

# Operating Systems

- Applications have to interact with operating system to get things done.

- services :-

- Resource management

- Abstraction

- protection

- abstracts the hardware using system calls

- one app doesn't impact the other.

- allocates CPU's time to different processes.

- User**

- Applications (chrome)

- Operating system (win),

- Hardware

- windows  
linux  
macos  
Android  
ios .

## Types of operating system

### 1) single tasking → MS-DOS (Inefficient)

- one process is there in a RAM & running

### 2) Multiprogramming & Multitasking

- during computations process is assigned to the CPU

- during I/O it's unassigned & assign some other process .

- multitasking is an extension of multiprogramming where process runs in time slots

### 3) Multithreading

- using different threads for different processes

- smallest unit of execution .

### 4) Multiprocessing

- multiple processeses in the & available

## Multithreading

→ Downloading  
browsing in  
browser and  
browsing

multiple things  
run on a process.

### Example :-

word processors → saving, typing, formating,  
spell checking etc.

IDE's → games etc

### Disadvantages of multithreading

- ↓ Difference in writing, testing.
- ↓ Deadlock and race conditions
- same resource is used by two threads.



### Threads v/s processes

process → code, data, files, heap, stack etc

thread → stack



shared all the  
others by all threads

## Threads are

- ↓ faster to create/terminate
- ↓ multiple threads in a process
- ↓ share address space
- ↓ easier to communicate
- ↓ context switching is equal.

↓ threads are lightweight

↓ consume less resources

### User Threads v/s Kernel Threads

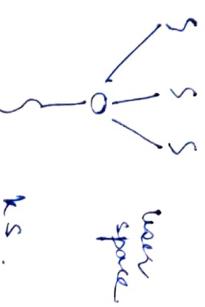
- in user space
- context switching faster
- one thread might block another thread.
- cannot take advantage of multicore system.
- creation is fast
- in kernel space
- context switching slow
- a thread blocks user only
- take full advantage of multicore system.
- slow

### Mapping of user threads to kernel threads.

#### one to one



#### many to one



#### many to many

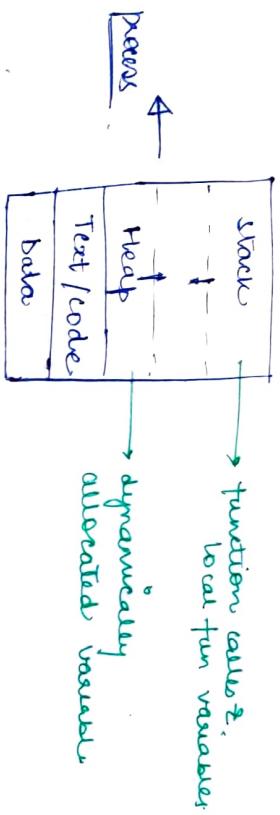
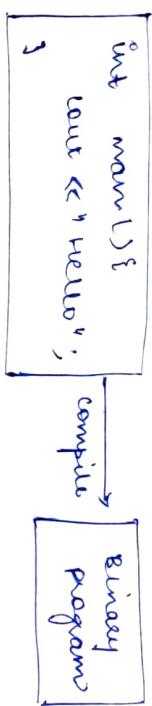
## multitasking

- ↓ partitioning
- to music
- ↓ browsing web

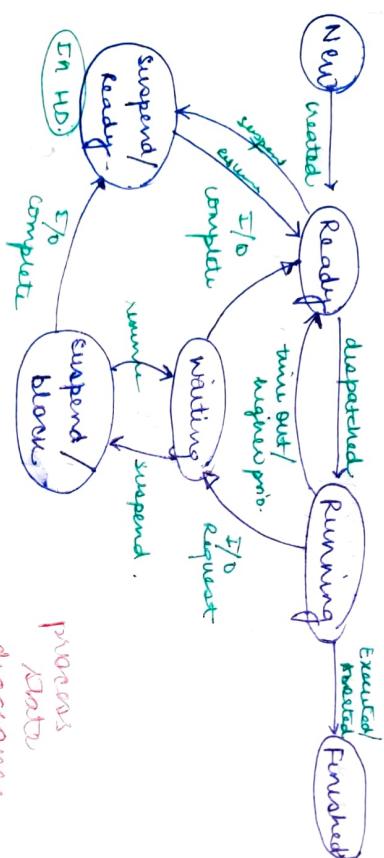
### processes

### running

Program → set of instructions to perform a task



### process states



### Process Control Block

- OS has to store all the variables and state of process before stopping it.

For this we use PCB process control block.

- 1) process ID
- 2) process state
- 3) CPU registers
- 4) Accounts information

- 5) I/O information
- 6) CPU scheduling information
- 7) memory information

- 1) Long-term scheduler → which brings the process from disk to RAM. (To ready state)
- 2) short term scheduler
- 3) medium term scheduler

medium term process from ready state to running state.  
(Dispatcher)

- The additional two states were managed by this suspend block & suspend ready.

### background of scheduling algorithm (short term scheduler)

- different queues

→ ready queue

- short term scheduler and dispatcher uses context switch and maintains ready queue.

- when in a process picked by the scheduler.

- (a) when some other process moves from running to waiting

- (b) when some other process moves from running to ready

- (c) when a new / exist existing process move to ready

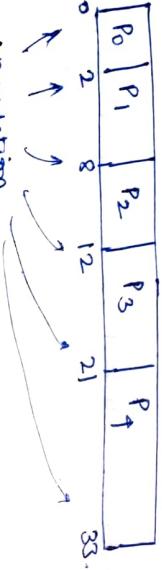
- (d) when process terminates.

- Arrival time
- Completion time
- Burst time
- sum of CPU time
- sum of ready time
- sum of waiting time
- Turn around time = start time - arrival time
- Waiting time → time spent in ready queue
- Response time (diff b/w arrival time & first turn time)
- TAT = Burst time

## Expectations from scheduling algorithms

- Max CPU utilization
- Max throughput
- Min turnaround time
- Min waiting time
- Fair CPU allocation

## FCFS scheduling algorithm (Non-preemptive)



process	Arrival time	Burst time
P <sub>0</sub>	0	2
P <sub>1</sub>	2	4
P <sub>2</sub>	6	4
P <sub>3</sub>	10	5
P <sub>4</sub>	15	8

turnaround  $\rightarrow$  completion time - arrival time

waiting time  $\rightarrow$  turnaround - burst

throughput offset  $\rightarrow$  one CPU bound process

2 many I/O bound process

↑ create big waiting queues

## shortest job first (SJF)

process      arrival time      burst time      comp time

process	arrival time	burst time	comp time
P <sub>0</sub>	0	5	5
P <sub>1</sub>	4	12	11
P <sub>2</sub>	2	3	6
P <sub>3</sub>	3	8	12



## Priority scheduling

process	arrival	priority	burst
P <sub>0</sub>	0	5	3
P <sub>1</sub>	1	3	5
P <sub>2</sub>	2	2	15 (1H)
P <sub>3</sub>	3	1	8



## PREEMPTIVE

## non-preemptive

- \* minimum average waiting time
- \* may cause high waiting and response time for CPU bound jobs.

## FCFS scheduling algorithm (Preemptive)

process	Arrival time	Burst time
P <sub>0</sub>	0	2
P <sub>1</sub>	1	5
P <sub>2</sub>	2	4



## preemptive

## shortest remaining job first (SRJF)

starvation of low priority

→ ageing → increase the priority with their age

### Round Robin scheduling (Preemptive)

→ time quantum

circular queue (ready queue)

→ avg waiting time can be higher but good response time

process Arrival Burst

$P_0$  0 2 2 1

$P_1$  1 1 1

$P_2$  1 1 1

time quantum  
 $\equiv 2$

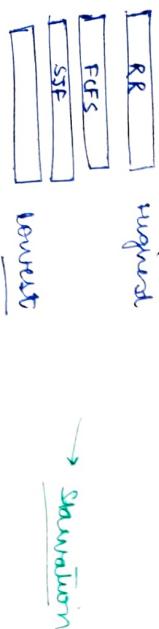


sensitive to time quantum  
small  
longer  
context switch overhead becomes FCFS

### Multilevel queue scheduling

→ have different queues and apply different scheduling algorithms on them

→ we can have priority queues where CPU is awarded among queues on the basis of priority

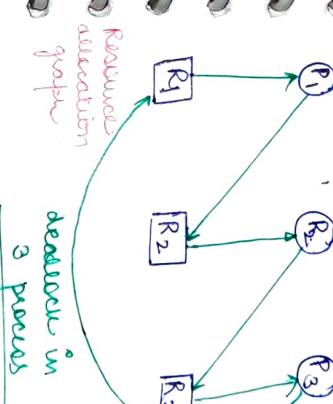


multilevel queue with feedback  
process should be allowed to switch between queues



### DEADLOCK

→ happen when resources are non-shareable.

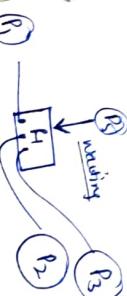


Process P1 is waiting for non-shareable resource R1 and it is waiting for other NS resource.

### necessary conditions

- mutual exclusion → resources are non-shareable
- hold and wait → processes must be in hold & wait i.e. holding one or more resources & waiting for others
- wait and wait → processes are waiting in mutual manner
- no preemption → resources can't be taken back by OS in the middle of process

these might be multiple instances of a resource



## Deadlock prevention methods

### 1) Deadlock prevention

- prevent one of the four necessary condition for deadlock by assigning some rules • OS grant all the request but requests are sent in a way that they never cause deadlock.
- deadlock avoidance
- OS has to decide whether a request can be granted or not.

Ex - banker's algorithm

### 2) Detection and Recovery

- OS periodically runs a job and check "if all the happened, is it was it in recovered. by killing our process."

### 3) Ignore the detection

- simply ignore the deadlock.

## Deadlock prevention

prevent / eliminate one of the following

four

- mutual Exclusion
- hold and wait

### posting

- instead of sending a wait request processes are put in a job queue.
- a process can tell in adv. what process it needs (impossible)
- or process while requesting for a resource must release all the resources used by it

### 3) NO preemptive

#### resources

- unpractical as the process might be hindered of execution and suddenly OS takes away the resources

## Req: Deadlock Avoidance

### Allocated

### Mark

### Available

### Mark

P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	R <sub>0</sub>	R <sub>1</sub>	R <sub>0</sub>	R <sub>1</sub>
0	0	1	7	5				
1	2	0	3	2				
3	0	0	9	0				
0	1	2	2	2				
0	0	4	3					

### Basic check

- total allocation is not more than maximum available
- resources are available or not

Ex → <4,3> are available R.N.

- OS assumes that resources are allocated and check that do not have safe state after allocation

P<sub>3</sub> → 2 1      ⇐  
Available → <3,2>

to check if safe state in there or not we generate a safe sequence

### safe sequence

- A sequence where two processes will run one after another and will get resources.

all the processes will get resources.

- Request made by P<sub>i</sub> can still be satisfied by current available resources + resources held by previous processes.

If there exist even one safe sequence two processes will never go in deadlock.

we need to generate need matrix first.

we need to generate need matrix first.

	Allocated					Need
P <sub>0</sub>	0	1	4	5	4	4
P <sub>1</sub>	2	0	3	2	1	2
P <sub>2</sub>	3	0	9	0	6	0
P <sub>3</sub>	2	4	2	2	0	1
P <sub>4</sub>	0	0	4	3	4	3

### Algorithm

```

safe-seq = { }

while ( all Ps are added ) {
    (a) find Pi such that needi ≤ available
    (b) if (no such i exist)
        return false.
    else (we found i) {
        available += allocatedi
        Add Pi to the safe-seq .
    }
}
return true;

```

### deadlock detection and recovery

→ detection → all resources have single instances and there is a cycle in resource allocation graph

→ it may be in multiple instances

use banker's algorithm (modified)

we do not include <0,0> while generating safe sequence

kill process

Prempt resource

Impractical

### Process synchronization

process → independent

cooperative

process may communicate with each other.

(P<sub>1</sub>)

```

int SIZE = 10
char buffer [SIZE];
int in = 0, out = 0;
void producer() {
    int count = 0;
    while (count == SIZE) {
        in = (in + 1) % SIZE;
        buffer [in] = produceItem();
        count++;
    }
}

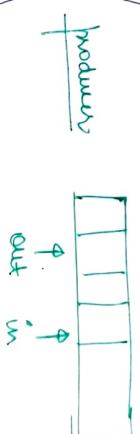
```

(P<sub>2</sub>)

```

void consumer() {
    int count = 0;
    while (count == 0) {
        count++;
        consumeItem();
        out = (out + 1) % SIZE;
    }
}

```



consumer

processes  
suppose the P<sub>2</sub> is  
preempted by OS  
at this point  
count--;

process

① neg = count  
wait  
neg = neg + 1  
count = neg

neg = neg + 1  
count = neg

suppose the P<sub>2</sub> is  
preempted by OS  
at this point  
count--;

before P<sub>1</sub> gets back  
P<sub>2</sub> get the processor

Execution

neg = count  
neg = neg + 1  
count = neg,

← it was the wrong  
count value

RACE condition

Critical section → The section which mandatory have to run as a whole is put in this section

part of program which tries to share access shared resources

## Synchronization mechanism

blocking interrupts locks (or mutex)

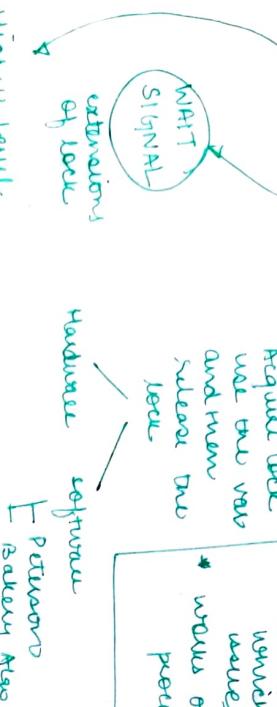
semaphores

monitors

WAIT SIGNAL

Acquire lock use the var and then release the lock

- \* process disabling OS interrupts under critical section
- \* allowing a user process to disable interrupts which cause errors
- \* wakes only on single processor system



## lock for synchronization

```
int amount = 100;
bool lock = false;
```

void deposit(int x){

```
    while (lock == true) {
        // waiting
    }
}
```

void withdrawl(x){

```
    if (amount <= 0) {
        lock = true;
        process will
        at this point
        sum bank the
        amount
    }
}
```

lock = true;
process will
at this point
sum bank the
amount
amount = amount + x;

lock = false;
process will
at this point
sum bank the
amount
amount = amount - x;

lock = false;
process will
at this point
sum bank the
amount
amount = amount - x;

lock = false;
process will
at this point
sum bank the
amount
amount = amount - x;

lock = false;
process will
at this point
sum bank the
amount
amount = amount - x;

lock = false;
process will
at this point
sum bank the
amount
amount = amount - x;

```

void deposit(x) {
    lock - test-and-set(lock) & ptx;
    lock = & ptx;
    * ptx = true;
    return end;
}

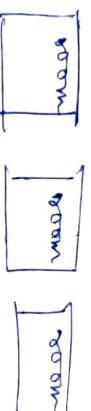
void withdrawl(x) {
    lock - test-and-set(lock + ptx);
    lock = & ptx;
    * ptx = true;
    amount = amount -
    x;
    lock = false;
}

```

## Semaphore

```
struct sem {
    int count;
    queue q;
```

number of  
resources  
available.



```
wait() {
    decrease
    count
    (if resource
    used)
}
```

In the queue  
the semaphore  
stores the  
processes

increase

count  
i.e. see

the queue  
if it has

process is  
used assign  
the resource to  
the process.

As any process approach and

try to use the resource

semaphore reduces the count

and when it's negative

) if negative, it stores

the process info in queue

2) if positive  
allocates the presource

if value of count  
is negative it will  
know the number  
of person waiting  
in the queue

void wait () {

s. count --;

if (s. count < 0) {

- ① Add the caller process to q.

② sleep(p);

3.

4.

③ wakeup(p);

5.

## Memory Management in OS

s. count +;

if (s. count ≤ 0) {

- ① Remove the process p from q.

② wakeup(p);

6.

void signal () {

s. count +;

if (s. count ≤ 0) {

- ① Remove the process p from q.

② wakeup(p);

7.

## Memory Management

Main memory

→ fast accessible

→ storing cost low

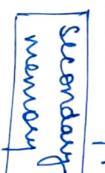
→ high capacity

CPU

→ fast accessible

→ storing cost high

→ low capacity

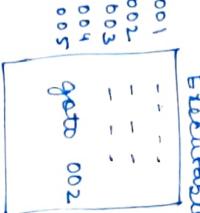


accesses main time

### Address Binding

→ Binary of a program contains relocatable addresses.

it must be brought in main memory and address in main memory is called physical add.



Execution, memory

001 ---  
002 ---  
003 ---  
004 ---  
005 goto 002

Monitors → make a class which contains shared variables and functions.

which will use that are synchronized.

Address binding → mapping of relocatable address to physical add.

compile time  
binding  
problems -  
a proj. is  
loaded into  
mem it  
cannot be  
mapped.  
again plug.  
main memory

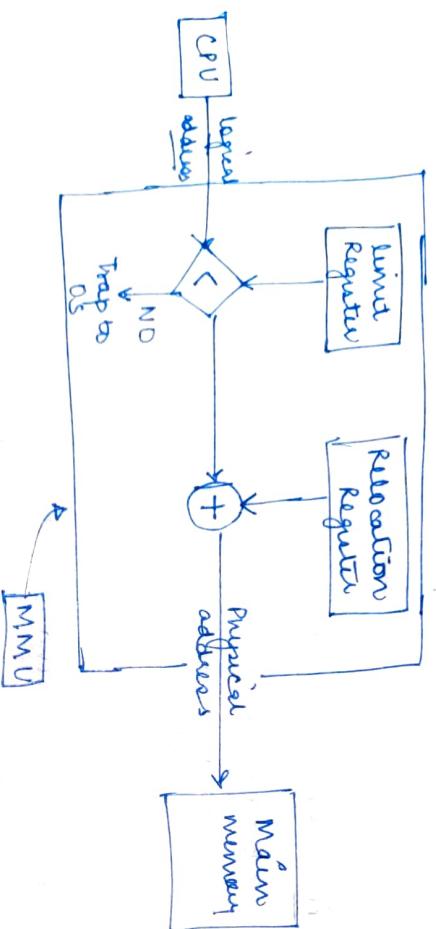
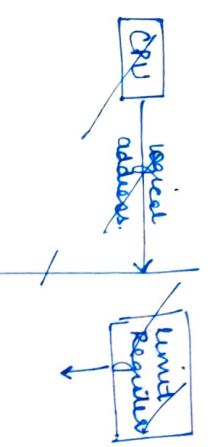
process can be moved  
during run time.

binary ex.  
file does  
not map  
to physical  
memory.

→ address generated by  
CPU are not phys.  
address; instead  
logical address is  
generated.  
MMU → convert LA  
to PA

## Run time Binding

- CPU generates logical address.
- happens through hardware
- Hardware → MMU → memory management unit



We can implement this using software too, but for every context switch OS has to run process ( $P$ ) that converts logical to physical & find, doing this for every instruction in a costly step.

## Evolutions of memory management

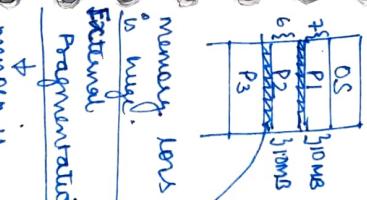
### D single tasking

We want memory to hold many man

& process at a time



External fragmentation  
Memory holes  
in huge.

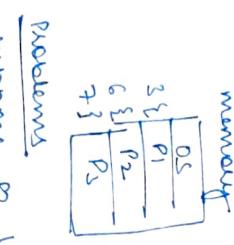


Static size

Unequal size

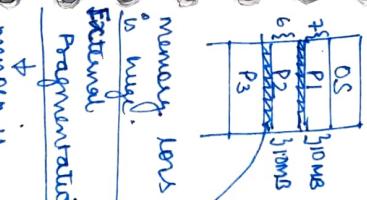
Dynamic

- contiguous allocation process due to next av. memory



- contiguous allocation process due to next av. memory

Internal fragmentation  
Memory is sufficient to hold a process but divided in chunks.



Problems

- Suppose P2 leaves  
the memory now  
cannot be utilized by anyone  
process.
- (i) Non-contiguous  
top to bottom  
+  
(a) Paging  
(b) Segmentation  
(c) Paging with segmentations.

of  
defragmentation  
reallocating the data  
to end

- defragmentation
- reallocating the data to end

## 2) Multitasking system



Dynamic

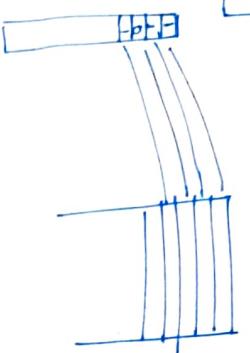
Allocation process

due to next av. memory

## Dynamic Partitioning

the holes created by the leaving of processes has to be managed efficiently

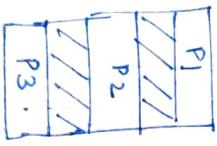
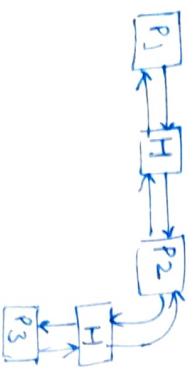
### D-Bitmap



requires lot of space

### Linked List

whole block is represented by a block

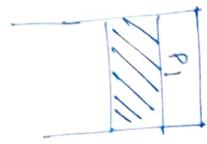


memory is divided into units and then mapped with the corresponding block in bitmap

- 1) First fit
- 2) Best fit
- 3) Next fit
- 4) Worst fit

→ scan from first fit  
use less space  
but can't accommodate two process

travel unuse list to get best fit  
fit → smaller holes



Next fit → begin from the place we stopped previously

worst fit → always allocate the biggest size next.

### First fit → Best

Paging in memory management

To internally program is stored in fragments

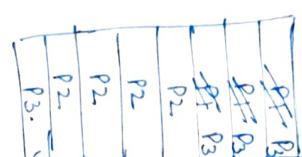
Main memory →



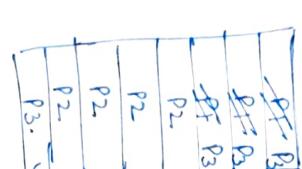
Frames of equal size

process

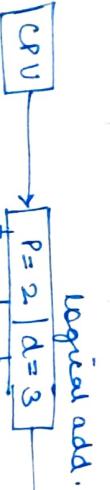
→ when you load a process in memory, its individual pages may be loaded at diff. locations or can not be



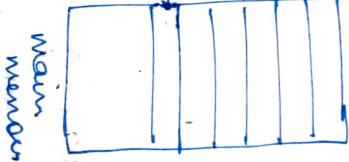
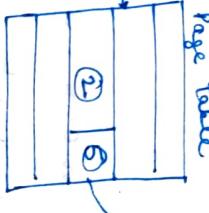
not stored contiguously



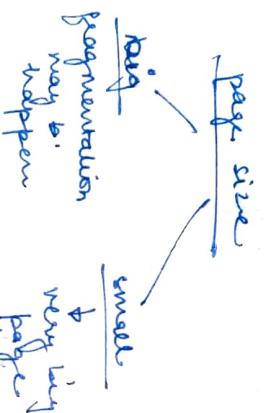
not stored contiguously



Page table stores  
the mapping of  
logical address  
page to mem.  
frame.



Page table stores  
the mapping of  
logical address  
page to mem.  
frame.



access page 2  
and wanna  
page 2 go to  
offset 3

\* All the pages may not be present in main mem.

→ Page fault

to keep track we have a bit called valid  
which keeps track of the bit

valid bit which keeps track of the bit  
which is stored or swapped out)

→ that page has to be loaded from hard disk

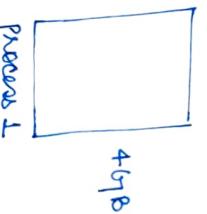


modified

if this page is modified in RAM

## Virtual Memory

some pages of process  
may be present in  
memory & some  
may not



\* Only load the required part of the process in  
the main memory and if any required  
page is not found (page fault), then the  
page is brought into memory from hard disk.

Page fault → costly operation

reading data from HD

low  
increase the  
access time  
by a huge  
ratio.

pure demand paging →

load the page from HDD when  
needed, and only load the  
required part of process in  
memory.

increases  
multitasking &  
programming.

locality of reference

→ load some nearby pages also.

TLB → Translational Lookaside Buffer

CPU generates logical address.

LA has to be converted into PA  
so we have to look this PA into page table &  
this lookup is very frequent and we

can optimize it using TLB.

### Demand Paging

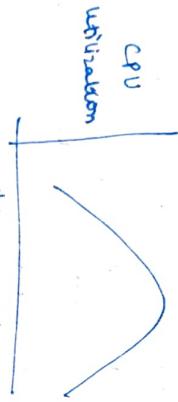
↳ only keep working set of process in memory

meaning

the condition  
when CPU utilization

goes down due to  
high level of multi-

programing of page faults



### Page Replacement Algo

move existing page from main memory to  
accommodate the demanded page

1) FIFO (suffer from Belady's anomaly)

2) Optimal

3) Least Recently Used.

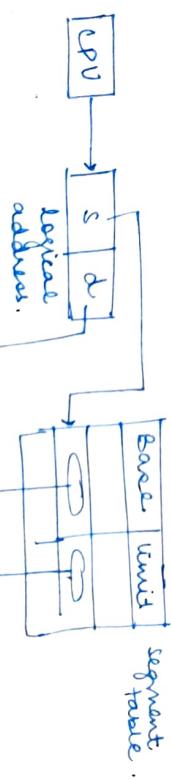
you remove  
the page  
which is going  
to use later  
in future  
if necessary

replace the  
earliest used  
page in  
time

↳ the no. of frames  
is increased, no of  
page faults inc.

Advantages of  
page segmentation  
over paging

Advantages of  
segmentation  
over pages



Virtual memory → All segments need not to be  
present in main memory.

Logical view		
Segment 1	Segment 2	Segment 3
Base	limit	Ap
1600	400	1
1000	1500	1
1111	1111	0
1111	111	0

Main memory		
seg. 1		
1111	1111	
1111	111	
1111		

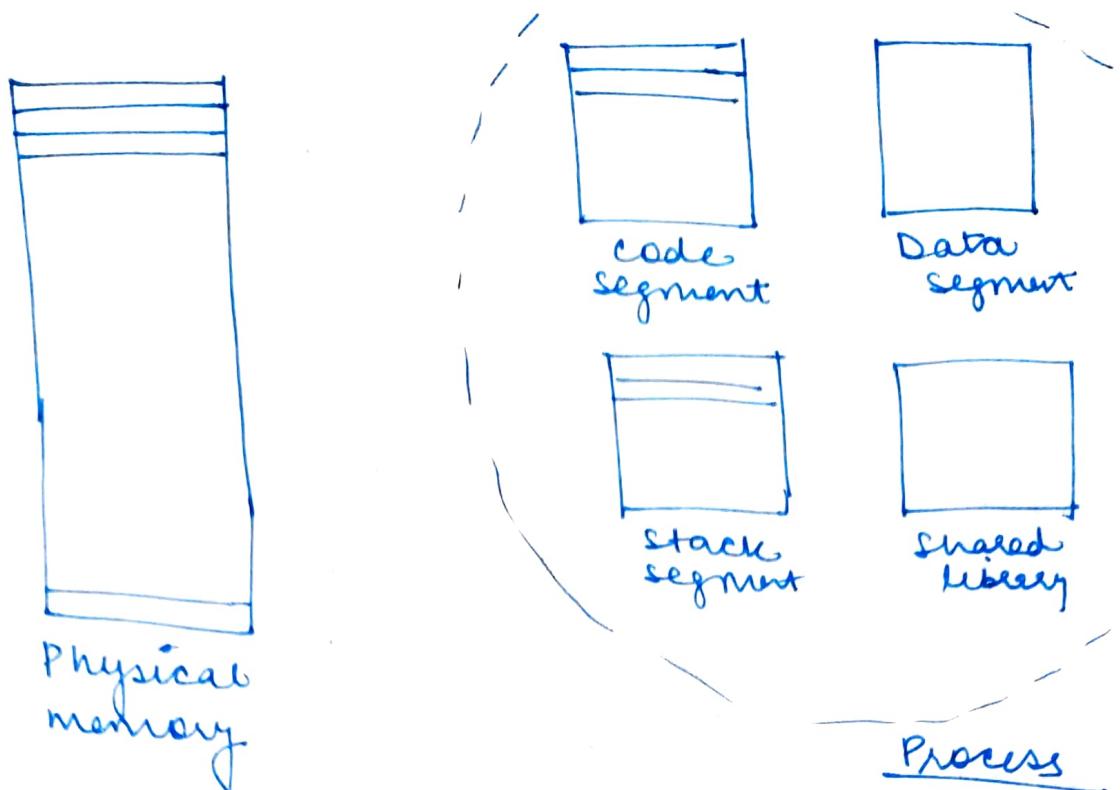
Segment table,  
size is smaller than page  
table size

segmentation in OS  
Alternative to paging

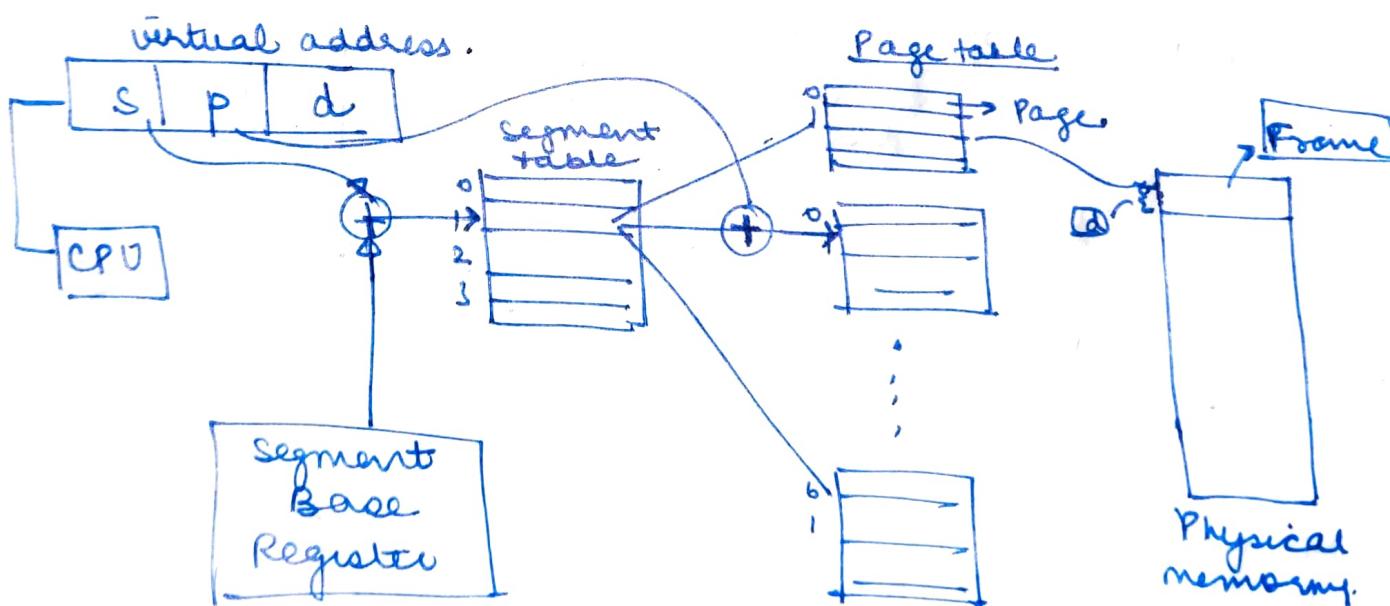
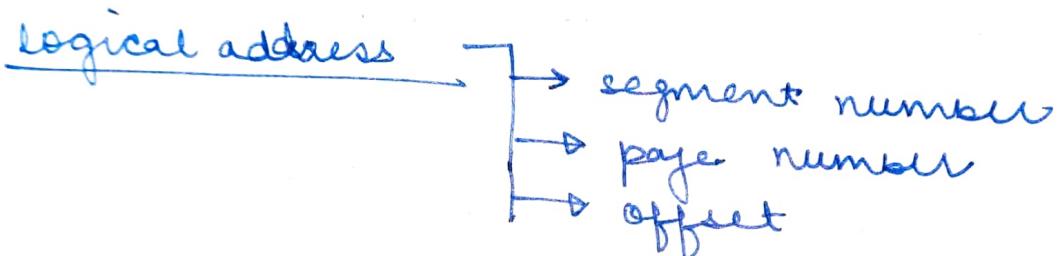
virtual  
physical

brought the related items together  
we divided the process according to user views,  
not necessary equal size

## Segmentation with paging



\* Divided into segments and individual segments have pages.



disadvantage → two lookups