COMPUTER SCIENCE

Computer Organization and Architecture

Secondary Memory

Lecture_01

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01 Updating Technique

02 IO Organization

Mapping Technique.

Replacement Algo

Multi Level Cache.

UPDATING Technique.

UPDATING Technique:

UPDATING Technique:

- CPU Perform Read & Write operation only on Cache Memory
- When the Data [myBlock] is available in Cache Memory then it is called Read Hit (OR) Write Hit.
- If Not Available in Cache, then it is called Read Miss & Write Miss then we have to perform Read allocate & Write Allocate.

UPDATING TECHNIQUE :

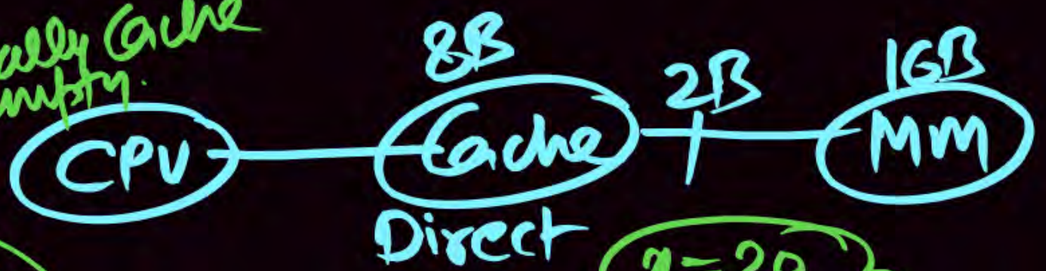
Read Allocate : When there is a Read Miss in a Cache then Copying (transfer) the Block from main memory to Cache Memory is called Read Allocate.

Write Allocate : When there is a Write Miss in Cache then Copying (transfer) the Block from main memory to Cache Memory is called Write Allocate.

Q. What is Read Miss, Write Miss, Write Hit ?

UPDATING TECHNIQUE :

Initially Cache is empty.



I_1 : MOV $R_1 \in$ [0000]

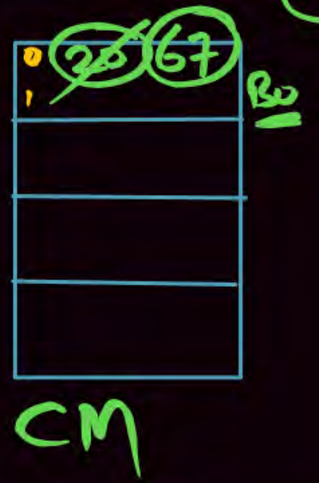
I_2 ADD R_1, #47

I_3 MOV [0000], R_1

Memory Read

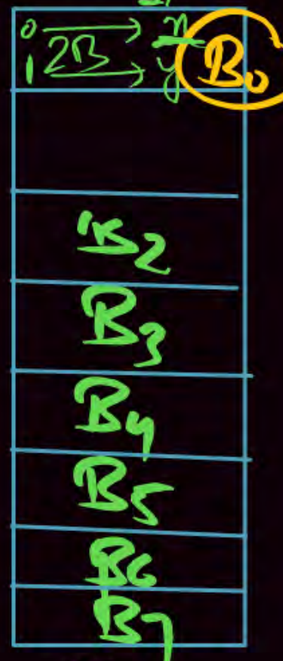
Memory write

firstly go the Cache memory



n = 20

000



Execution Sequence :

I_1 : [0000] Cache Cache Empty

$R_1 = 20$

Read Miss then Read Allocate

(then Bring the Data from MM to CM)

I_2 : $R_1 \in R_1 + 47 \Rightarrow R_1 \leftarrow 20 + 47 = 67$

$R_1 = 67$

I_3 : MOV [0000], R_1 ; $M(0000) \in R_1$; Cache Write Hit

$M[0000] \in R_1$

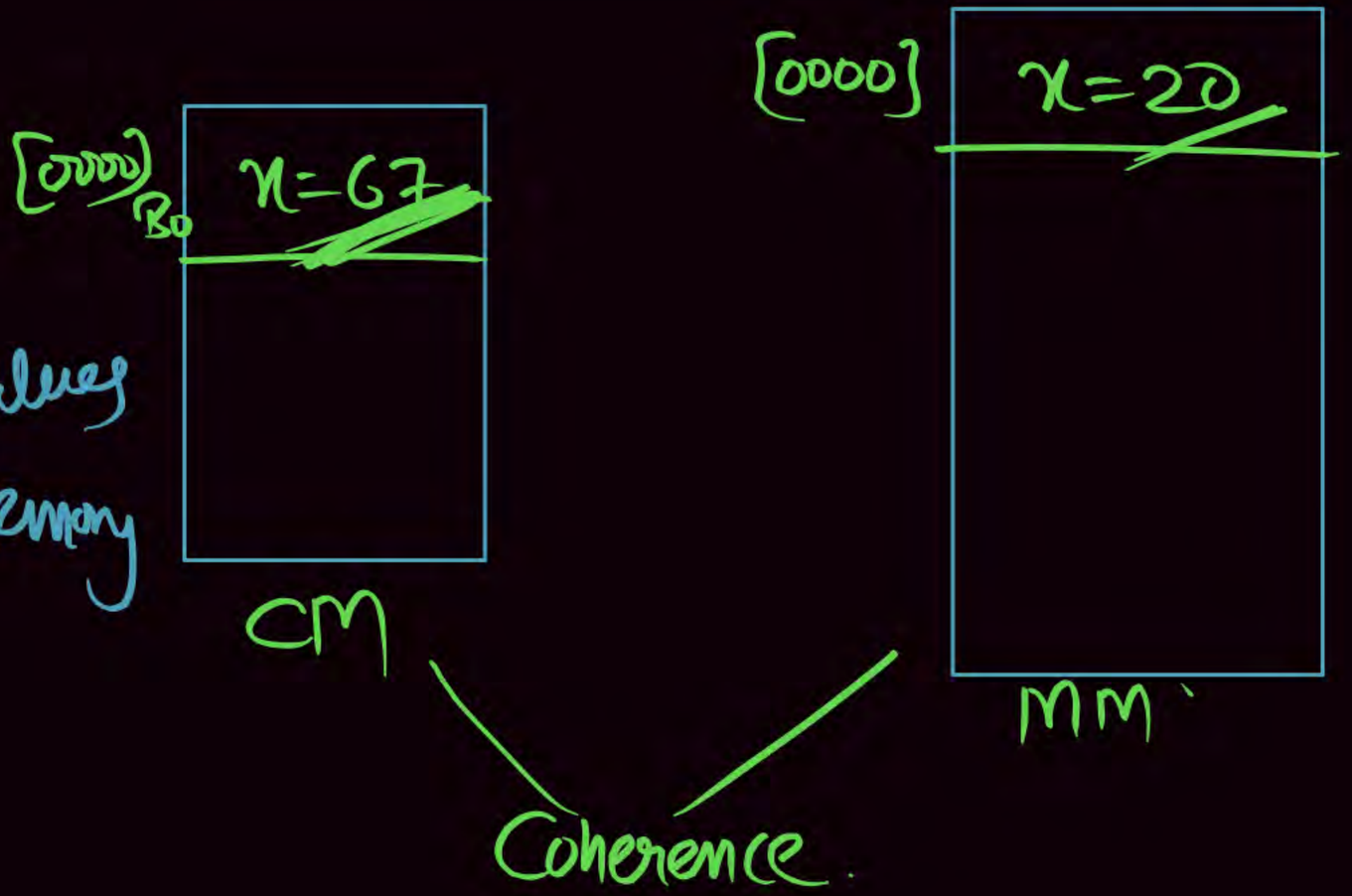
$M(0000) \in$ Cache (B0)

UPDATING TECHNIQUE :

Coherence :

Same address Contain

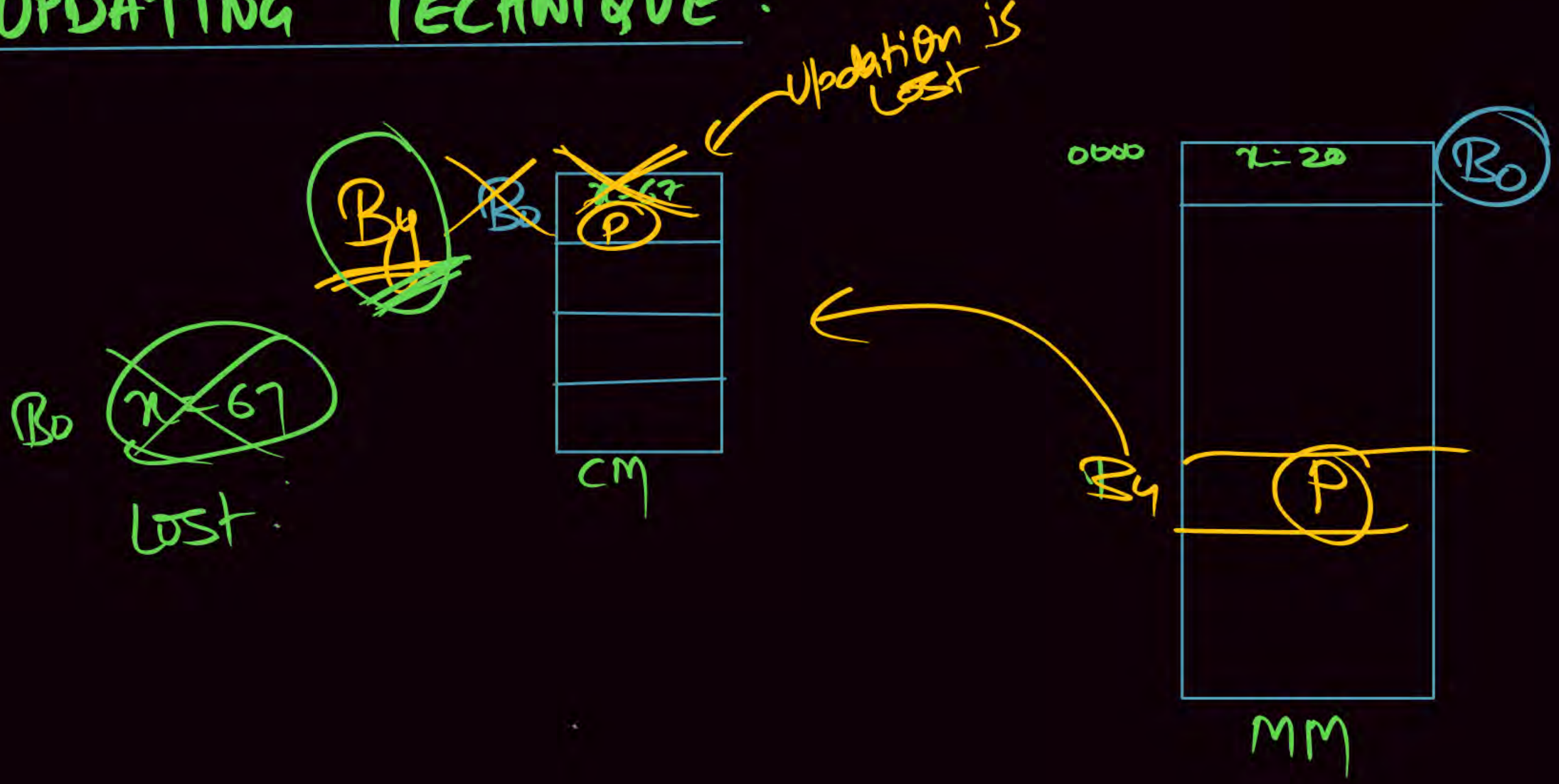
Different - Different Values in Main Memory & Cache Memory.



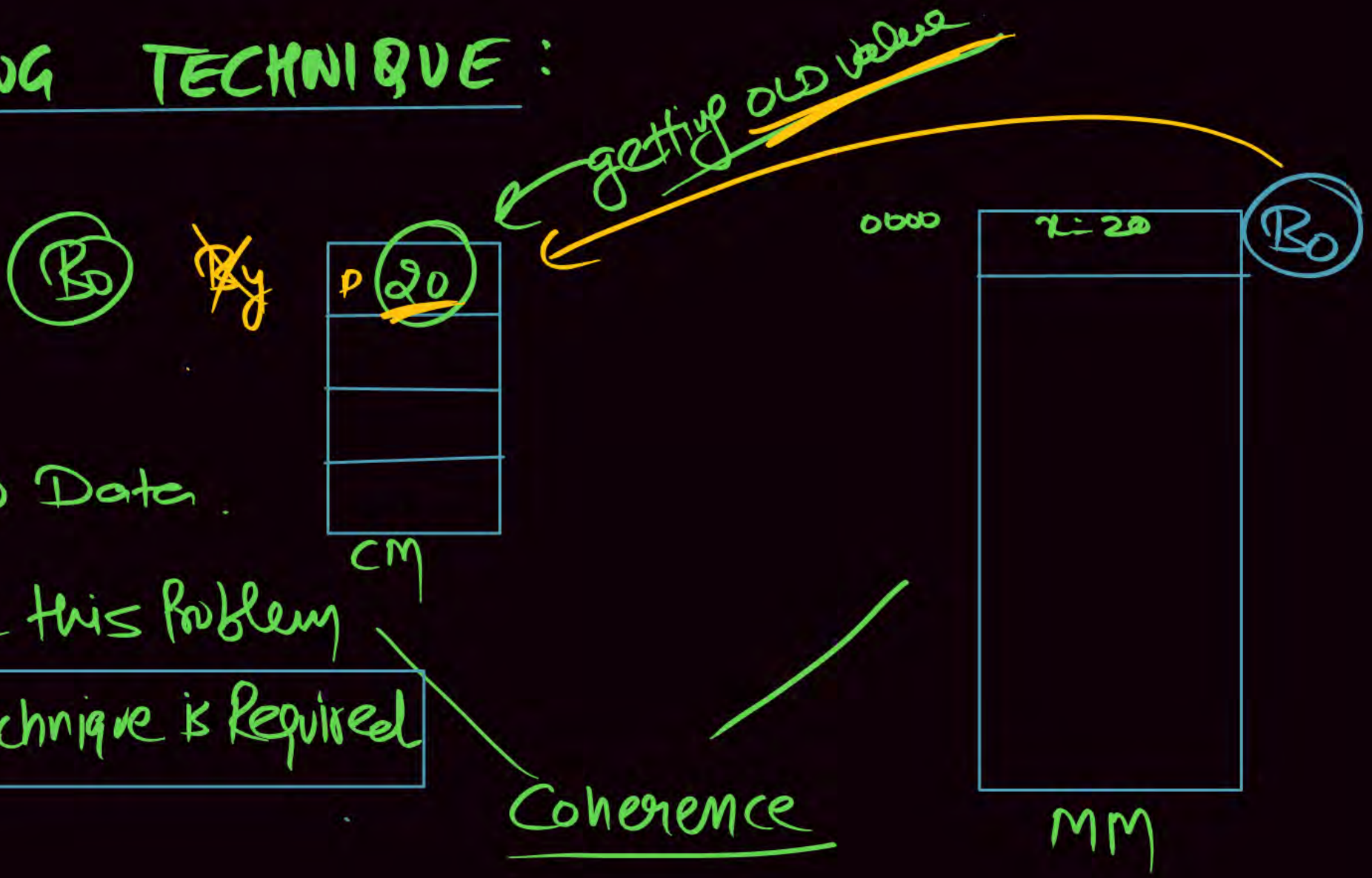
Q) WHY Updating Technique is Required ? Need ?

Soln) Assume in future there is Cache Miss for the Any Block which is Mapped to CM Line '0' then this updated Data is Replace by the New BLOCK (∵ All the Updation get Lost) that means whatever work done by CPU & Load in the Cache that Replaced by Any New Block so All the Updation get Lost & if in Future if we Bring Block B0 then get the OLD Value.

UPDATING TECHNIQUE :



UPDATING TECHNIQUE :



getting OLD Data.

So to Solve this Problem

Updating Technique is Required

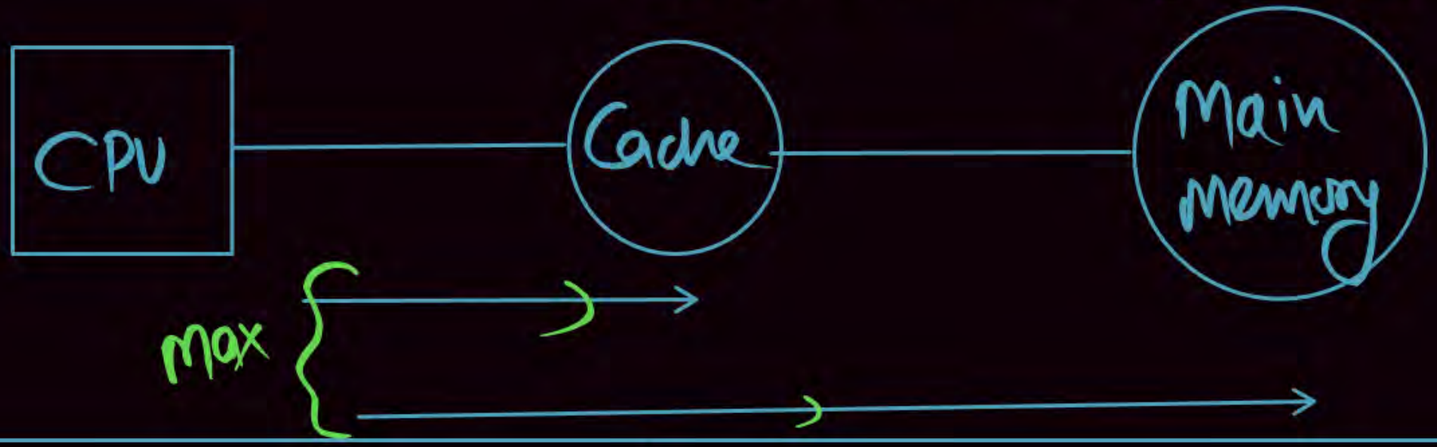
Coherence

① Write Through

② Write Back.

① Write Through [WT] : In the WT Both Cache Memory & Main Memory Update Simultaneously.

- No Coherence [No Inconsistency]



$$\left[\begin{matrix}\text{Word updation} \\ \text{Time}\end{matrix}\right] t_w = \text{Maximum}\left[\text{Updation time in Cache}, \text{Updation time in Main Memory}\right]$$

Read: Hierarchical

h_r: Read Hit Ratio.

$$T_{avg\,Read} = h_r * t_c + (1 - h_r)(t_m + t_c)$$

- h_r → Read Hit
- t_c → Read Data
- $(1 - h_r)$ → Read miss
- t_m → Read Allocate
- t_c → Read Data

$$T_{avg\,write} = h_w T_w + (1 - h_w)(t_m + t_w)$$

- h_w → Write Hit
- T_w → Word Updation
- $(1 - h_w)$ → miss
- t_m → Write Allocate
- t_w → Word Updation

$$T_{avg_{WT}} = \%\text{ of Read operation} \times T_{avg_{read}} + \%\text{ of write operation} \times T_{avg_{write}}$$

Disadvantage in WT :: for frequent updations in Cache, then give worst Performance.
(:: Every time Main Memory Access).

50 write operation
↳ 50 Times MM Access

Read: Simultaneous

$$T_{avg\,Read} = h_R * t_c + (1 - h_R)\,(t_m)$$

- h_R → Read Hit
- t_c → Read Data
- $(1 - h_R)$ → Read miss
- t_m → Read Allocate

h_R: Read Hit Ratio.

$$T_{avg\,write} = T_W$$

② Write Back (WB): In the Write Back, Only Cache memory Update, main memory Update Later. (in the WB, we Update Only in Cache memory

So Coherece is Present.

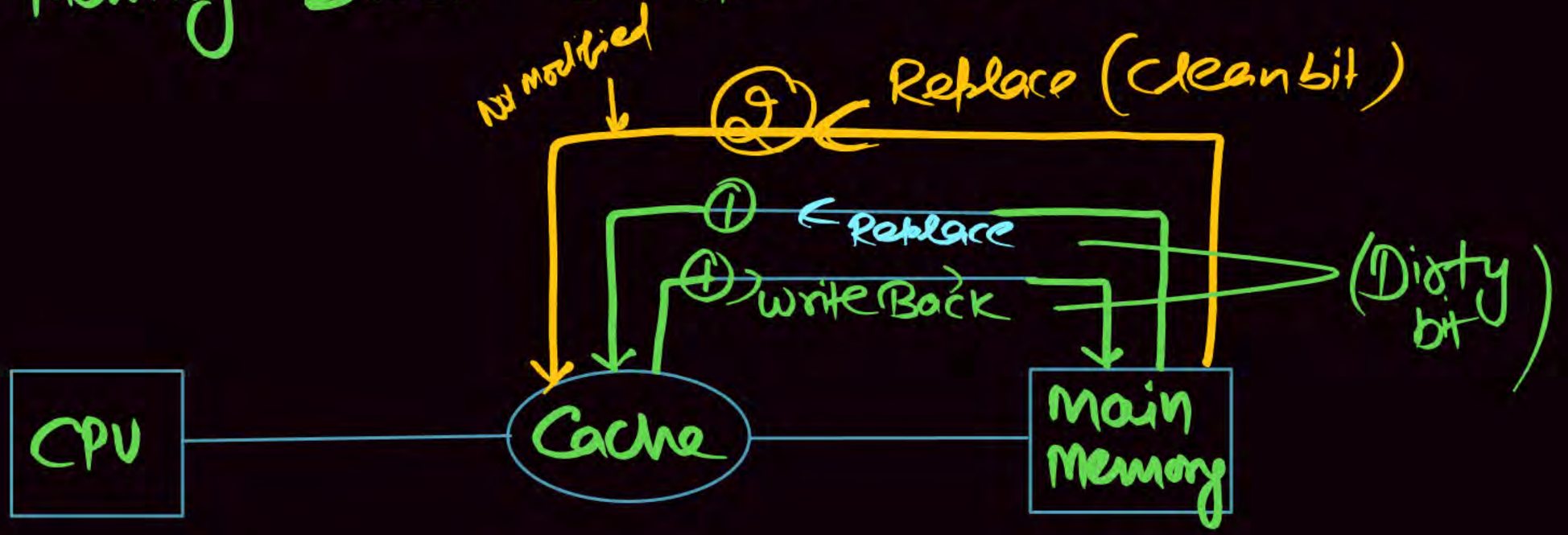
But Coherence does not Lost of Data Problem in WB Cache

Why ?

Because in write Back, Each Cache Line Maintain Some extra bit [Update bit / Dirty bit] to Maintain the Status of the CM Block.

- If Cache memory Block is Update then Dirty bit [modified bit] is Set to 1 [Dirty bit = 1 (Modified Data)].
- Before Replacing the Block we check the status of the Block
  - If Block is updated Block (Dirty bit set[1]) then first this Updated Block is write Back into Main Memory After the Replace with New Block.
  - If Block is Not Update [clean bit (set 0)] then Directly Replace with New Block.

If Cache memory Block is Updated block.



Dirty bit = 1

Data Modified
Dirty bit = 1

Not Modified
clean bit = 1

$$T_{avg_{read}} = h_r * t_c + (1 - h_r)\left\{\%\ \text{Dirty bit}\left[T_{wb} + T_m + T_c\right] + \%\ \text{clean bit}\left[T_m + T_c\right]\right\}$$

T_{wb} → Write Back Time; T_m → Read Allocate; T_c → Read Data; T_m → Read Allocate; T_c → Read DATA

$$T_{avg_{write}} = h_w * t_c + (1 - h_w)\left\{\%\ \text{Dirty bit}\left[T_{wb} + T_m + T_c\right] + \%\ \text{clean bit}\left[T_m + T_c\right]\right\}$$

T_{wb} → Write Back; T_m → Write Allocate; T_c → Write Data; T_m → Write Allocate; T_c → Write Data.

$$T_{avg_{WB}} = \%\ \text{of Read operation} \times T_{avg_{read}} + \%\ \text{of write operation} \times T_{avg_{write}}.$$

Q.

Let WB and WT be two set associative cache organizations that use LRU algorithm for cache block replacement. WB is a write back cache and WT is a write through cache. Which of the following statements is/are FALSE? [2022: MSQ 1M]

A. Each cache block in WB and WT has a dirty bit. → No Dirty bit

B. Every write hit in WB leads to a data transfer from cache to main memory. → False [Before Replace the Block, transfer the Data from C to M (Write Back) iff Dirty bit is set.]

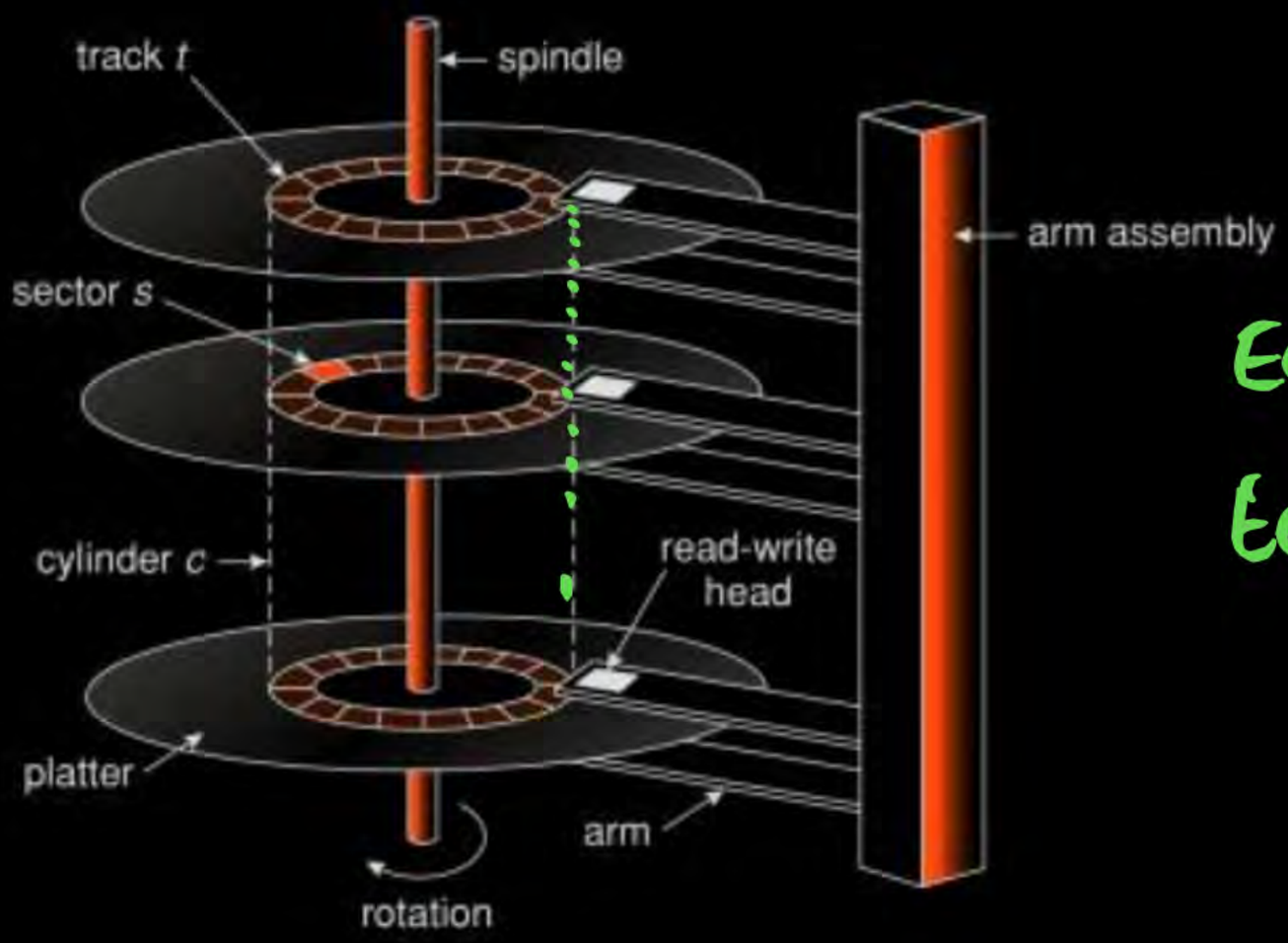
C. Eviction of a block from WT will not lead to data transfer from cache to main memory. → True. (Bcz Simultaneous Update)

D. A read miss in WB will never lead to eviction of a dirty block from WB. (Depends on Mapping function & Replacement Algo)

III GATE PYQ
Done.
Till Now.

Secondary Memory & IO

Moving - Head Disk Mechanism



Each Track 0 : form Cylinder 0

Each Track 1 : form Cylinder 1

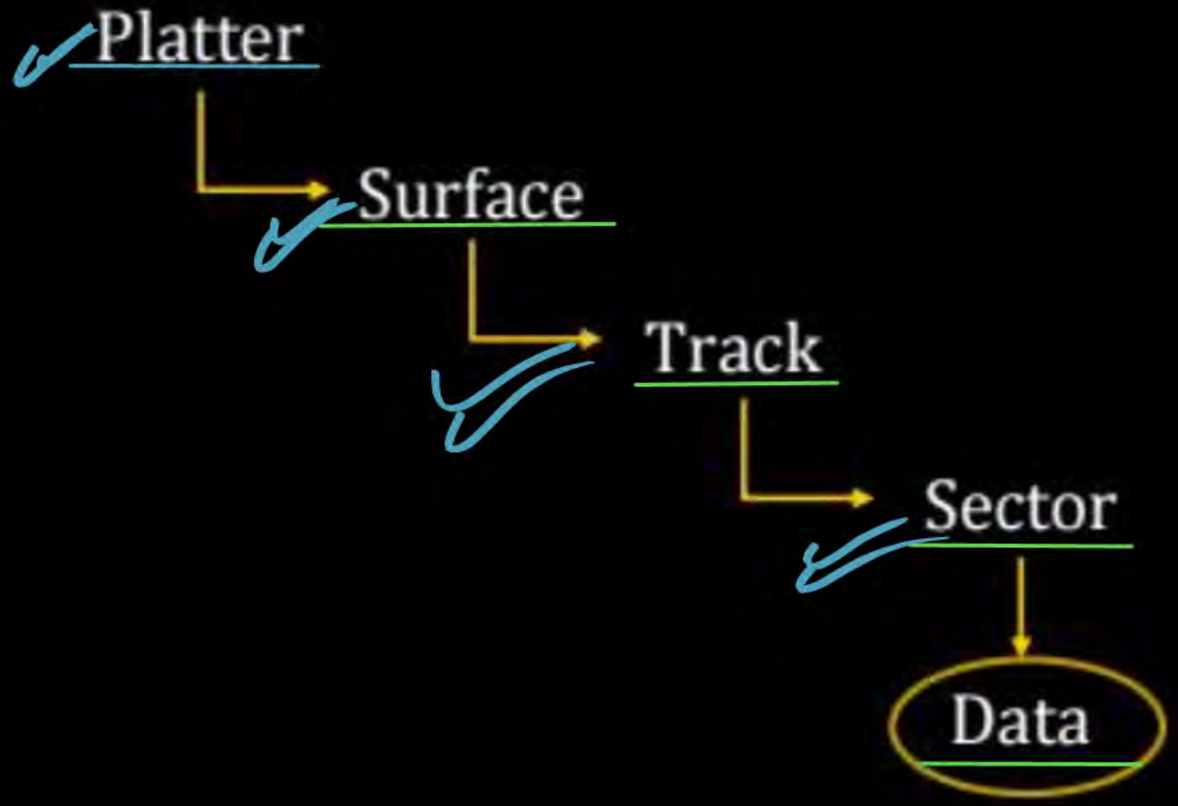
Magnetic disks provide the bulk of secondary storage for modern computer systems. Conceptually, disks are relatively simple.

Each disk platter has a flat circular shape, like a CD. Common platter diameters range from 1.8 to 3.5 inches.

The two surfaces of a platter are covered with a magnetic heads are attached to a disk arm that moves all the heads as a unit.

The surface of a platter logically divided into circular tracks, which are subdivided into sectors.

The set of tracks that are at one arm position makes up a cylinder. There may be thousand of concentric cylinders in a disk drive, and each track may contain hundreds of sectors. The storage capacity of common disk drives is measured in gigabytes.

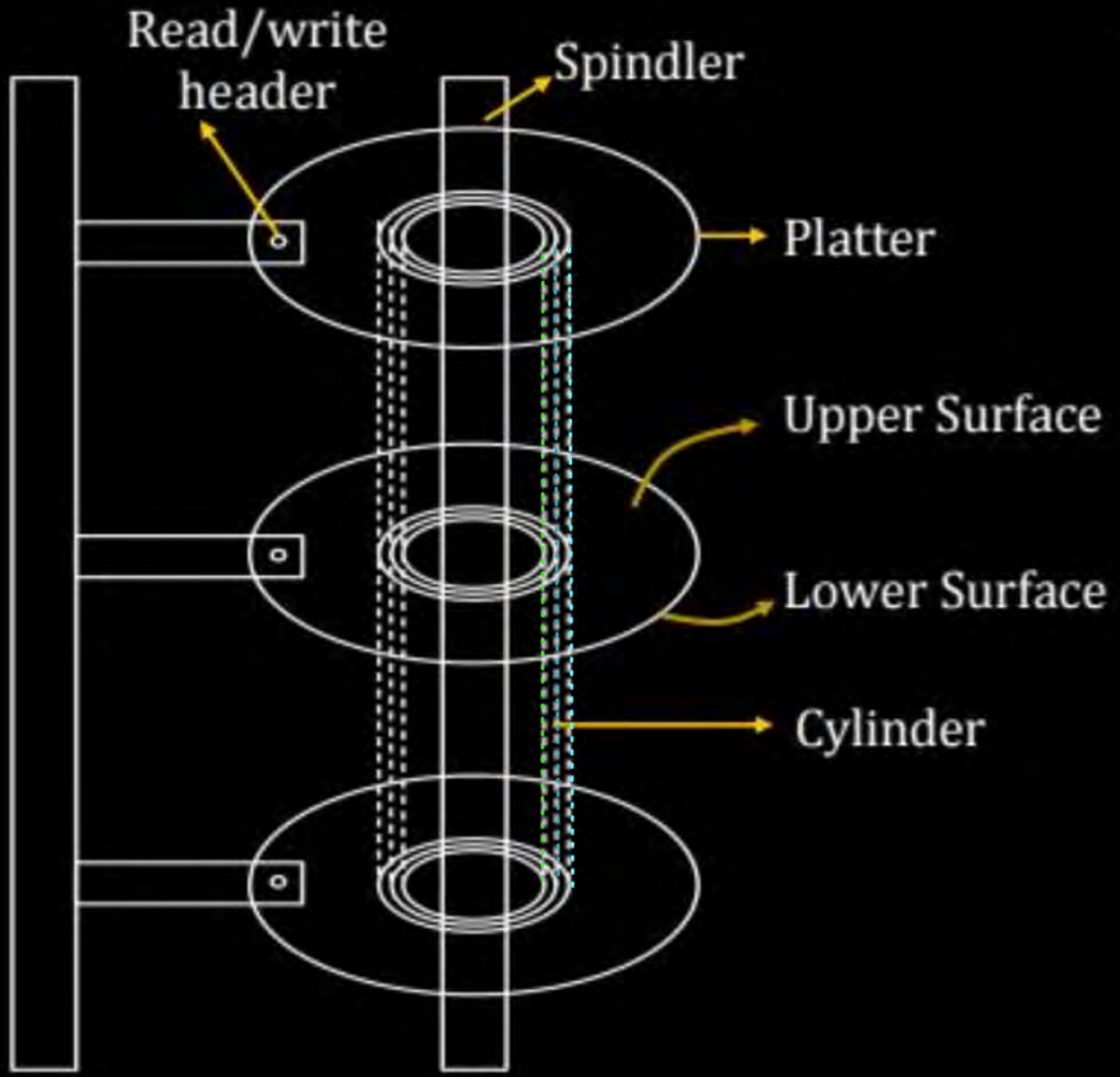


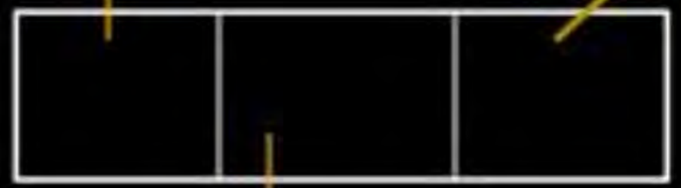
Cylinder: Same Track of each Platter.

Cylinder 0: Track Number '0' of each Platter.

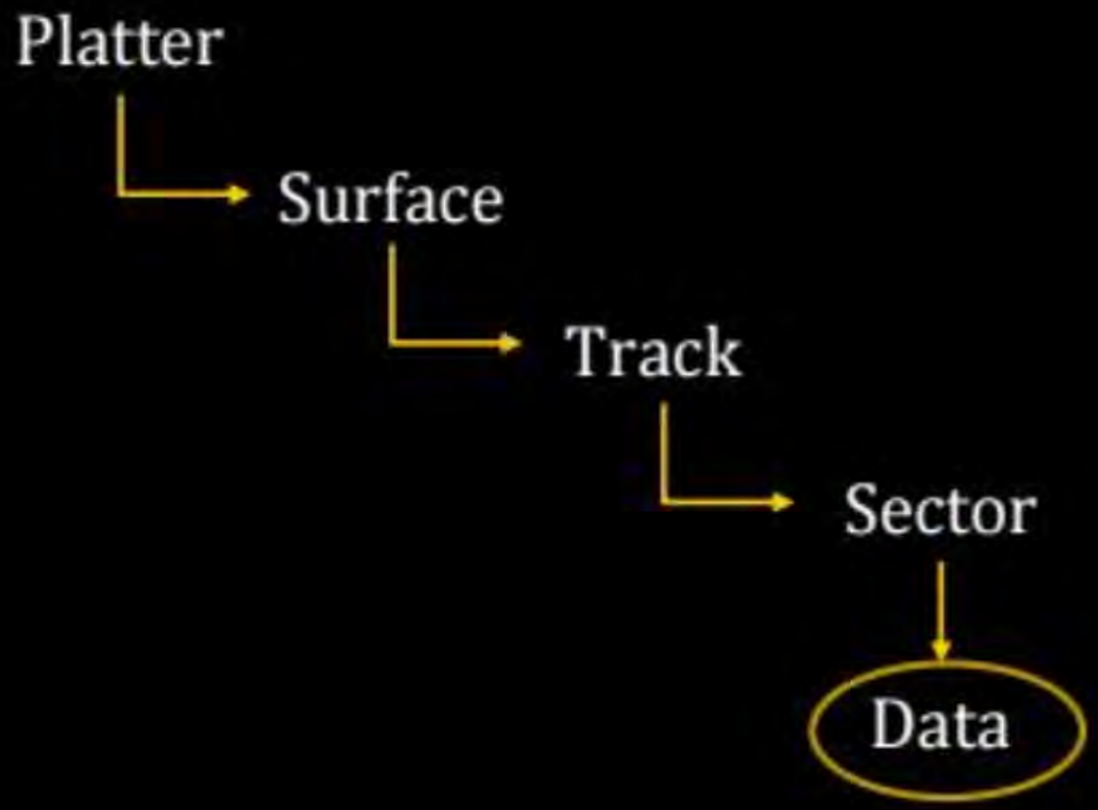
Cylinder 1: Track Number 1 of each Platter

Disk - structure





Sector
Or
Disk Block


Platter
Surface
Track
Sector
Data

Q. Consider a disk which has 16 platter, each platter has two surface. Every surface has 1K Track is further Divided into 512 sector and every sector can store the 8KB Data, then calculate.

(i) What is the capacity of Disk?

(i) How many bits are required to identify any particular sector of the Disk?

① Capacity

② S.T + R.L + D.T.T + Overhead.

③ Sector Addressing <C, h, S>

16 Platter, Each Platter has 2 Surface.

Total Surface = 16 × 2 = 32 Surface

Each Surface has = 1K Track

32 Surface ⇒ 32 × 1K ⇒ 32K Track

Each track 512 Sector

Total Sector = 32K × 512

Each Sector Capacity = 8KB

= 32K × 512 × 8KB ⇒ $2^5 \times 2^{10} \times 2^9 \times 2^{13}$

$= 2^{37}$ Byte

2^{37} B ⇒ 128 GB

Solution (i) 1 platter - 2 surface

16 platter - 16×2 i.e. 32 surface

1 surface - 1K Track

32 surface - $32 \times 1K$ track $\Rightarrow$ 32K Track

1 track - 512 sector

32k Track $\Rightarrow$ $32K \times 512$ sector

Each sector capacity $\Rightarrow$ 8KB

Total Disk capacity $= 32k \times 512 \times 8KB$

$= 2^5 \times 2^{10} \times 2^9 \times 2^{13} \Rightarrow 2^{37}$ B

Disk capacity = 128 GB

(ii) #bits required to represent sector in a disk

$= 16 \times 2 \times 1k \times 512$

$= 2^4 \times 2^1 \times 2^{10} \times 2^9 \Rightarrow 2^{24}$ = 24 bits

Q. Consider a disk pack with 16 surfaces. 128 tracks per surface and 256 sectors per track. 512 bytes of data are stored in a bit serial manner in a sector. The capacity of the disk pack and the number of bits required to specify a particular sector in the disk are respectively

(a) 256 Mbyte, 19 bits
(b) 265 Mbyte, 28 bits
(c) 512 Mbytes, 20 bits
(d) 64 Gbyte, 28 bits

[GATE - 2007]

$16 \times 128 \times 256 \times 512$

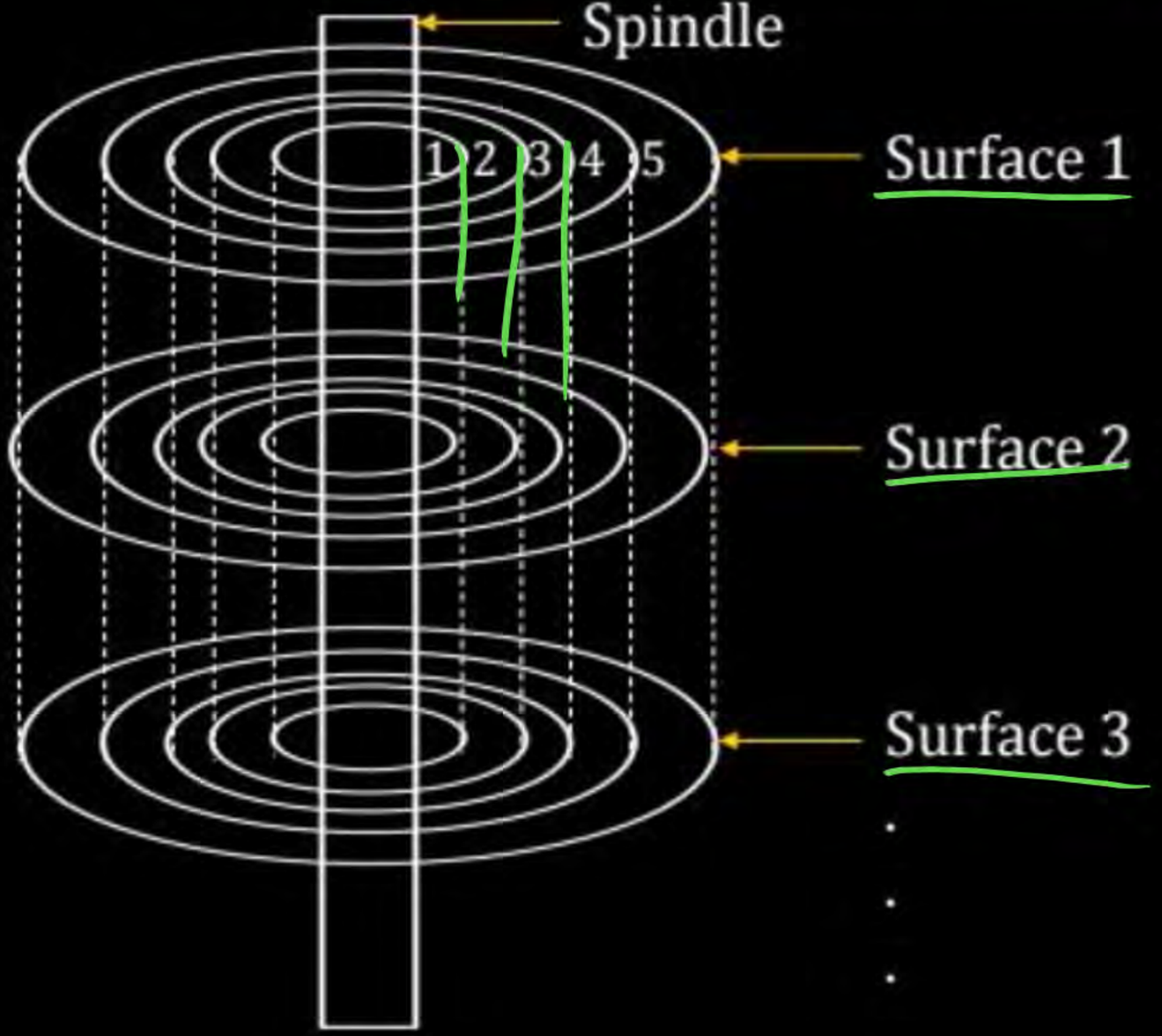
$2^4 \times 2^7 \times 2^8 \times 2^9 B$

$2^{28} \Rightarrow 256$ MByte

$2^4 \times 2^7 \times 2^8 = 2^{19}$

$= 19$ bit

Same track number in all the surface will form a cylinder.



cylinder in the disk = # track, in the surface

Track capacity = # sector/tracks * # Bytes / sector

each sector Capacity

Cylinder capacity = # surface in the disk * track capacity

Disk capacity = # cylinder in the disk * cylinder capacity

To access the data from the hard disk different adjustments are required in the hard disk so, the associative adjust latencies are -

(1) Seek time [S.T]

(2) Rotational time [R.L]

(3) transfer time [D.T.T]

Disk I/O operation

- Seek time → One track to other track
- Rotational Latency → Sector ⇒ R.L = 1/2 X Rotation Time
- Transfer time
- Transfer rate ⇒ In 1 Sec ⇒ How Much Data transferred.
- The read / write header can never be outside the track it will be pointing to any particular track of the surface.
- read / write header will be move in forward & backward direction & disk in one direction (either clockwise or anti-clockwise)

1) Seek time: The amount of time taken to move the read / write header from its current position to the desired track is called as seek time.
2) Rotating Latency: The amount of time taken to relate the track when the read / write header comes to exact position (sector)

The Rotation Latency is considered as $= \frac{1}{2}$ Rotation time

3) Transfer time: The amount of time taken to transfer the required data. (Byte)
4) Transfer rate: The number of bytes found for unique line is called as transfer rate of disk. (In 1 sec).

Q Assume 1 Track Capacity = 4KB & 1 Rotation time is $\frac{1}{6}$ sec.

Data transfer time & Data transfer Rate ?

Data Transfer time

4KB ⟶ $\frac{1}{6}$ sec

1 Byte ⟶ $\frac{1}{6 \times 4k}$ sec.

x Byte ⟶ $\frac{x \text{ Byte}}{6 \times 4k}$ sec

Data transfer Rate.

In One Rotation One Complete track Traversed

4KB ⟶ $\frac{1}{6}$ sec (1 Rotation)

In $\frac{1}{6}$ sec ⟶ 4KB.

In 1 Sec ⟶ 4KB x 6 ⇒ 24KB Per Sec

Data transfer Rate.

$$\text{Disk Access} = S.T + R.L + D.T.T + \text{Overhead (if given)}$$

Q. Consider a disk system, which has an average seek time of 30 ns and rotational rate of the disk is 360 RPM. Each track of the disk has 512 sector, each of the size 512 Byte, then calculate.

(i) Average Seek time

(ii) Average rotational latency → 1/12 sec

(iii) data transfer time for 4 sector (continuous)?

(iv) Data transfer rate? → 1536 KBPS

360 RPM

360 Rotation Per minutes (60 sec)

1 Rotation = $\frac{60}{360} = \frac{1}{6}$ sec.

Rotation latency $= \frac{1}{2} \times$ Rotation time

$= \frac{1}{2} \times \left(\frac{1}{6}\right)$

$R.L = \frac{1}{12}$ sec

1 Track Capacity = #sector/track × Each sector Capacity

512×512 Byte

$\Rightarrow 2^9 \times 2^9$ Byte $= 2^{18}$ B

$= 256$ KByte

256 KB —— $\frac{1}{6}$ sec

$\frac{1}{6}$ sec —— 256 KB

In 1 sec $\Rightarrow 256 \times 6$

$= 1536$ KBPS

(i) Seek time = 30 ns = 30×10^{-9} sec

(ii) Rotational Latency ⇒ 360 rotation = 60 second

$$\frac{1}{2} \text{ rotation} = \frac{1/2 \times 60}{360} = \frac{1}{12} \text{sec}$$

R.L = 0.083 sec.

(iii) Transfer time ⇒ In one rotation time, we can read the total size of the track & to read the required data how much time is required?

1RT = we can read total size of data

? = To read required data.

Rotation time = 1/6 second

Total size of 1 track = $2^9.2^9$ B ⇒ $2^8.2^{10}$ B = 256 KB

Required data = 4 sector

= $2^2.2^9$ B ⇒ $2^1.2^{10}$ B = 2KB

256KB —— 1/6 sec

1B — 1/(6X256KB)

2KB / (6X256KB) sec

1 Track

256 KB $\rightarrow$ 1/6 sec

1B = 256 KB $\rightarrow$ 1/6 second

2 KN $\rightarrow \frac{1/6 \times 2KB}{256KB} =$ 0.0013 sec

(iv) Data transfer rate

In one rotation time $\rightarrow$ we can transfer total size of the track.

In one sec $\rightarrow$ how much data we will transfer

$\frac{1}{6}$ sec $\rightarrow$ 256 KB

1 second $\rightarrow \frac{256KB \times sec \times 6}{sec} =$ 1536KBPS

MCQ

An application loads 100 libraries at start-up. Loading each library requires exactly one disk access. The seek time of the disk to a random location is given as 10 ms. Rotational speed of disk is 6000 rpm. If all 100 libraries are loaded from random locations on the disk, how long does it take to load all libraries? (The time to transfer data from the disk block once the head has been positioned at the start of the block may be neglected.) D.T.T is Negligible.

[GATE-2011-CS: 2M]

A 0.50s

B 1.50s

C 1.25s

D 1.00s

S.T = 10 msec

6000 Rotation in 60 sec

1 Rotation = $\frac{60}{6000}$ = $\frac{1}{100}$ sec $\times \frac{10^3}{10^3}$ = 10 msec

R.L = $\frac{1}{2}$ x 10 msec = 5 msec

D.A.T for L Library = S.T + R.L + D.T.F + overhead

= 10 + 5 = 15 msec

for 100 Library = $15 \times 10^{-3} \times 100$

= 1.5 Sec.

NAT 1

Consider a disk pack with a seek time of 4 milliseconds and rotational speed of 10000 rotations per minute (RPM). It has 600 sectors per track and each sector can store 512 bytes of data. Consider a file stored in the disk. The file contains 2000 sectors. Assume that every sector access necessitates a seek, And the average rotational latency for accessing each sector is half of the time for one complete rotation. The total time (in milliseconds) needed to read the entire file is ____.

[GATE-2015(Set-1)-CS: 2M]

NAT ②

Consider a typical disk that rotates at 15000 rotations per minute (RPM) and has a transfer rate of 50×10^6 bytes/sec. If the average seek time of the disk is twice the average rotational delay and the controller's transfer time is 10 times the disk transfer time, the average time (in milliseconds) to read or write a 512-byte sector of the disk is _____.

[GATE-2015(Set-2)-CS: 2M]

Q.

If the disk is rotation at 3600 rpm, determine the effective data transfer rate which is defined as the number of bytes transferred per second between disk and memory. (Given size of track = 512 bytes)

[GATE-: 2 Marks]

Q. A hard disk system has the following parameters:
Number of tracks = 500
Number of sectors/track = 100
Number of bytes/sector = 500
Time taken by the head to move from one track to adjacent track = 1 ms Rotation speed = 600 rpm
What is the average time taken for transferring 250 bytes from the disk?

[GATE 2007-: 2 Marks]

A 300.5 ms

B 255.5 ms

C 255 ms

D 300 ms

THANK YOU!