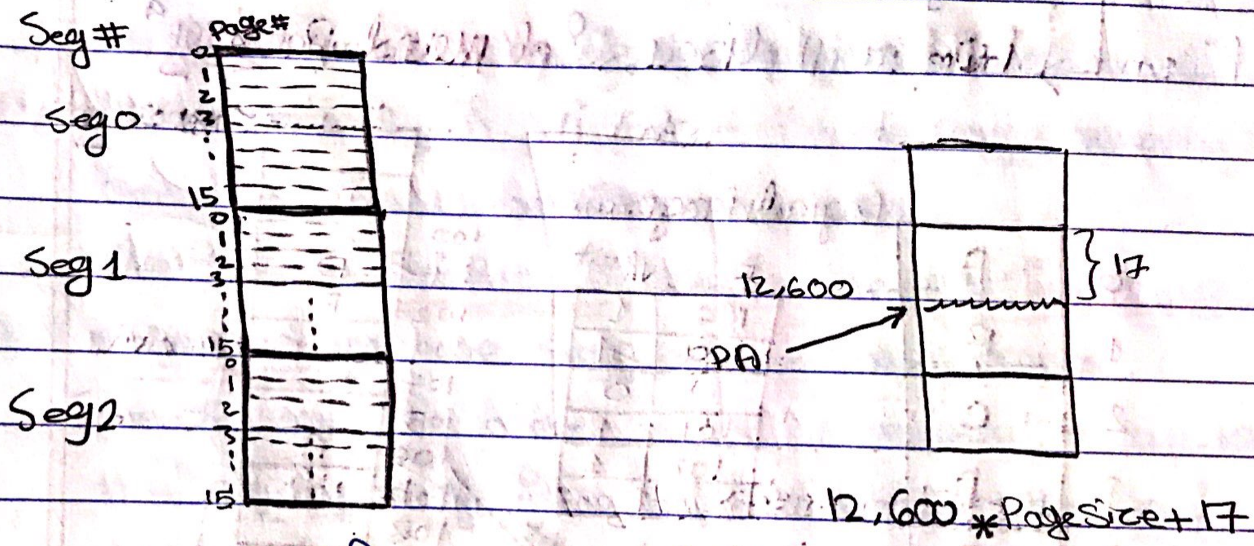
example: given LA which generates:

$S = 2, d = 350$

$PA = B + d = 18,000 + 350 = 18,350$

Segmentation with Paging

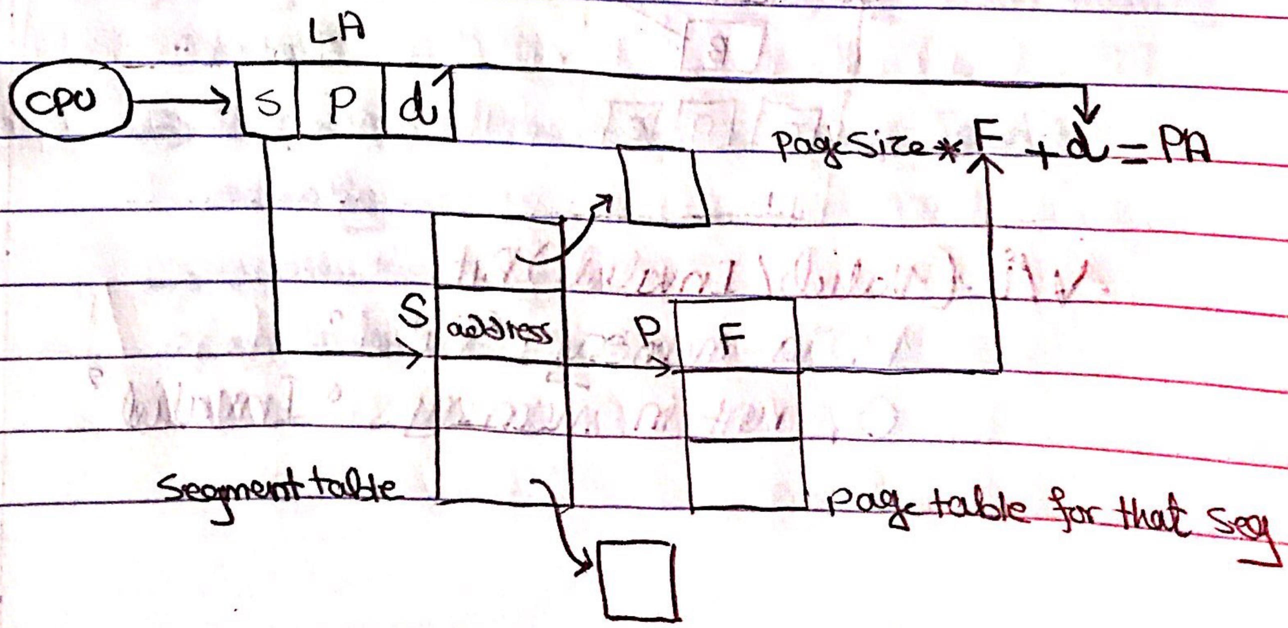
"paging the Segments"



If Seg Size = 64K.

→ page Size = 4K.

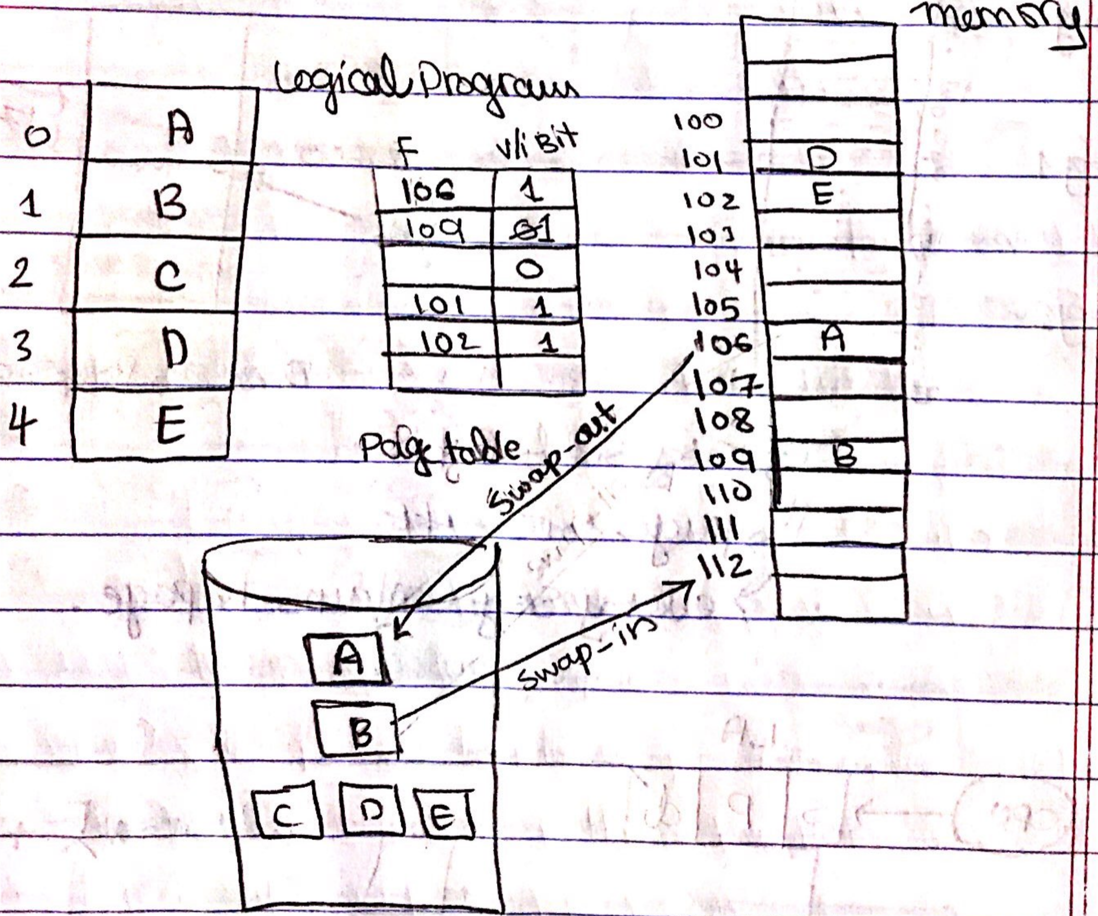
→ every Seg contains 16 page.



Chapter#9:

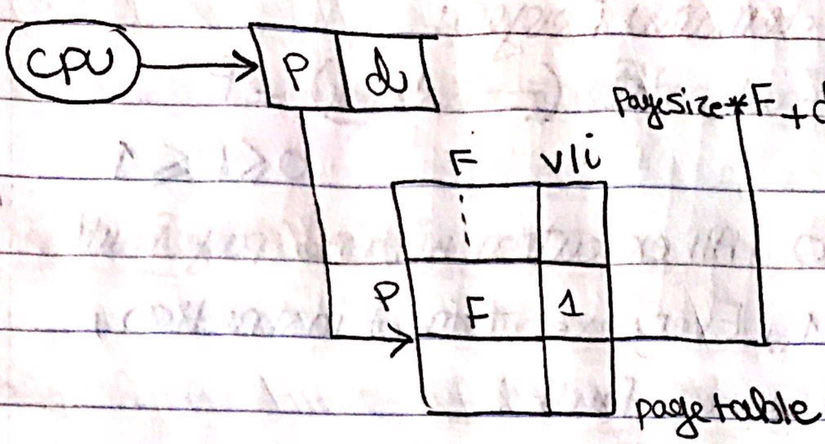
Virtual Memory Management.

- How to run bigger ~~pa~~ programs on Smaller memory.
- No need for the whole program to be Loaded into memory, only part of it will do.
- We will discuss "demand Paging"



v/i (Valid/Invalid) Bit:

1: in memory. "valid"
0: not in memory. "Invalid"



- The LA is checked through the page table if it's a valid address, that's, if v/i Bit = 1 (the page memory) that it continue execution as usual.
- What if the v/i Bit = 0, that's the page isn't in memory, then we say a $\boxed{\text{page fault}}$ occurs.
- The OS looks for a free frame in memory, swap-in the required page from HD, it updates the page table & resumes execution.
- What if there's no free frame?
  - → It selects a victim frame
  - → may be, it swap-out the page from memory to HD.
  - → It swap in the required page from HD to memory
  - → update the page table.
  - → resumes execution.

Performance of demand pages:

- Assum page fault rate (probability) = P

$0 \leq P \leq 1$

→ If P = 0, All execution with no page fault. "perfect"

→ If P = 1, Every execution of instruction, there's a page fault.

- Assum memory access = m

$$EAT = (1-P) * m + P * \underbrace{[\text{swap in Page} + \text{maybe swap-out page} + m]}_{\text{Page fault overhead}}$$

Example: Assum memory access (m) = 10 mics

- Page fault rate (P)
- Page transfer (swap) time = 10 mils
- 40% of the time the page needs to be swap-out.

$$EAT = (1-P) * 10 + P * [\overset{\text{swap-in}}{10 * 1000} + 0.4 * 10 * 1000 + 10]$$

$$= 10 - \cancel{10P} + 10{,}000P + 4{,}000P + \cancel{10P}$$

$$= 10 + 14{,}000P \simeq 14{,}000P$$

⚠ تحويل الوحدات الأكبر لوحدات أصغر

mils, mics → mils ⇒ mics

∴ **Result:**

Performance depends on P (page Fault Rate).

Objective: Minimize the Page Fault Rate.

⚠ **Note:** A new bit called "dirty Bit" is added to the page table to indicate if the page is modified.

1 = page is modified

0 = page isn't modified.

Page Replacement Algorithms:

The OS must select the victim frame so that, to minimize the page fault rate.

1 FIFO

Replace the page which enters the memory First (oldest page in memory).

example: given the following page references.

1 2 3 4 1 2 5 1 2 3 4 5

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	4	4	4	5	✓	✓	5	5	✓
	2	2	2	1	1	1			3	3	
		3	3	3	2	2			2	4	

9 page faults

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	1	✓	✓	5	5	5	5	4	4
	2	2	2			2	1	1	1	1	5
		3	3			3	3	2	2	2	2
			4			4	4	4	3	3	3

10 page faults

∴ Belady's Anomaly!

2 Optimal Replacement:

Replace the page which won't be used in the future for the longest period.

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	1	✓	✓	1	✓	✓	3	3	✓
	2	2	2			2			2	4	
		3	4			5			5	5	

7 Page faults

⚠ Major problem: How the OS know in advance the next page in which execution occurs?!

* Optimal replacement is used as a bench mark!

[3] Least Recently Used [LRU]

Replace the page which have not been used in the past for the Longest period of time.

1 2 3 4 1 2 5 1 2 3 4 5

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	4	4	4	5	✓	✓	3	3	3
	2	2	2	1	1	1			1	4	4
		3	3	3	2	2			2	2	5

10 page faults "3 Frames"

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	1	✓	✓	1	✓	✓	1	1	5
	2	2	2			2			2	2	2
		3	3			5			5	4	4
			4			4			3	3	3

8 page faults "4 frames"

* Implementation:

(1) Add a Counter to the page table that contains the last time the page is referenced (used)

	time of reference
	10:3:20 → Integer
	10:3:11

page table

(2) Keep a queue of referenced pages

1	3	5	1	2	4

↑ Front

→ or we can use a stack, Every time we use a page, push it into stack.

↳ the stack top is the latest used page

LRU approximation:

Add one bit to the page table called reference Bit

↳ 1 ≡ The page is referenced (used), Read or Written.

↳ 0 ≡ Page isn't referenced.

	reference bit

Page table.

→ LRU approximation, Replace the page whose reference Bit is 0.

Second chance:

→ replace 1 0

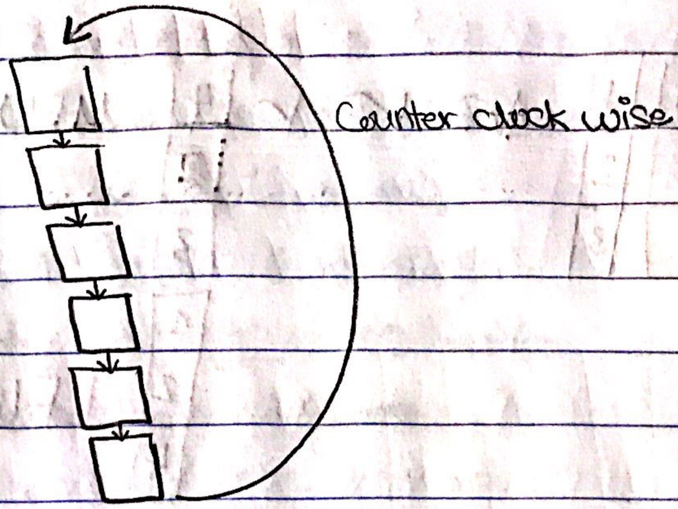
→ no change 0 1

→ no change 0 1

→ replace 1 0

→ no change 0 1

→ no change 0 1



Enhanced Second chance:

Use the reference bit & the dirty bit. (Reference bit, dirty bit)

best
- → (0,0) ≡ Page isn't referenced & not modified. 1
- → (0,1) ≡ Page isn't referenced but modified. 3
- → (1,0) ≡ Page is referenced but not modified. 2
- → (1,1) ≡ Page is referenced & modified. 4

worst

☆ Counting Algorithms:

1_ MFU (Most Frequently Used)

Replace the page which has been used for the maximum # of all times.

2_ LFU (Least Frequently Used)

Replace the page which has been used for the minimum # of all times.

1 2 3 1 2 1 4 3 4 5

1	1	1	✓ ✓ ✓	4
	2	2		2
		3		3

MFU

1
2
4

LFU

Global vs. Local Replacement

May. 19. 2018

Allocation of Frames for processes :-

(1) Equal Allocation : Each process gets the same number of pages (frames).

example: memory 100 frames, 5 processes

- Every process gets $\frac{100}{5} = 20$ frames.
- unfair → not good performance.

(2) Proportional Allocation according to size :

example: Assume the size of process $P_i = S_i$

Assume we have m frames of memory

Process P_i gets $\frac{S_i}{\sum S_i} * m$

- Assum memory 100 frames, 3 processes with sizes 100, 400, 700 KB.
- $P_1 = \frac{1\cancel{00}}{12\cancel{00}} * 100 \simeq 8$ frames
- $P_2 = \frac{\cancel{1}4\cancel{00}}{3\,\cancel{12}\cancel{00}} * 100 \simeq 34$ frames
- $P_3 = \frac{700}{1200} * 100 \simeq 58$ frames.

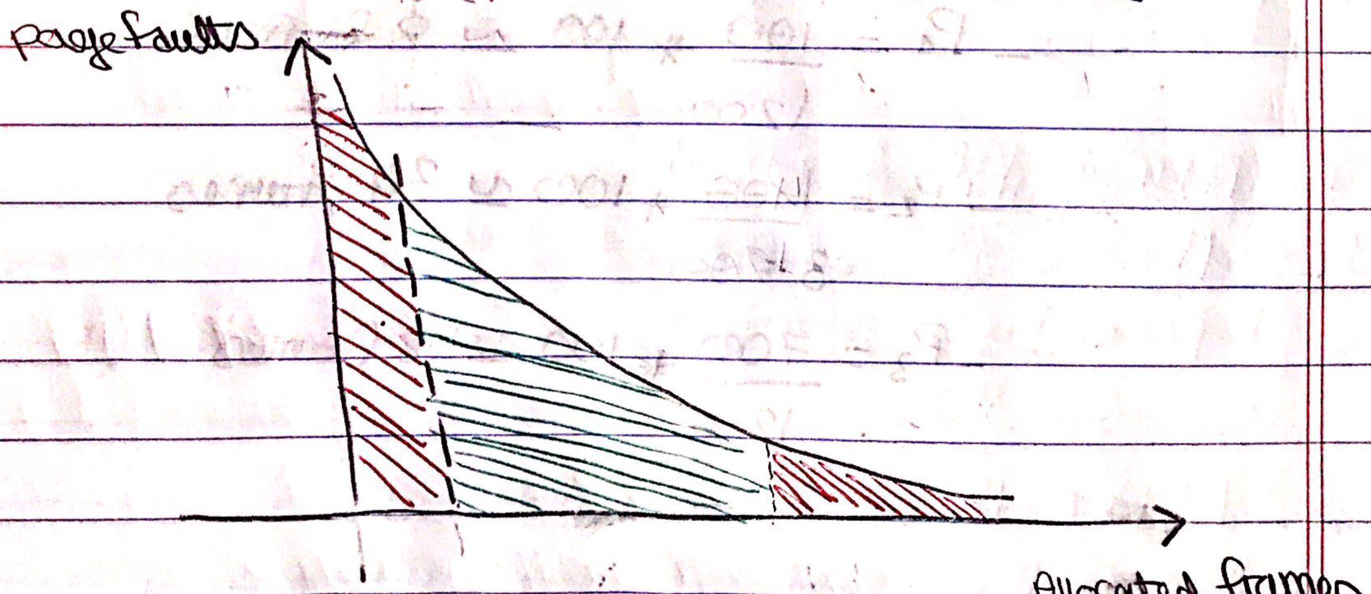
(3) Proportional according to priority:

example:

process	priority
P_1	2
P_2	3
P_3	7 → highest priority

- If we have 100 frames of memory
- $P_1 = \frac{2}{12} * 100 = \frac{1}{6} * 100$
- $P_2 = \frac{3}{12} * 100 = \frac{1}{4} * 100 = 25$ frames
- $P_3 = \frac{7}{12} * 100$

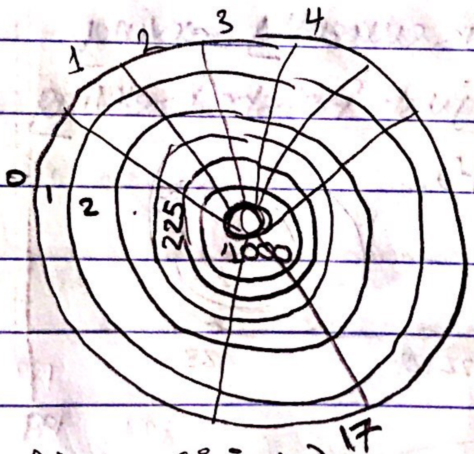
Thrashing: The OS is busy swapping page in & out.

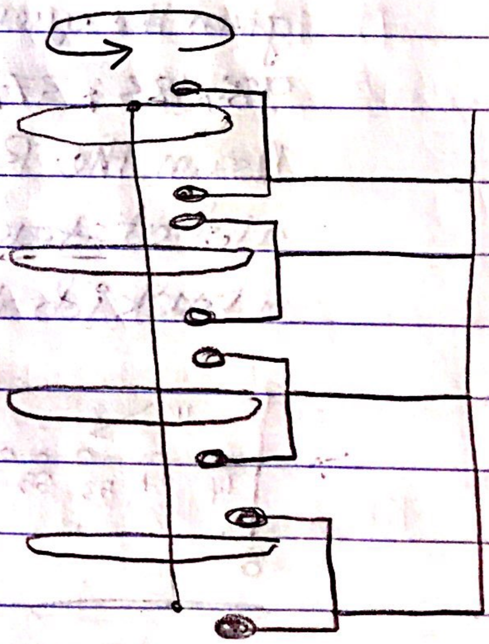


Good performance.

Poor performance.

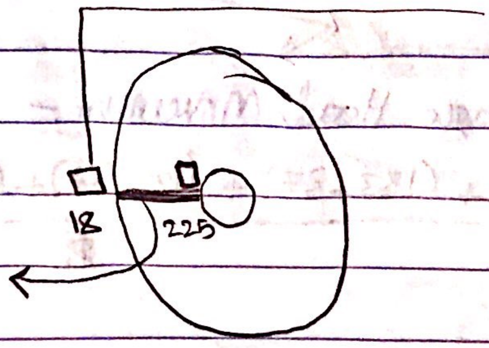
- Sometimes the number of Allocated frames for the process is low, which leads to poor performance (low system utilization).
The OS thinks that the degree of multiprogramming is low,
→ OS increases the degree of multi programming.
→ The system gets wors.
→ Most of the time the ~~system~~ OS is doing swapping of page.





Address (i, j, k)
track # ← i
j → Surface#
k → block#

(225, 3, 17)



The time to move from track 18 → 225 is called "seek time" mechanical move.

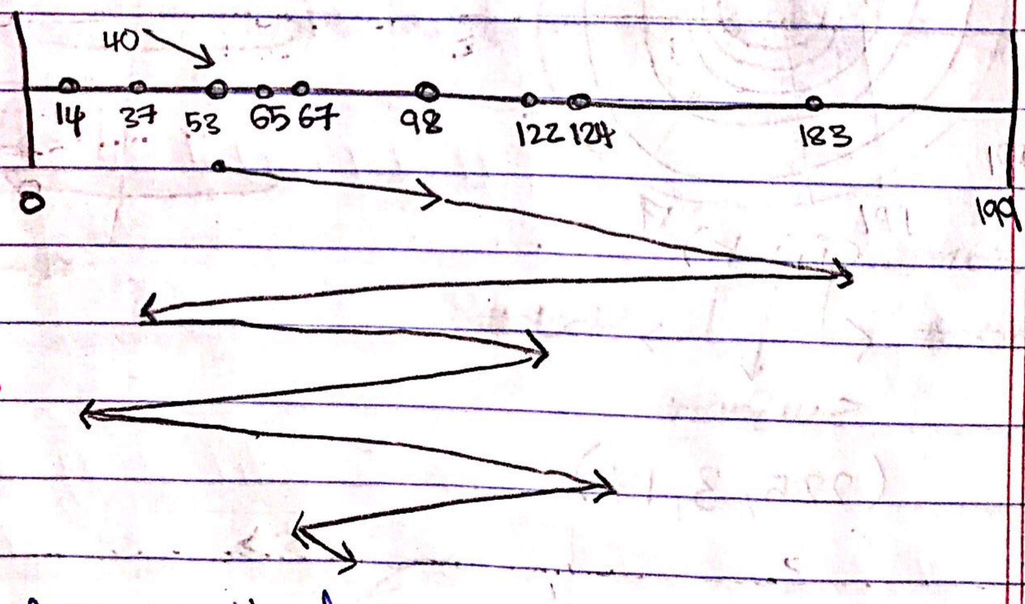
تعتمد ع سرعة الدوران

HD access time = Seek time + Latency time + transfer time.

We have no control

→ we could improve the seek time by selecting a good disk scheduling algorithm. (minimize seek time)

example: Assum HD has 200 tracks (0 — 199)
given the queue of HD requests as follows:
98, 183, 37, 122, 14, 124, 65, 67.
Assum the R/W head is currently serving a job at track 53 & just finished serving a ~~track~~ job at track 40.

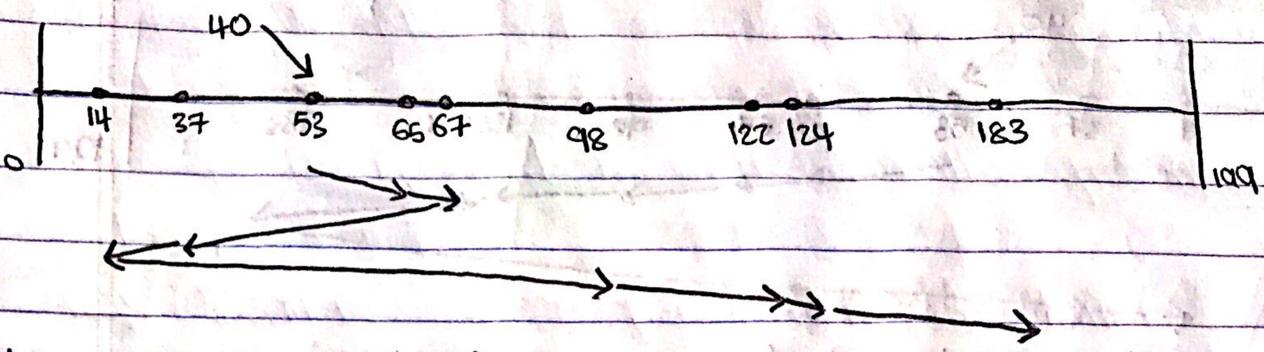


(1) FCFS

→ Average Head Movement =

$$\frac{(183-53)+(183-37)+(122-37)+(122-14)+(124-65)+(67-65)}{8}$$

(2) Shortest SeekTime First (SSTF)

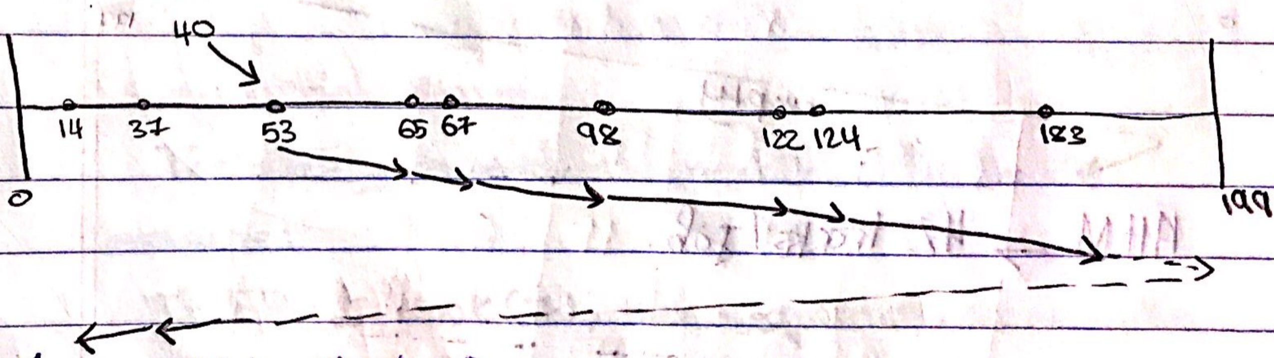


AHM → 29 tracks / Job.

SSTF gives the <u>optimum</u> solution
minimum

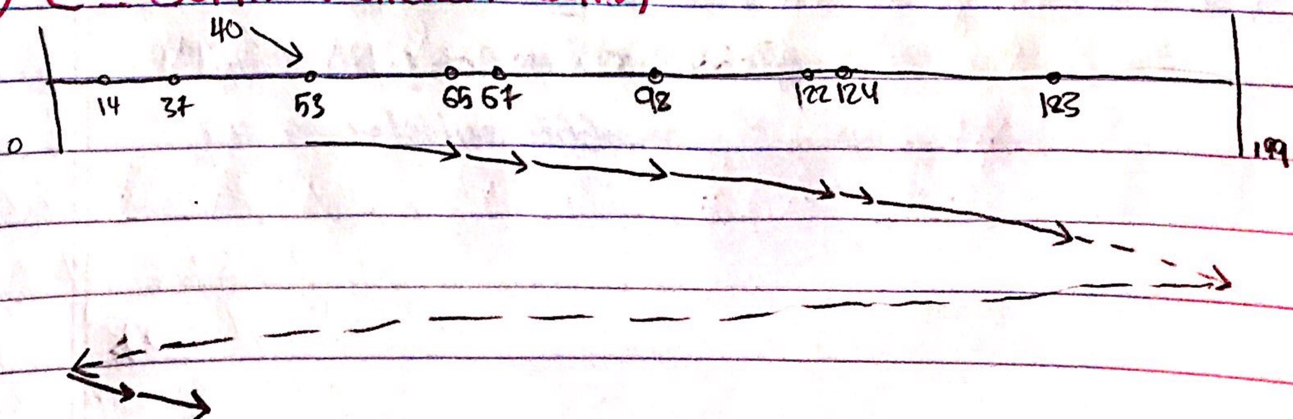
⚠ Problem: starvation

(3) SCAN (Elevator)



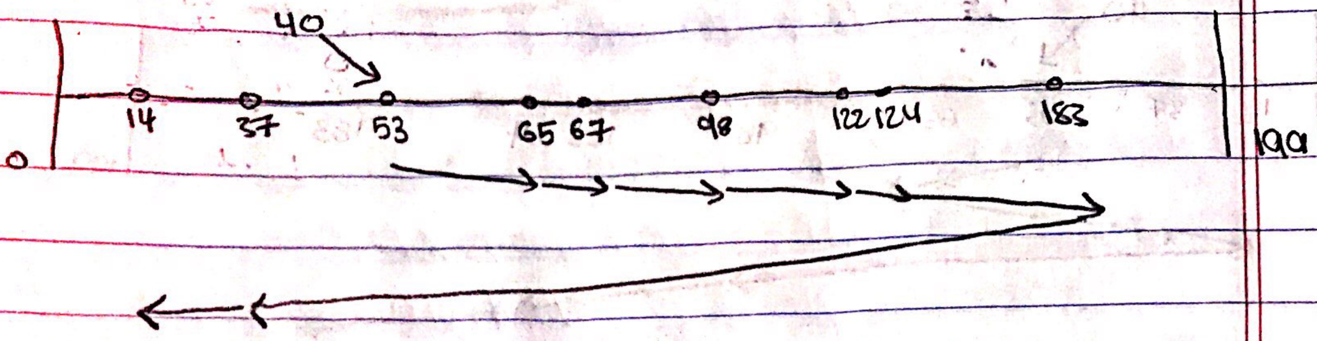
AHM → 41 tracks / Job.

(4) C_SCAN (Circular SCAN)



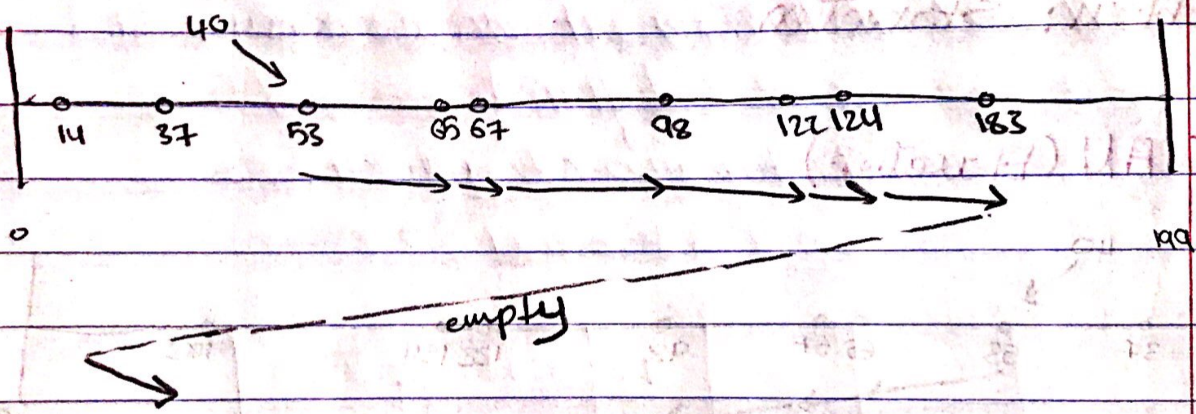
AHM → 47 tracks / Job.

(5) Look:

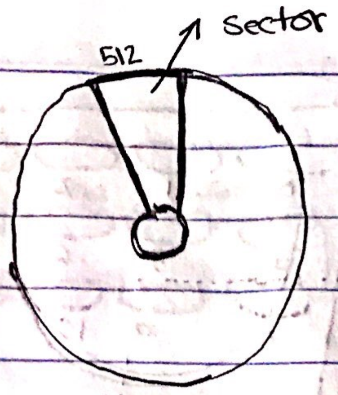


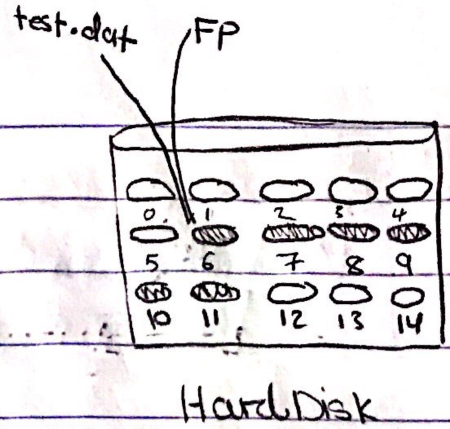
AHM → 37 tracks/job.

(7) C_Look:



AHM → 42 tracks/job.





File Access:

(1) Sequential Access.
(2) Direct Access.

- Location: Address of First block in the file (constant, can't be changed)
- File Pointer: The current location where the file is located.

→ **Sequential Access:**

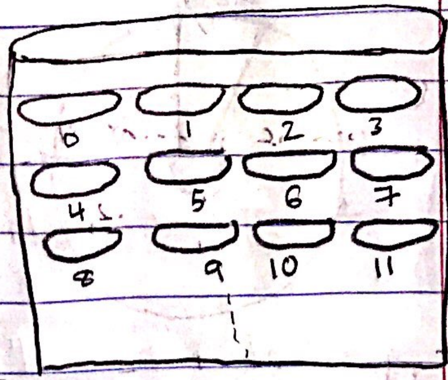
The ability to read the next Block in the file.

example:

If FP at Block (7), then sequential access is the ability to read/write Block (8).

→ **Direct Access:**

The ability to read/write Block # in the file:
(n is relative Address ‘رقم Block في الملف’



Allocation Methods:

How the disk blocks are selected and allocated for the file.

⚠ Note: Every storage device, has "device directory" which contains the information about the files stored on that device.

Generally, it's a "hash table".

Device directory

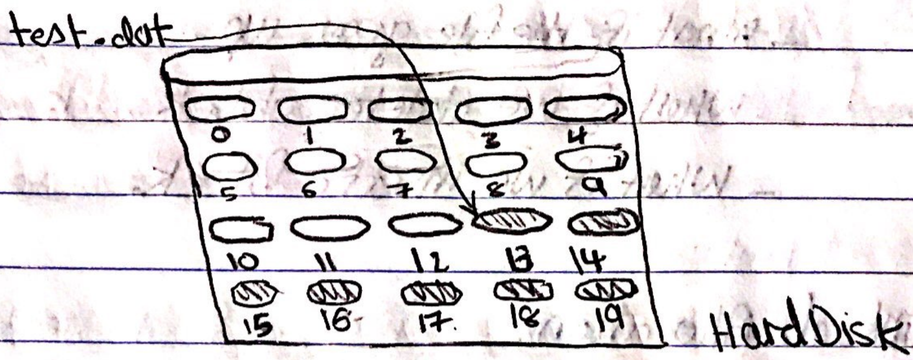
Name	Location	FP	Size	
sam.txt	11	11	6	
All files on the device				

(1) Contigious Allocation:

_ The OS selects contigious blocks of the file.

Device Directory

Name	Location	size	FP
test.dat	13	7	13



∴ Advantages:

It supports both sequential & direct access easily.

→ Sequential Access:

If FP at address X,

∴ The next block address is X+1.

→ Direct Access:

Assum we want to read block #5 (5 relative) in the file

The physical address of block #5 in the file = Location + 5 − 1 = 17

∴ To access Block # n,

PA = Location + n − 1

Disadvantages:

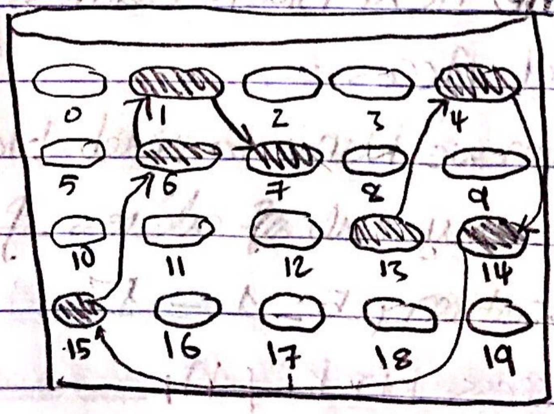
(1) Fragmentation (holes).
↳ Solution: Compaction (defrag).

(2) "Major Disadvantage"
- what if the file grows up.
- what if we delete a block.
- what if we insert a block.

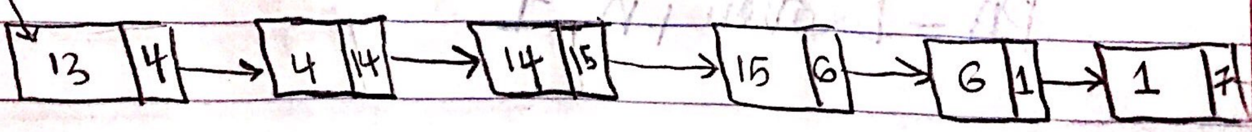
(2) Linked Allocation:

- The file blocks are selected as a linked list of blocks.

Name	Location	Size	
test.dat	13	7	



location



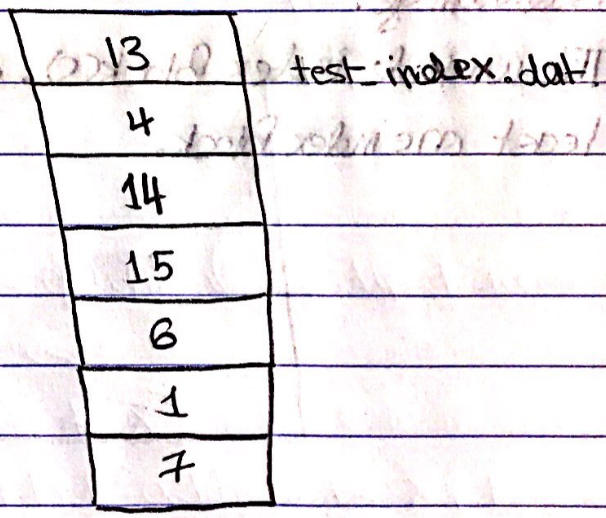
∴ Advantages:

No fragmentation

- File can grow, insert, delete as you like.

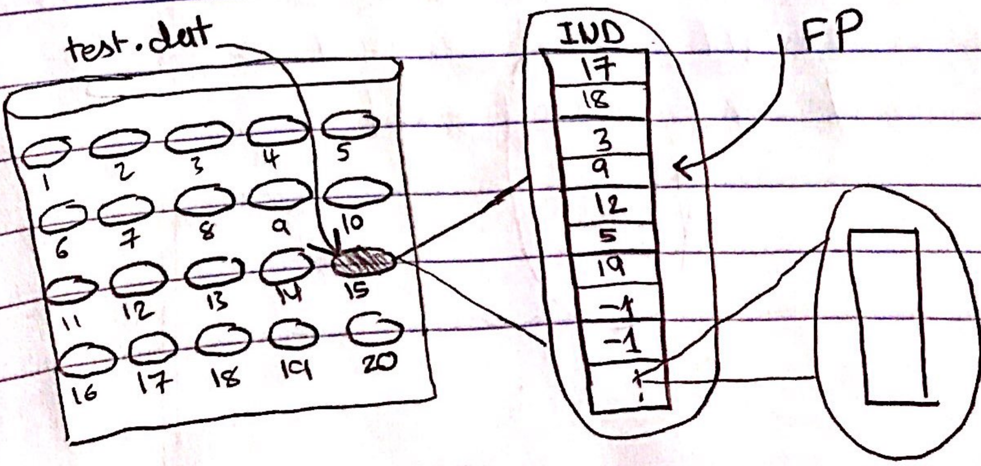
⚠ Disadvantage: "Major"

- It only supports Sequential Access easily.
- Direct Access isn't ~~so~~ supported & needs other tools such as an "index file".



(3) Indexed Allocation:

- Each file has at least one index block which contains the addresses of the file data blocks.



∴ Advantages:

It supports both sequential & Direct Access.

→ Sequential Access:

IF FP at IND[n];

next block address equals IND[n++];

→ Direct Access:

To access block # n in the file, its PA = IND[n].

⚠ Disadvantage:

The wasted index Block(s). each file needs at least one index Block.