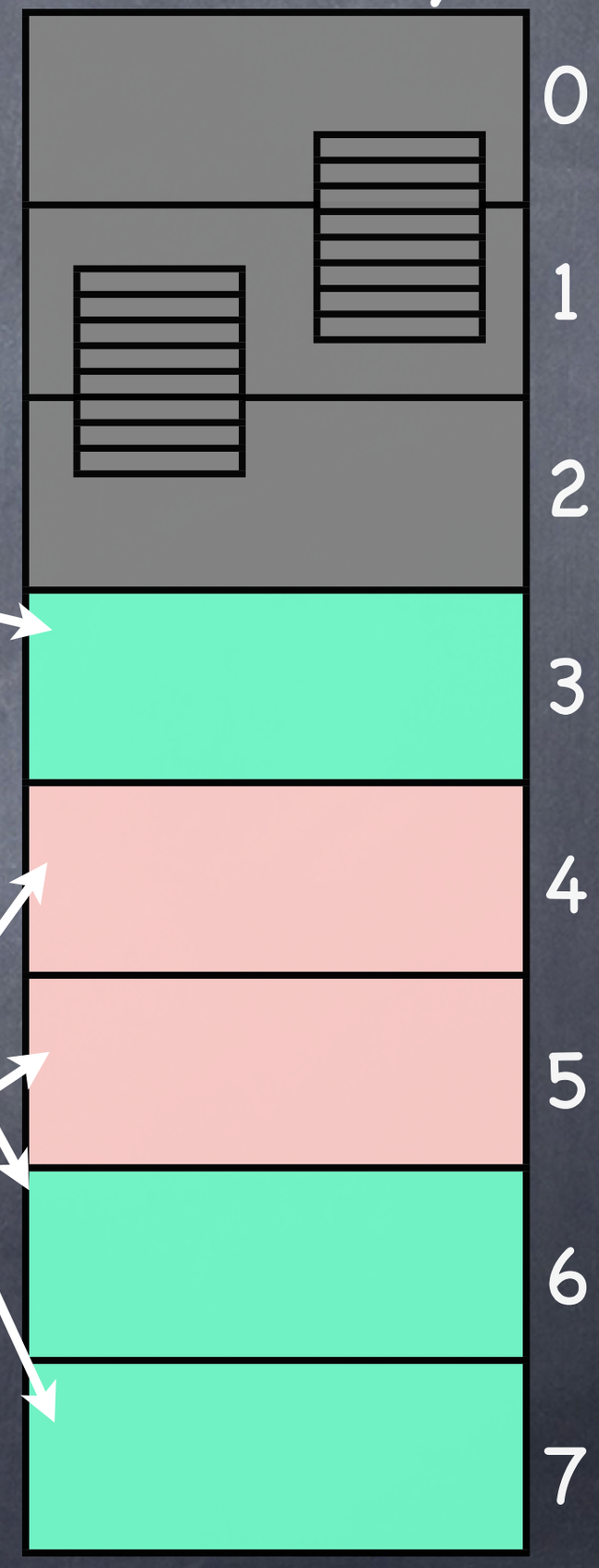
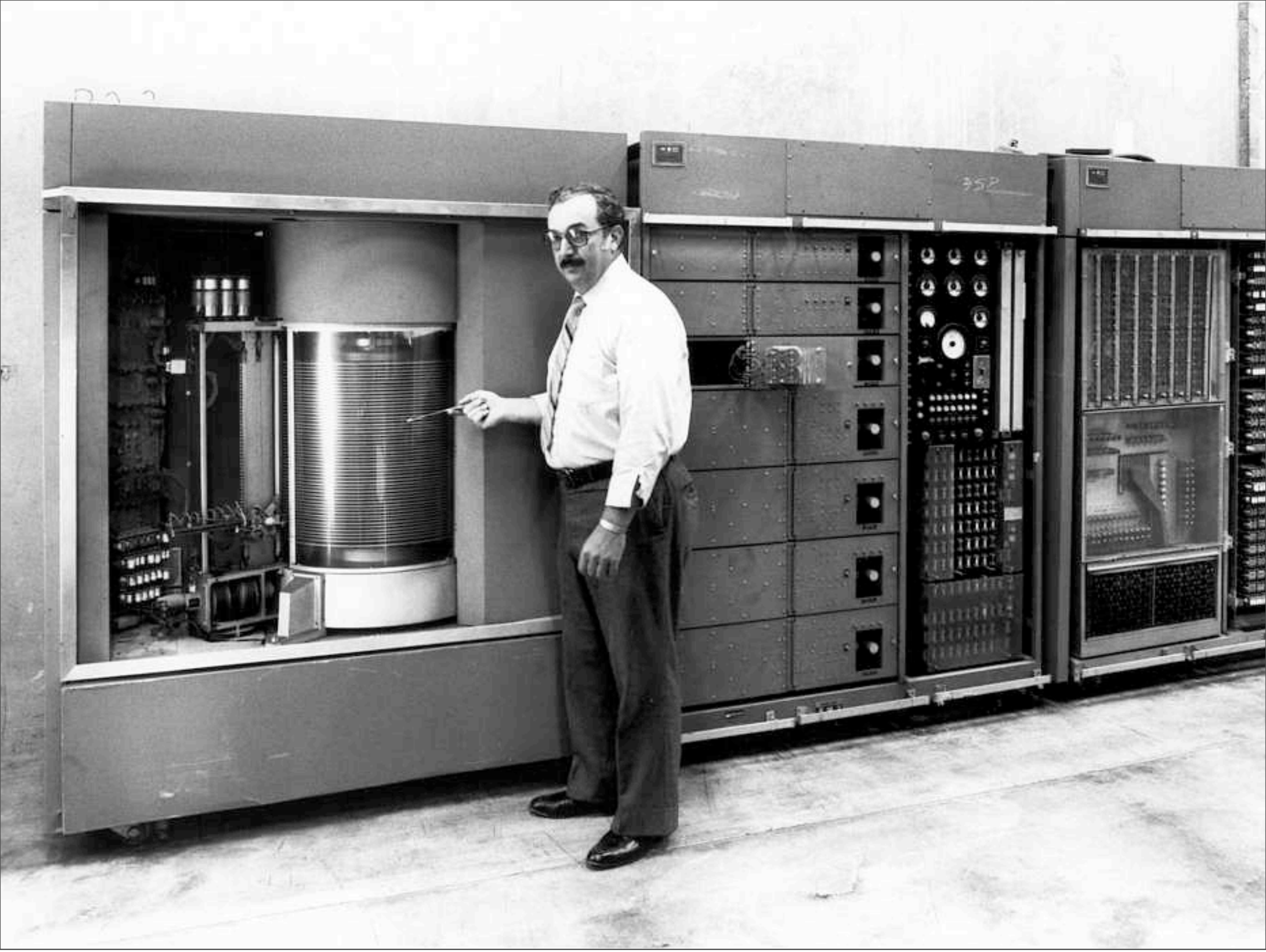
Real/Physical Memory

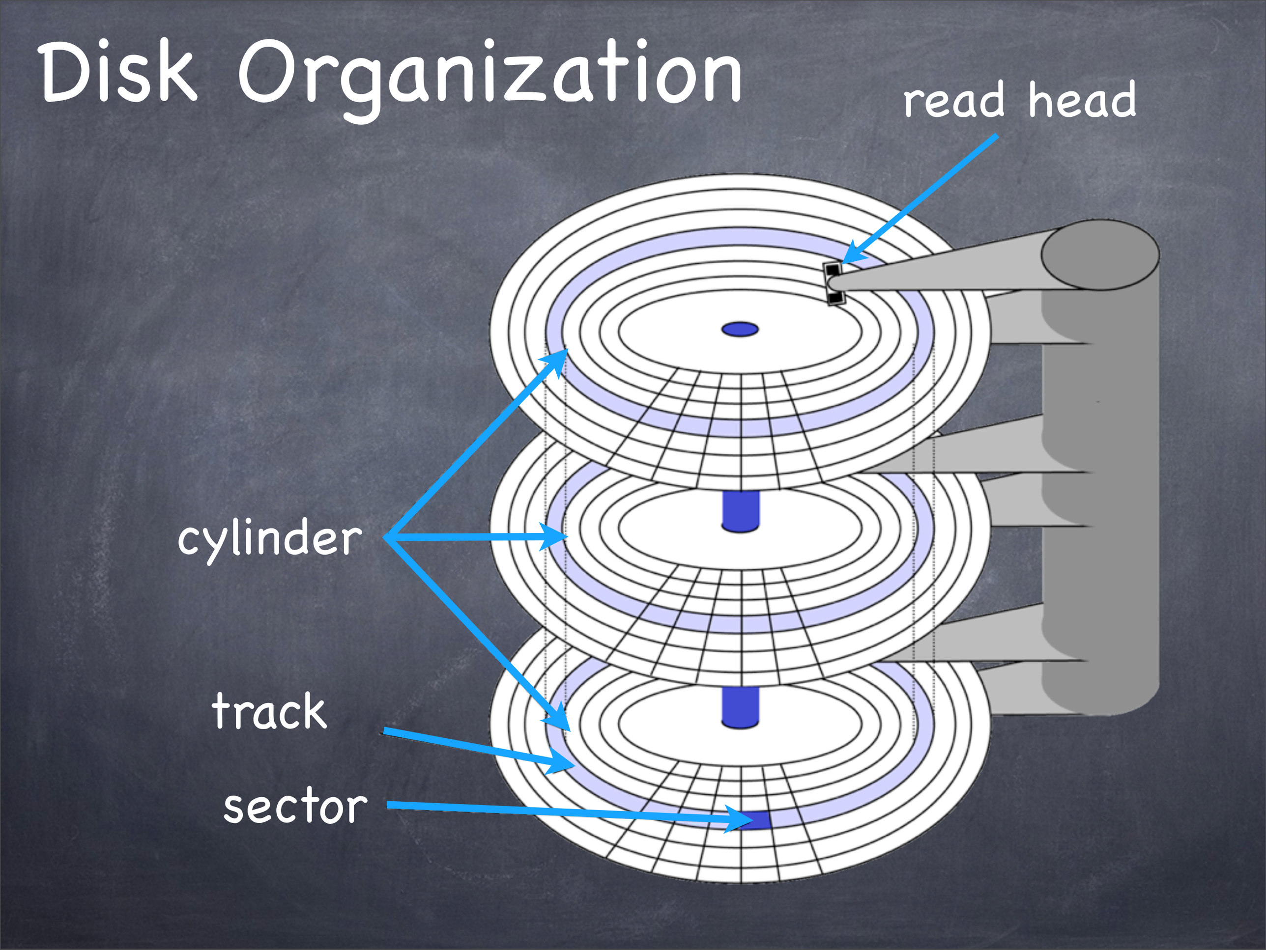




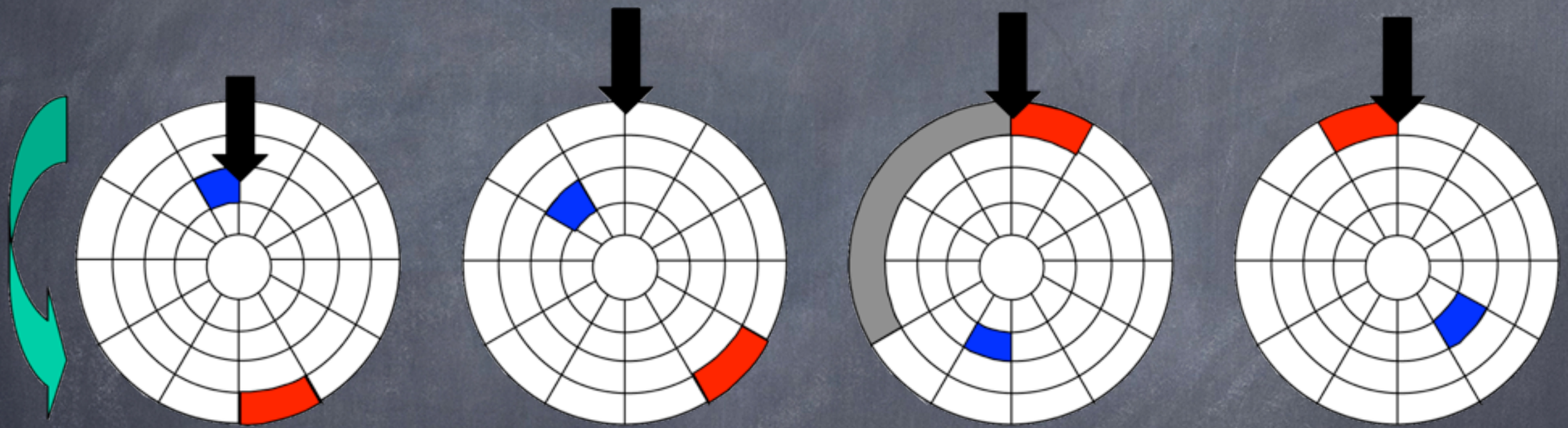
Tuesday, November 27, 12

Tuesday, November 27, 12

Disk Organization



Delays in disk accesses



Complete accessing blue

Seek to cylinder for red

Rotational latency to access red

Access red

Seagate Cheetah Specs

Specifications	600GB[1]	450GB[1]	300GB[1]
Model Number	ST3600057SS ST3600957SS[2] ST3600857SS[3] ST3600057FC ST3600957FC[2, 4] ST3600857FC[3, 4]	ST3450857SS ST3450757SS[2] ST3450657SS[3] ST3450857FC ST3450757FC[2, 4] ST3450657FC[3, 4]	ST3300657SS ST3300557SS[2] ST3300457SS[3] ST3300657FC ST3300557FC[2, 4] ST3300457FC[3, 4]
Capacity			
Formatted 512 KB/Sector (GB)	600	450	300
External Transfer Rate (MB/s) 4Gb/s Fibre Channel 6Gb/s Serial Attached SCSI	 400 600	 400 600	 400 600
Performance			
Spindle Speed (RPM)	15K	15K	15K
Average Latency (ms)	2.0	2.0	2.0
Seek Time Average Read/Write (ms)	3.4/3.9	3.4/3.9	3.4/3.9
Transfer Rate Internal (Mb/s, OD–ID) Sustained (MB/s, 1000 x 1000)	 1450 to 2370 122 to 204	 1450 to 2370 122 to 204	 1450 to 2370 122 to 204