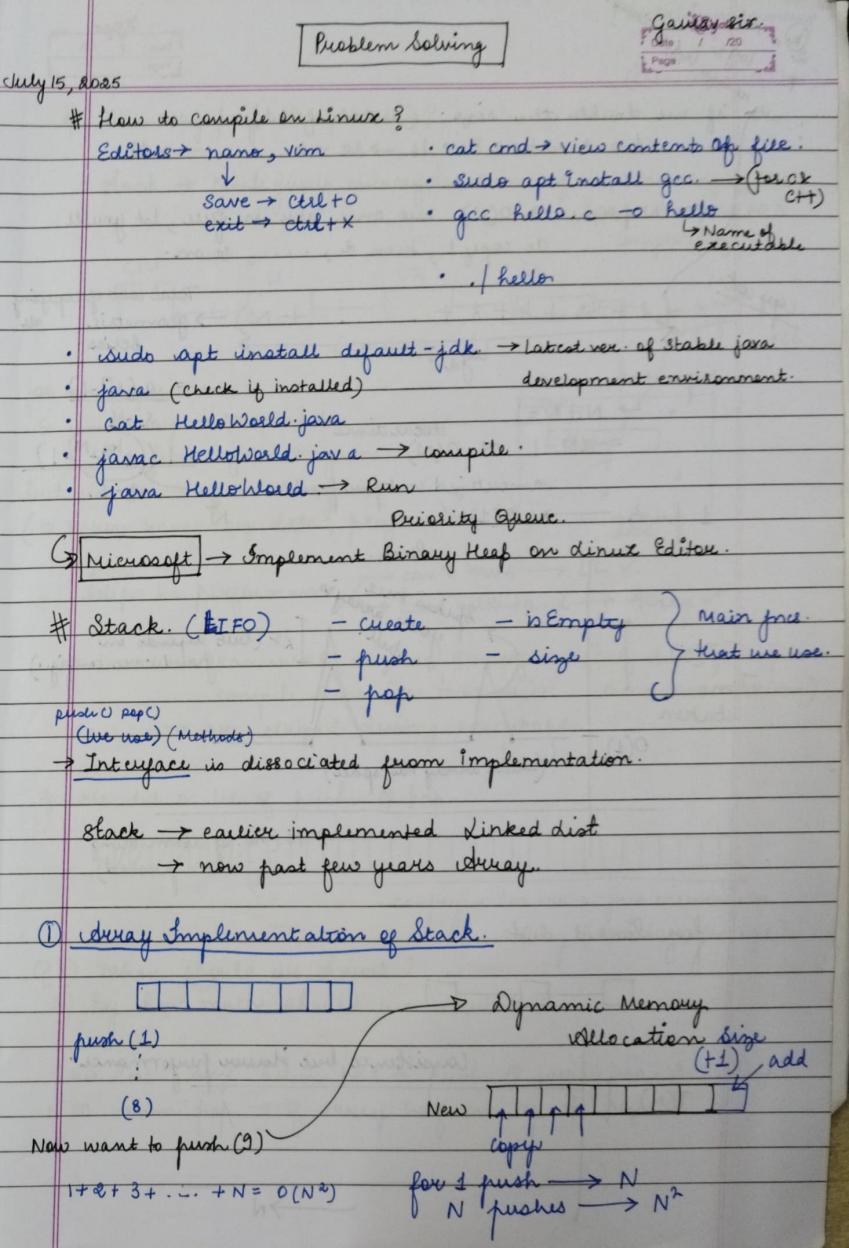


S. No.	Date	Description	Page No.	Remarks	Teacher's Sign
		<p>TV remote (interface) → press button without knowing circuitry (Implementation) ↳</p> <p>stack ↳ stack push, pop, peek - Array - LL</p> <p>flexibility - You can change the implementation without changing the code that uses it. why? dissociated from - not tightly connected.</p> <p>Flexibility → Implementation can change for optimization without breaking user code.</p> <p>Abstraction → Users focus on what is done, not how.</p> <p>Reusability → Same interface, different backends.</p>			



$$\begin{aligned} @k &= n \\ 2^k &= \log_2 n \\ k &= \log_2 \log_2 n \text{ times} \end{aligned}$$

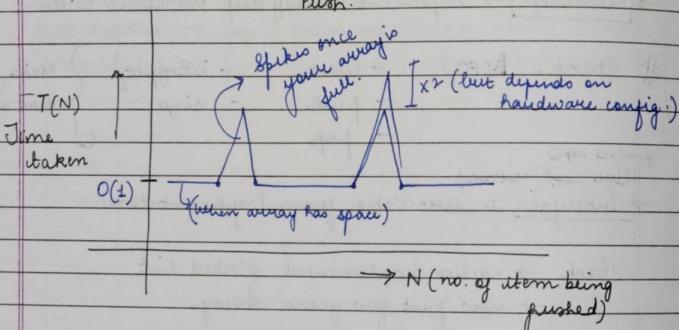
when if we double the size: (instead of +1)
 $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow \dots \rightarrow N$

for N pushes $\rightarrow O(N)$ but once arr is full, 1st you'll do copy 1, then 2, ..., so on.

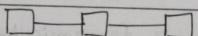
copy cost:

$$N \text{ pushes} \xrightarrow{\text{Total cost of copying}} 1 + 2 + 4 + 8 + \dots + N \xrightarrow{\text{geometric series}} a(r^n - 1) = a(\frac{r^n - 1}{r - 1}) = 1 (\frac{(\log_2 N)^n - 1}{\log_2 N - 1})$$

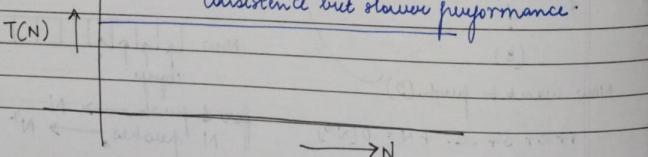
$\hookrightarrow N + N - 1 \approx O(N)$. amortized cost per push.
 $1 \text{ push} \rightarrow O(1)$



for linked list

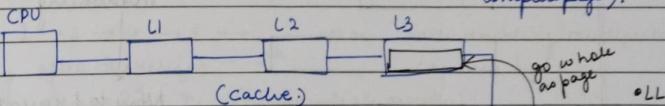


consistency but slower performance.



Then why prefer arrays $>$ LL?

slack \rightarrow contiguous memory location. if implementing by Array
 \rightarrow go in Memory as a complete page.

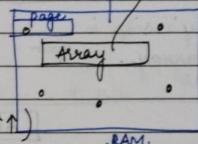


for any operation

so in Array \rightarrow No need to fetch again & again

but in LL \rightarrow again & again

(so when using big data, performance $\uparrow\uparrow$)

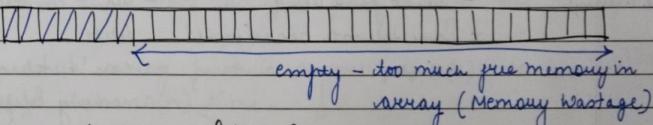


helps in performance

- \hookrightarrow can't have \rightarrow LL \checkmark
- \hookrightarrow can withstand \rightarrow Array \checkmark

\rightarrow assert \rightarrow framework is used during (only during compile time, not runtime)
compile time (for testcase). time, not runtime)
 \rightarrow are striped during executable

we did a lot of pushes & pop ...



Q1) When should we shrink?

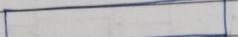
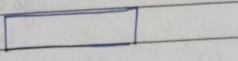
Q2) By how much should we shrink?

- we inc. size when had to push & array was full, size \uparrow .
- so when pop \rightarrow if array half empty \downarrow size.

New if series = push pop push pop

↳ frequent growing & shrinking
(allocating & deallocating at every operation)

Threshing



Now to prevent this



new array's size is $\frac{3}{4}$ th old array. \leftarrow Array is half empty, reduce the size by $\frac{1}{4}$ th. $\boxed{\text{1/4th}}$

Arrays

Memory allocation

contiguous (faster access)

Access time $O(1)$ (random access)

Resize overhead $O(n)$ (during resizing)

Better

Cache friendliness May space waste after resize



(use when) - want fast reads

- can tolerate occasional resize

- want constant insert/ delete

- can't tolerate memory bloats



Linked list

Scattered (pointer chasing)

$O(n)$

$O(1)$ (insert at head)

Poor

Overhead due to pointers

The Resizing Pattern. ①

1	$1 \rightarrow 2(2^1)$	1	} copy cost (elements copied).
2	$2 \rightarrow 4(2^2)$	2	
3	$4 \rightarrow 8(2^3)$	4	
4	$8 \rightarrow 16(2^4)$	8	
k	n	$1, 2, 4, 8, 16, \dots \rightarrow GP$	

$1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow \dots \rightarrow n$ each doubling multiplies capacity after k resizes = 2^k

$$2^k = n \quad (\text{exponential growth})$$

$$k = \log_2 n \quad (\text{logarithmic})$$

∴ we resize $\log_2 n$ times

→ copying $n/2$ existing elements in new array

Now total cost of copying $1 + 2 + 4 + 8 + \dots + n/2$

$$\begin{aligned} \text{sum} &= a(r^k - 1) / (r - 1) \\ &= (2^{(\log_2 n)}) - 1 / (2 - 1) = n - 1 / 1 = n - 1 \end{aligned}$$

$$\text{Total copy cost} = n - 1 \quad \star$$

Unless we are not resizing, normal 1 push → $O(1)$. \star
 n push → cost = n .

$$\therefore \text{Now total} = n + n - 1 = 2n - 1 \approx O(n)$$

Amortized cost. — n pushes $O(n)$

$$\therefore \text{avg cost per push} = \frac{O(n)}{n} = O(1)$$

Dynamic array push is amortized $O(1)$, occasional resizes take $O(n)$ time.

avg cost of an op. over a seq. of op.

c/linux

July 18, 2025

Linux Distros
→ Fedora
Ubuntu
RHEL

Apache Server

ICMP - lightweight, fine
(provide outside health check)

- ps
- kill
- kill -9

• port forwarding

VM dual boot
(machine inside machine) (one machine operational once, can't communicate).

ssh → sharing user terminal to outside world using sockets at backend.

- 1) given - int Array, find → size n
→ Top k elements
① sorted ordered
② unordered.

2) n size Array (large no. ele).

- Ram Selection sort → took 5 second

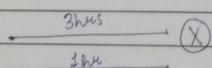
takes ls

↓
16k ele.

- Ram merge sort → took 7 sec.

Is it correct?

TC $\rightarrow n^2$ v/s $n \log n$



'incorrect measurement to ask

TC:

(Correct parameter → No of instructions)

as algorithm design we don't have control over execution time

depends on CPU (super computer),
I/O op./Interrupts.

wrong measurement
(nothing to judge how good algo is)

SSH, 80, 443

HTTP, HTTPS port.

• Vi

• find

/proc/cpuinfo: check CPU

/proc/meminfo: check memory

top: check current usage

• df -h

No. of instructions sent to CPU.

n^2 v/s $n \log n$ Runtime complexity

void Selection sort (int [] a, int n) {

for (i=0 → n)

min = i

for j = i+1

if (a[j] < a[min])

min = j

swap(j, min)

Programs

compile

(fa cut) execute

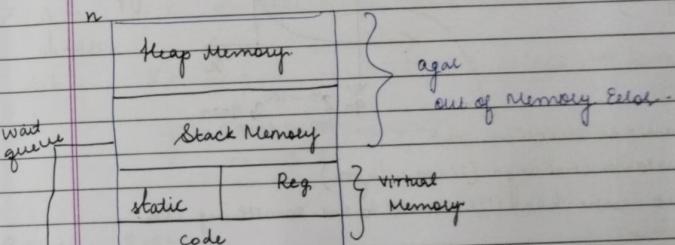
run

execute

③ Swap → PCB → Memory

PCB → Process Control Block.

n



CPU

Cache \gg RAM \gg HDD
← X1000 ← X1000

Cache Eviction Policy →

LRU / LFU.

• dirty bit on → something has been changed so have to update in RAM.

* go algo & inst? bhyegi for same task - better.

* system processes take preference over user processes.

Code running at Priority 4

Date: / / 20
Page: /

Priority 0

* (in Java) Garbage collector - Daemon Thread.

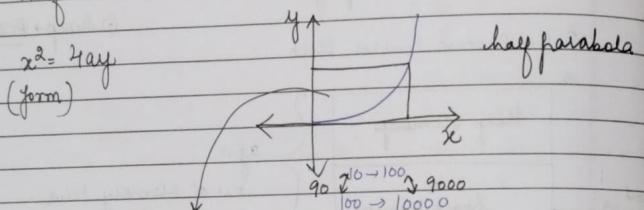
(low priority process)

RAM > 70% - Then system process GC ka priority 5
karega.

* Linux → CFS
algo used.



↳ RT of selection sort = $n^2 + 5n$.



- Can use selection sort

chebara chahunga (linear lagra)

- but user baadil'll want to use something else.

* Selection sort → Always $\Theta(n^2)$ → doesn't matter much
↓
be random, ascending vs descending for.
worst case, best case, Avg case - $\Theta(n^2)$

• algorithm - judged on certain criteria

1) Runtime Complexity (kahan chalane h.)

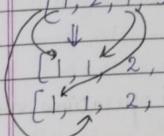
2) If 2 Algo give same RT Space Complexity - RAM?

→ Cost

→ Indirectly RT

- Behavioural
3) Cache friendly or not → indirectly speed.
- 4) Stable Sort
- 5) No. of swaps → agar swap slow h den matter karega.

① $[1, 2, 1, 3, 5]$



Not stable sort.

shuffling ↑ unstable.

string sort

First Last

Z A

RS RR
RL RS
↑
stable.

Riz Ranjan

Rit Sharma

↓ sort

↓ sort

intermediately

Z a b . . . c ← like Quick sort (unstable).

↓ later

a b . . . x z

jiska intermediately result
nathik ho.

② Smart watch → Merge sort X
(RAM).

Selection Sort

Runtime Complexity :-

$$C(n) = (n-1) + (n-2) + (n-3) + \dots + 2 + 1$$

∴ Sum of first k integers,

$$\Rightarrow \frac{k(k+1)}{2} \quad k = n-1.$$

$$\Rightarrow \frac{(n-1)(n-1+1)}{2}$$

$$\Rightarrow \frac{n^2 - n}{2}$$

outer loop runs
(n-1) times
(inner loop)

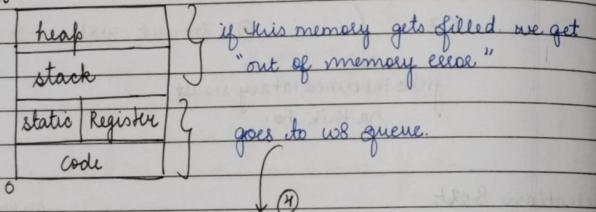
- ① inst^n for $\min = i$
 ② inst^n for $\min = j$
 ③ for swap

for worst case these 5 operations may occur $5n$ times.

$$\therefore \text{Total Instructions} = \frac{n^2}{2} - \frac{n}{2} + 5n \text{ (not exact).}$$

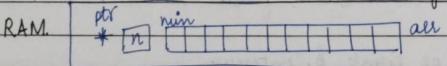
* lets see how it gets executed

- ① We get .o file after compilation
- ② User process \rightarrow OS process
- ③ Process has its own PCB.



④ gets [CPD]

⑤ memory allocated.



- signals dirty lists made on changes made to be reflected in RAM.
- ⑥ Some bits are taken in cache for swap & comparison.
- ⑦ swapped.
- using dcv these bits evicted.

Therefore we may conclude by saying:

\rightarrow algo \rightarrow that can solve \rightarrow same problem \rightarrow less operations \rightarrow better.

L Runtime Complexity for SS. \rightarrow always $O(n^2)$.

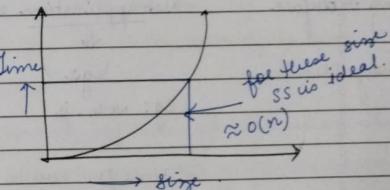
\rightarrow no. of inst n sent to CPU

Graphical Representation

$$RT = n^2$$

$$y^2 = 4ax$$

$$x^2 = 4ay$$

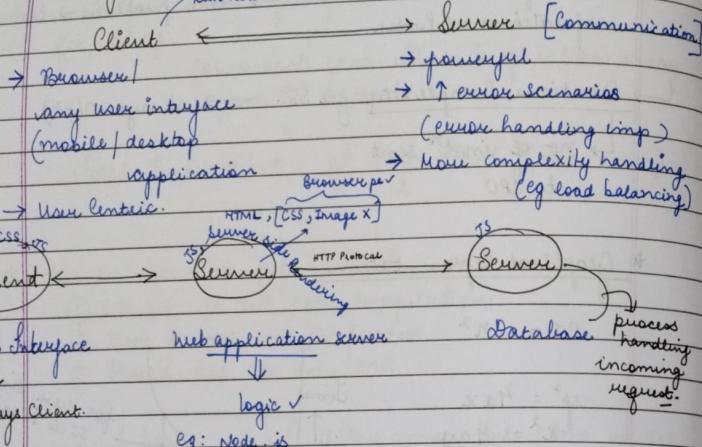


July 19, 2025

Web

Server →
 anything always running
 service always listening
 (always listening)
 mode - active

Starting Basics → HTML, CSS, JS/TS
 Run here hai



- always Client.
- eg: Node.js
- C ↔ S
- ek time per server thi
- k jab info chahi tab Client bangaya
- SERVER.
 - ① listening mode
 - ② Processing & Storing Data
 - ③ Business logic
 - ④ Connectivity
 - ⑤ Running Process
- # Ap server start kare ho itya kya kaise?
- starting a process on any OS.
- # In what cases DB connectivity can stop & why? denon ho gai

How to check DB connectivity
 if its responding / not
 giving data?

- ① Connection with Server
- ② Check Process Running
- ③ Execution / logs

- Internet connectivity X
- Machine crashes
- Machine ok, process crashes / stop
- Memory leaks
- DB process stopped

{ source of data, rel. of data }

| will never switch to NoSQL, There is structure.

Bank
User itself

← Banking Web

← I wanna buy something

(source not defined)

| we don't know behaviour of user / source — Need of NoSQL | we don't
of data. knows structure

DB
Product company, Search Engines

• ECMAScript.

js → pure script language → website interactive (button language)
 click kare toh Agar, date age piche ho jao)

- ES6 came into pic. people only ran on browser.
 ↳ its not lang, only standard of programming, rules define karta.

* Java → oracle
 JS (Implementation) → Browser.

↳ diff browser apne tareka se browser implement karta hai

(Specification of JS)

ES (only specifies / defines → let, ? kya)
 (use as standard)

JS → Single threaded, asynchronous, Object-oriented language.
 (ek time per ek process run ho rhi)

JS mai multi threading

As a language processing JS → multithreading / multiple execution kar
 ↓
 Sabse kya kaise?

Language se nhi kar sakte

(Runtime Env.)

↳ kyun kyu sakta then? → (web API) Browser helps JS to do multiple tasks / multithreading

② index.html - Why?

↳ By default load hoti [Tab kei bhi website access karate hai, we

never give name → it loads index.html → to find entry point

✓ like in java → `main`

html → index.html

google.com kholui → by default uska index.html khol dega.
agar index.html name hai
↳ we manually have to mention while accessing.

HTML

- * tag v/s elements
 - ↳ to DOM mai (jab DOM banta h)
 - to render hole h.
 - to FEE mai dikhta

* head, body

↓
define what we want to do.

↓
dependencies
(sabse pehle execute)

• Delayed Rendering on some action

Eg. Amazon

↳ kholene pur kuch
dikhaao jis update
kaudena on some
behavior.

- Client side rendering
 - ↳ again Browser.
 - ↳ kaun kera
 - ↳ browser.
- 1. index.html }
2. API call
3. Parsing

• Network perspective (multiple calls X)
Server side rendering
→ CSS ke alawa sab kaurke FEE ko dedeta.

• Everything in JS is an object.

`var x=10` → (isn't obj. we think)

X.

↳ there are properties to it → : . obj

(2-pass compilation)

↑
* Hoisting in JS → it moves variable declarations to top of innermost scope of func

(Valueable is accessible outside not value)

Scope →
Block
Func.

func () {

if () {
 var x = 20;

y
y

EXECUTE
karte hme

func () {
 var x;

x = undefined
x = 20;
y → x = 20

* setTimeout → X JS feature

↳ Web API provided by Browser.

↳ template literals

• (additional functionality but string hi hoti)

→ HTML as a string / multiline string

→ dynamic value to populate '\$ { }'

July 21, 2025.

Problem-Solving

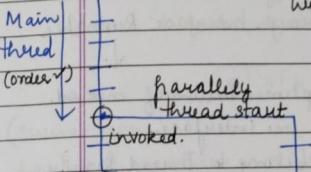
- Main thread \rightarrow priority 5
 \Downarrow
threads created by main \rightarrow priority 5.
- If a thread is created by not main, it will get parent thread's priority.

Ganesh Sir
Date: 1 / 120
Page:

July 21, 2025

CN | OS

Multi threading



on executing randomly we don't know java

kisko (priority) order

mai karega.

they execute independently.

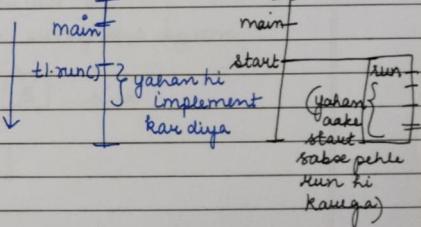
thread dies after execution.

② By default a thread has value = 5
(in java) (1 - 10)

parallel (order main)
start | run \rightarrow synchronously only

fork / invoke thread implement kaado thread kendo
(like a simple call).

atag se thread test execution (how execution)
ka environment implementation would lock like)
banana jahan jake run karsakta
hai parallelly.



Environmental Variables.

↳ thread [new \rightarrow running \rightarrow block \rightarrow terminate]

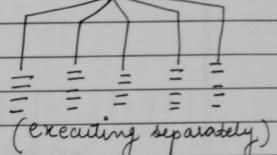
(apni lifecycle heth)

t1. run(); \rightarrow (ok ✓)

Sohel
Date: 1 / 120
Page:

Single threading
(1 base mai 1 task process)
very bad customer experience.

Amazon payment thread start



(executing separately)

t1.start();
t1.start();
(already running / even again) [can't reuse same thread again]
(can't do again)

Date: / /20

Thread implementation
in ()

Thread ki family
ko belong karta h
soare methods

1. Lambda func
2. Through class Thread
3. Through Interface Runnable

- force implementation of method defined in interface.
- doesn't belong to Thread family so have to pass implementation to a thread.
- methods nahi honge (use case:- itna access nahi dena).

July 25, 2025

C | linux.

Ritesh sir

Date: / /20

Page: -

- Q: array → Top k elements → max heap. Ist soln.
- 1) Build max heap
 - 2) call k times → delete max ele.
- (virtually)
treats array as a full binary tree.

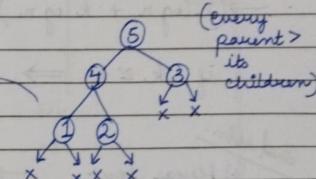
[5 3 4 1 2] ✓ valid.

(min- apne

parent se compare
karo)

[x 5 4 3 1 2]

2i 2i+1
left child right child.



[5 2 1 4 3]

(at all point
ele swaps -
compares to
parent)

[0 1 2 3
x 5 2 1 4]

Parent index

[x 5 4 1 2 3]

Max heap
→ good to find largest but
not kth largest.

- ↳ delMax → ① Swap with last ele
② decrease array size by one.

[x 3 4 1 2 5] sink

[x 4 3 1 2]

At 1) Build.

n ele → can be as bad as n

→ newly inserted if largest. (worst case)

n ele tak
n time karne
pad sakte

Height times swim karega ($\log n$)

$\rightarrow n \log n$

Date : / / 20
Page :

travel down.
 ↓
 sink kaune mai abhi log n times (for 1 ele)
 ↳ might be able to delete 1.
 → k max ele → k times del. ↳ k log n.

→ $(n \log n + k \log n)$ RTC

if $k \approx n \Rightarrow 2n \log n \approx n \log n$

2nd soln:
 1) Merge sort → $n \log n$.

2) return $[k:n]$

↓
 array supports random access ∴ $O(1)$

→ $(n \log n + 1)$.

3rd soln:
 Selection sort → instead of moving min move max.

→ $(n * k)$

↳ but $k \ll n$

if $(n \approx k \Rightarrow n^2 \text{ ho jaega})$.

↳ SSH v/s SSL

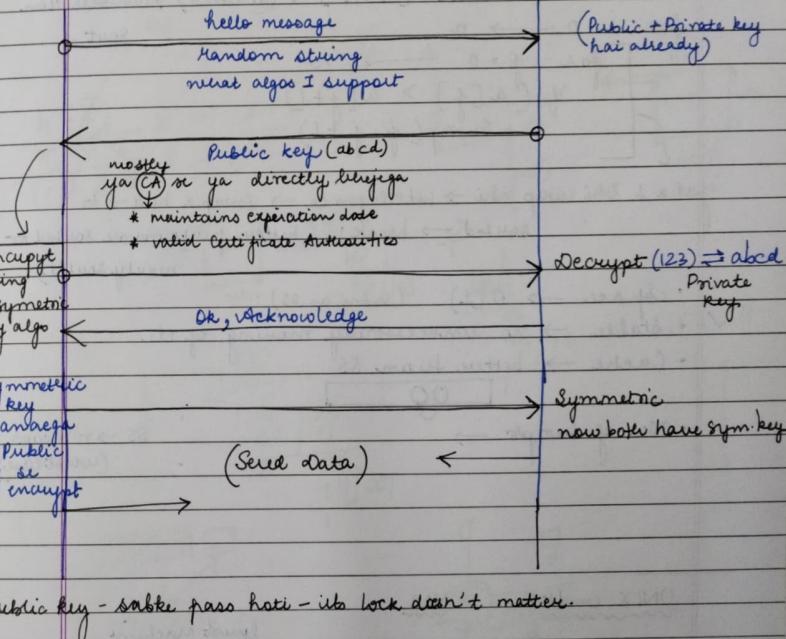
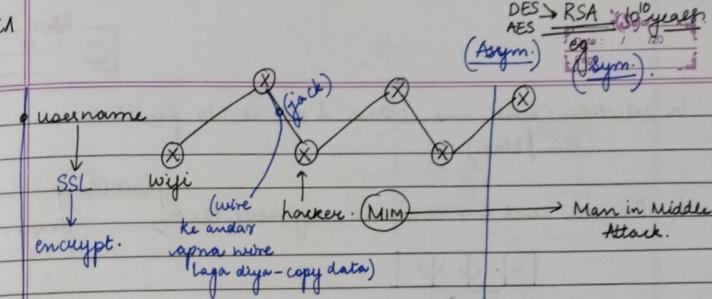
Secured Shell

Secured Socket Layer (just running below Application layer.)
 ↓
 HTTP layer)

(to access remote terminal)

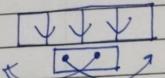
* when HTTP uses SSL → HTTPS.

text ↗ some
 for encryption



In Selection sort \rightarrow I pass 1 ele. at its position.
(min/Max)

In Bubble sort \rightarrow compare neighbour ele $\xrightarrow{\text{Bubble up}}$ down.



n times $\rightarrow (n-1)$ operations
 $n * (n-1)$

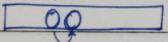
RTC $(n^2 - n) > (a \text{ little})$ than Selection sort.

```

for i = 0 → n
  for j = 0 → n
    if (a[j] > a[j+1])
      Swap(j, j+1)
  
```

yaha 1 bhi swap nhi \rightarrow intelligence \rightarrow swap x hua \rightarrow to sorted \rightarrow break; (better performance sorted or nearly sorted).

- Space $\rightarrow O(1)$ (same as SS).
- Stable \rightarrow no unnecessary moving of ele.
- Cache \rightarrow better than SS



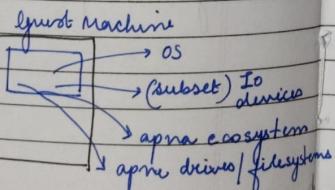
- No. of swaps \rightarrow

SS \rightarrow n swaps
(worst case)

UNIX cmd's:

VM

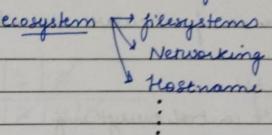
host machine



BIOS

- ↳ hypervisor
- ↳ virtualisation

Guest Machine is a Program for Host Machine (with special permissions - CPU memory, IO devices).



Benefit of VM?

- ① Can have as many machines.
- ② config manager (have my own) scale up/down no. of instances.
- ③ (Packer) if I upload / deploy code on VM, my machine can't be damaged, at max VM down.

light
Docker \rightarrow VM \rightarrow software, code, OS sub mentioned

Kubernetes

\hookrightarrow container VM | remove docker (acc. to load)
(cost control, automatic)

- HTTP servers be there communicate with VM.
(mount, FS)

- Vagrant \rightarrow help to config my VM.

- Port forwarding.

(processes running on this
 \rightarrow top machine, mem & CPU utilization)

\rightarrow cat /proc/cpuinfo
 \rightarrow cat /proc/meminfo

Swap memory

buffer

zombie

July 26, 2025

- Settlement - it's done based (doesn't block main thread)

- ↳ browser - queue - main thread.

- cases → after a certain interval

- ↳ after a particular thread [0 time → feels currently executing thread finish

- Karega execution, wake back

- we can't control everything

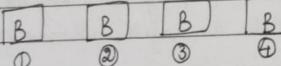
- (Runtime env.)

- [yeah] Running thread

- [current cycle set, then settle out walla code]

Ques:

(Buttons) Elements → same everything, class same, no id.
{access in JS, how?}



we use - getElementByClass() it returns array of all elements and then we can choose the required ele (eg: 3rd Button).

Node.js → acts as a server, server side logic

npm → utility provided (node package manager)

Express.js → is just a library

✓ 448 → HTTPS

8080 → HTTP protocol → can use any port number

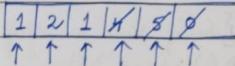
convention 8080

July 28, 2025

Ques) Try to target O(1) TC.

Stack implementation

Min, Max.



stack min - [1 1 Ø]

stack Max - [1 2 4 5]

push(ele)



if stackempty() {

min.push();

max.push();



min → min.peek()

Max → max.peek()

pop();

if (ele < min.peek())
push.

else if (ele > max.peek())
push.

class MinMaxStack {

stack<Integer> st = new

stack<>();

stack<Integer> min = new

stack<>();

stack<Integer> max = new stack<>();

public void push(int val) {

if st.push(val);

if (min.isEmpty()) min.push(val);

if (max.isEmpty()) max.push(val);

else if (val < min.peek()) min.push(val);

else if (val > max.peek()) max.push(val);



public void pop() {

int ele = st.pop();

if (!min.isEmpty() && min.peek() == ele) min.pop();

if (!max.isEmpty() && max.peek() == ele) max.pop();



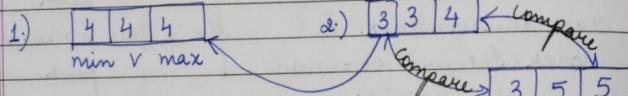
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```
public int top() {  
    return st.pop();  
}
```

```
3 public int getMin() {  
    return st.min.peek();  
}
```

```
3 public int getMax() {  
    return max.peek();  
}
```

now (insert, deletion)
→ Hint :- O(1) TC → linked list



now if pop
will have min & max
for the current el.

```
class MinMaxStack {  
    class Node {  
        int val;  
        int maxTillNow;  
        int minTillNow;  
        Node next;  
        Node(int val, int maxTillNow, int minTillNow)  
        {  
            this.val = val;  
            —  
            next = null;  
        }  
    }  
    Node head;
```

13 of 100
Date : / / 20
Page :
public MinMaxStack() {
 this.head = null;
}

```
3 public void push(int val) {  
    if (head == null) {  
        head = new Node(val, val, val);  
    } else {  
        Node newNode = new Node(val, Math.min(val,  
            head.minTillNow), Math.max(val, head.  
            maxTillNow));  
        newNode.next = head; head = newNode;  
    }  
}
```

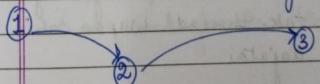
```
3 public void pop() {  
    if (head != null) {  
        head = head.next;  
    }  
}
```

```
3 public int top() {  
    return head.val;  
}
```

```
3 public int getMin() {  
    return head.minTillNow;  
}
```

```
3 public int getMax() {  
    return head.maxTillNow;  
}
```

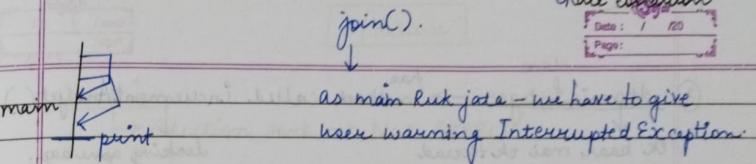
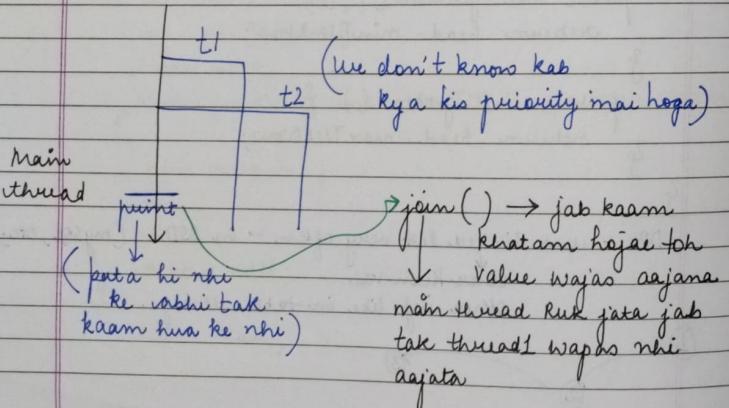
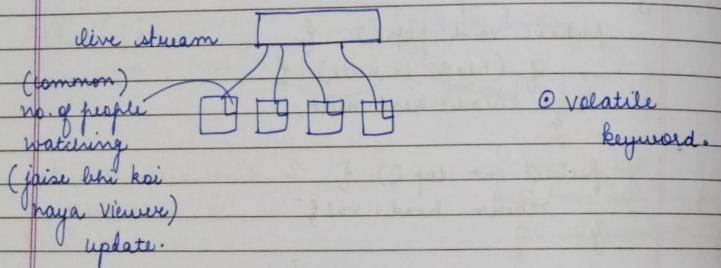
DBs - uses linked list very often - in SSD. (mysql, etc.)
↓
other than val
other info like in table all info.



- ✓ DB \rightarrow data non-contiguous LL
- ✓ indexing \rightarrow address, contiguous mukta, RAM mai take dekhte hi pata (SSD mai kaha se lana)
- \downarrow
- ki cost hoti hai (RAM mai memory).
- Chal jae ke Kaha jana hai.

\rightarrow Agar indexing X \rightarrow same DB search karne ka
 \rightarrow Agar \uparrow indexing, Sab category \rightarrow cost \uparrow RAM, slower.

How thread handle same resource?
Mutex lock?



JAVA \rightarrow read, +, write

t1 \rightarrow Resource - R+W

$$C = 16 W 16 12$$

t2 \rightarrow Read = 1 tab tak t1 is fast so +5 aur kardiya

(overwrite here)

12

mutex \rightarrow flag / lock

lock \rightarrow common resource, toh ek baar mai ek hi thread update karne

Semaphore \rightarrow ek baar mai itne hi log access kar sakte Tall Plaza (ek baar mai 5 cars, 5 lanes)

① synchronized - java makes sure ke ek baar mai ek (method per thread use kar paen.) laga diya, ya block bana diya)

working

wait indefinitely

② Make our own lock \rightarrow Lock class ReentrantLock
③ trylock() \rightarrow ke agar lock avail tab dede, so if true \downarrow I will get lock it will give true & also provide lock. (value ki tarah check) if avail.
after using \rightarrow unlock();

✓ Ek thread ne lock le liya to update resource, tab dusra infinite while lock loop, then 1st thread would release lock for 2nd to be avail

class `AtomicInteger` → has method called `incrementAndGet()`
 ↓
 ek baar mai ek thread access kar paata (singular)

Atomic Boolean

Ques) Write your own implementation of `AtomicInteger`.
 ↳ (2)

Aug 1, 2025.

C | Linux

class

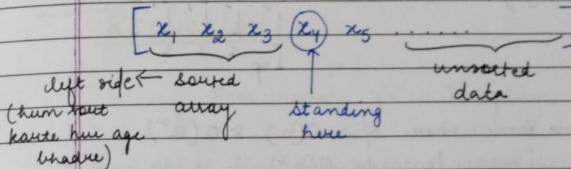
convention

↳ Selection sort → NOT STABLE

[2, 2, 1]

[1, 2, 2]

↳ Insertion sort: (Playing cards)



Ques) If data is already sorted, which algo prefer?
 ↳ Insertion sort
 ↳ as internal swapping is not required.

(i.e. already sorted, single ele)

for $i = 1 \rightarrow n$
 $j = i$

while $a[j] < a[j-1] \& j > 0$
 swap ($j, j-1$)
 $j--$

modified Bubble sort

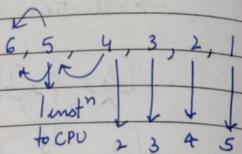
[5, 3, 1, 4, 2]

↑
 3, 5, 1, 4, 2,

Runtime Complexity \rightarrow worst case $O(n^2)$

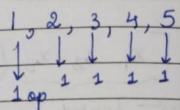
$$(n-1)n > n^2$$

Steep Parabola 

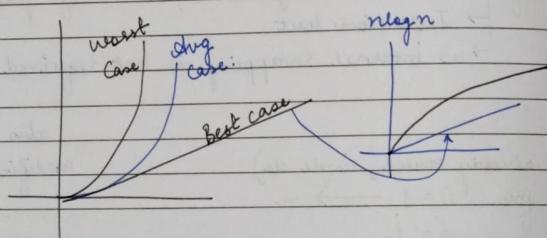


Best case \rightarrow already sorted data

$$(n-1) \sim O(n)$$



Avg case \rightarrow somewhere b/w $O(n)$ & $O(n^2)$
[more towards $O(n^2)$].



\hookrightarrow choose I.S. if n is small.

Space Complexity $\rightarrow O(1)$ No extra space.

Cache Friendly \rightarrow neighbouring ele.



not jumping far.

Stability \rightarrow

TC \rightarrow No. of instructions we are sending to CPU

[2, 2, 1]

[1, 2, 2] keep their positions.

No. of swaps \rightarrow going backward \rightarrow if 9 step swapping, loop stops there.

$\therefore O(n^2)$ swap

\hookrightarrow sorted data $\rightarrow O(1)$ swaps.

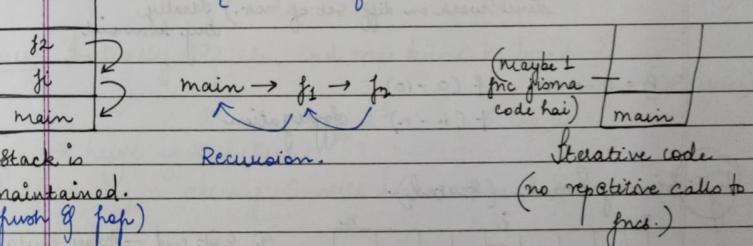
RECURSION

Recursion v/s Iteration

- has no. of lines of code.
- might have more lines of code

\downarrow
{Source code | compilation code, size}
might be less.

{But No. of instrns sent to CPU = SAME}



- additional space might be required to maintain func stack

*f() {

=

f() \rightarrow end mai hai

(toh ispr aur push mhi karne, pop hi logo)

Intelligent compiler \Rightarrow change to Iterative code.

Routine \rightarrow Recursion \rightarrow Respective Iterative
space \rightarrow might be ↑ because of functional stack but if
are not asking for extra space $O(1)$

Recursion \rightarrow compact code
 \rightarrow might need additional space.

1) problem \rightarrow can it be broken into sub problem
(smaller n)
part of same problem.

2) Exit / Base cond. (waerna oo loop).

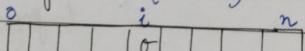
3) P broken \rightarrow S1 (both are parts of same problem)
 \rightarrow S2 & P

if multiple recursion, then MUTUALLY EXCLUSIVE
BOUNDARIES

* S1 working $0 \rightarrow 20$
S2 $n \rightarrow 5 \rightarrow 15$ \times Time Exponential
↓
need to make
some work on diff. set of nos. Ideally
try to avoid

$P = 0 \rightarrow n$ $f(0 \rightarrow 10)$
 $f(11 \rightarrow n)$ aggregation

Eg I: Binary Search. (Sorted).



② Exit cond - Array empty.

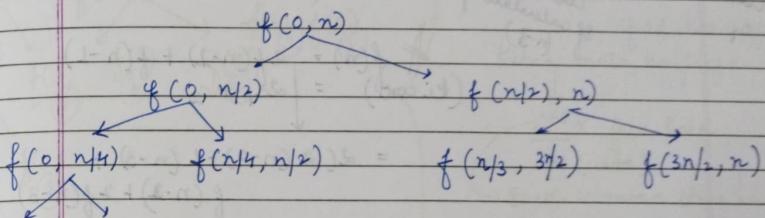
- ① $k = 0 \rightarrow$ Exit cond. (found)
- $k < 0 \rightarrow$ Search backward
- $k > 0 \rightarrow$ Search forward

$f(0, n) \rightarrow \checkmark$

$f(0, l+1) \rightarrow \checkmark$

$f(i+1, n) \rightarrow \checkmark$

Bsearch (key, arr, l, r)
if ($l > r$) return;
mid = $(l+r)/2$;
if ($a[mid] == key$) return mid;
if ($a[mid] > key$)
return BS(key, arr, l, mid-1);
return BS(key, arr, mid+1, r);



tab tak chalta rahega \rightarrow 0 ele left ($L > R$)

at every iteration, my search boundary is reduced to half.

Ques: Initially 32 ele, end mai kitne k baad?

$$2^5 \quad \log_2 2^5 \rightarrow 5 \log_2$$

(GP series)

log n \rightarrow height of this tree

\hookrightarrow after $\log n$ attempts I will reach this end.

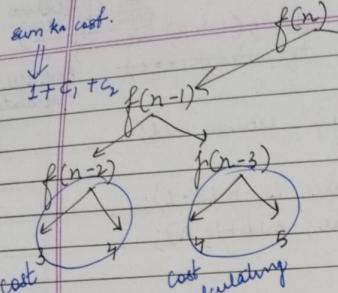
if os making Fnc Stack $\Rightarrow \log n$ times

Eg II: Fibonacci Series.

$$\therefore f(n) = f(n-1) + f(n-2)$$

1, 1, 2, 3, 5, 8

if ($x = 0$ or $x = 1$) return 1;
return fib(n-1) + fib(n-2);



$$\begin{aligned}
 f(n) &= 2f(n-2) + f(n-1) \\
 (\text{ki cost}) &= |2c_1 + c_2| \\
 &= 2(2(n-4) + f(n-3) + \\
 &\quad f(n-3) + 2f(n-3)) \\
 &= 2^2(n-4) + 3(n-3) + (n-2) \\
 3^{\text{rd}} \text{ step} \rightarrow &= 2^3(\dots)
 \end{aligned}$$

n^{th} step job $\rightarrow = 2^n(f(1))$

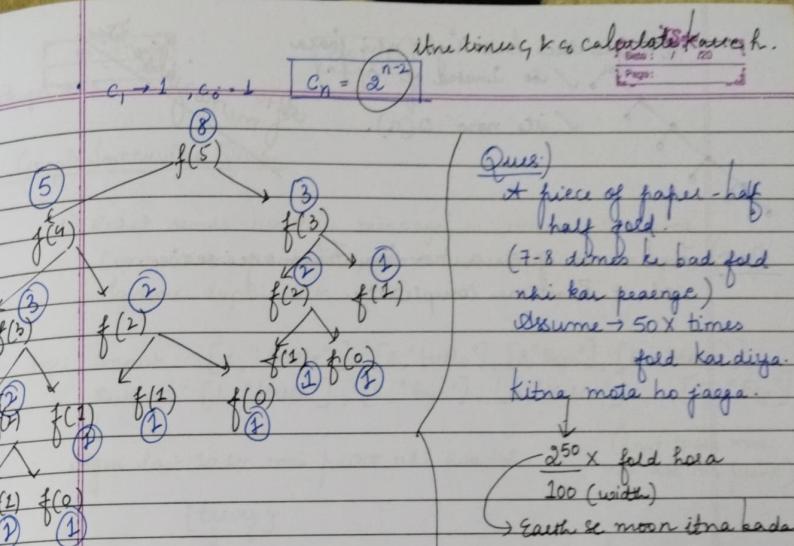
$f(1)$ parne pehanchega

2^{n-1} around.

COST ↑↑

(as net working on distinct steps)
boundary

$$\begin{aligned}
 \nexists \rightarrow c_n &= c_{n-1} + c_{n-2} \\
 \text{step } ① \rightarrow c_{n-2} + c_{n-3} + c_{n-2} &= 2c_{n-2} + c_{n-3} \\
 [c_7 = 2c_{7-2} + c_{7-3}] \quad \xrightarrow{\text{boundary}} & \\
 \text{step } ② \rightarrow 2(2c_{n-4} + c_{n-3} + c_{n-3}) & \\
 &= 2^2(c_{n-4} + 2c_{n-3}) \\
 &\cdot c_n = 2^{n-1}(c_{n-8-2} + c_{n-7-1}) \\
 &\cdot c_n = 2^{n-1}(c_1 + c_2)
 \end{aligned}$$



$$\text{fib}(n) = \text{fib}(n-1) + \text{fib}(n-2)$$

Sln: ① \rightarrow Iteration
② \rightarrow memoize | cache
previously calculated value.

$$\begin{aligned}
 c_n &= c_{n-1} + c_{n-2} \\
 &= c_{n-2} + c_{n-3} + \dots \quad \text{cache}
 \end{aligned}$$

Ques.) 5 lakhs everyday
1 price everyday

Feb $2^{28} < 5 \times 28$
March $2^{31} >> 5 \times 31$

$O(n) \leftarrow \text{fib}(n, a)$

if ($n == 1 \text{ or } n == 0$) return n ; $a[1] = 1 \text{ ret } 1$;
 $a[0] = 0 \text{ ret } 0$;

if ($a[n] == -1$) return $a[n]$;

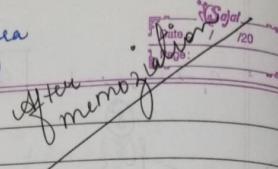
if ($a[n-1] == -1$) $a[n-1] = \text{fib}(n-1)$;

if ($a[n-2] == -1$) $a[n-2] = \text{fib}(n-2)$;

$a[n] = a[n-1] + a[n-2]$; return $a[n]$;

n height tree but eight nhi jaara
✓ so instead of $O(2^n)$
✓ its now $O(n)$.

Ques) Find sum of even no. in Fibonacci series.
code + Runtime complexity.



OS | CN

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Aug 7, 2025

Google Interview Ques.

- 1) Robot sends weather message in incremental time.
Connection problem, send but duplicate ho jata.
Ignore duplicates.

Ex: Input : [1, "Hello"], [2, "Hello"], [3, "Bye"], [12, "Hello"],
Output : [1, "Hello"], [3, "Bye"], [12, "Hello"], [13, "Bye"]
↓
Agar last 10 sec mai print nhi hua toh. (Last 10 sec mai
nhi aae toh print)

{Tricky}

- 2) 10 sec future and past mai shouldn't be printed.

Input: [1, "Hello"], [3, "Hello"], [8, "Bye"], [10, "Yoo"],
[12, "Hello"], [13, "Bye"], [22, "Bye"].

Output: [10, "Yoo"].

→ Infinite stream, have to make sure future mai bhi na
aee.

↓
(Real Implementation of Cloud to handle duplicates.)

(Queue + Map Usage).

Scheduling Algorithms.

- ↓
• CPU time switching is so fast
Content

May 5, 2015

Cojal
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java → flag
ca → enable assertions (assert class)

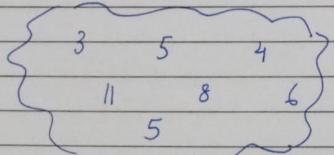
Priority Queue

↓
utility data structure

- Use case :-
- [A* search] Artificial Intelligence
 - Computer Networks [web cache]
 - OS (Scheduling, load balancing)
 - Data compression (Huffman Codes)
 - Graphs (Dijkstra's Algo, Prim Algo.)
Shortest Path
 - Number Theory [Sum of Powers]
 - ML (spam filtering (Bayesian spam filter))
(stats applications).

→ Max Priority Queue:

insert



delete:

- ① 11 (getting max priority item).
- ② 8
- ③ 6
- ⋮

- ✓ Visually think of it as binary tree.
✓ Implemented as array.

Stack → LIFO

Queue → FIFO

P. Queue → Highest Priority item
(can be max/min)
acc. to use case.

Interface

public class MaxPriorityQueue

```

    {
        public void insert (int x);
        public int delMax ();
        boolean isEmpty();
        public int max();
        public int size();
    }

```

(Interface methods so
avail & usable by all)
↓ Exposed to all.

→ Need to keep in mind
why & which func. to
make public / private /
protected. (func / var.)

Some Implementation

unordered array (for LSP)

ordered arr. (for LIP)

Insert

1

N

$O(N^2)$

DeleteMax

N

1

$O(N^2)$

unordered

1	8	3	4
---	---	---	---

ordered

1	2	3	7	5
1	2	3	5	7

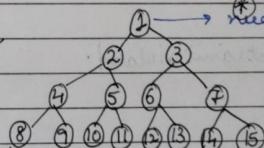
if, left shifting, binary → $\log N$

In Priority Queue, both insert & delete $\Rightarrow \log N$.

→ parent ; 2i, 2i+1 indexes → children.



Max Priority Queue

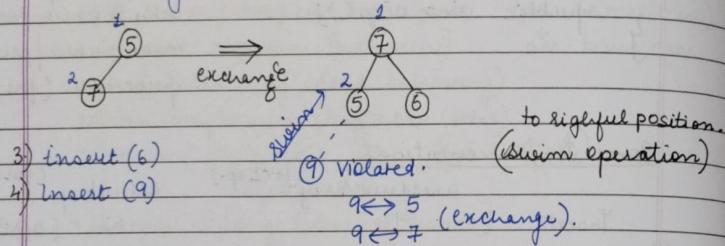


→ needs to be > than children.
can be in any case
Parent < Children X

Front	9	7				
X	X	6	5			
1 2 3 4 5 6 7 8						

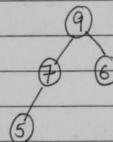
- 1) insert (5)
2) insert (7) → at N+1.
↓

now original constraint has been violated.

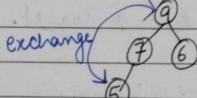


(height of tree).

④ sink operation:
↳ 1 op → $\log_2 N$
↳ N op → $N \log_2 N$



Max / Min ele → Root.



(pick largest child & swap
neigh most)



5	9	7	6	9
---	---	---	---	---

(depth of tree).
④ sink operation → 1 op → $\log_2 N$
→ N op → $N \log_2 N$

import java.util.PriorityQueue;

public class TestPriorityQueue

{
public static void main (String[] args)

PriorityQueue<Integer> pq = new PriorityQueue();
pq.add (5);
pq.add (3);
pq.add (9);
pq.add (-1);
pq.add (15);

System.out.println (pq.poll());

In Java

give -1 (by default
3 minPriority
5 Queue).

↓
(No default max
P.Q. reverse signs
& reverse again.)

Interview.

Ques.) kth largest element in array.

CN | OS

Aug 11, 2025.

* TCP / UDP :- Net Transport layer. (4th)
(building block of communication)

* What is Protocol ? → definition of Rules

→ Networking - what kind of format
we'll send data (binary) etc

⊗ TCP → 3 way handshaking.



Transmission
control
Protocol.

• chat

- error handling
- congestion control kind
- sequence ?

Transmitting
data.



we make sure
control on it

- No data loss occurs .

e.g. HTTP (application layer)

HyperText

uses TCP → no data is lost .
so that can display
data in HTTP .

⊗ UDP 
↓

• depends on our
use case .

User Datagram Protocol. (lightweight)

- continuously , network less hoga ya
lich mai so it skips & continuous .
- no guarantee of delivery or order .

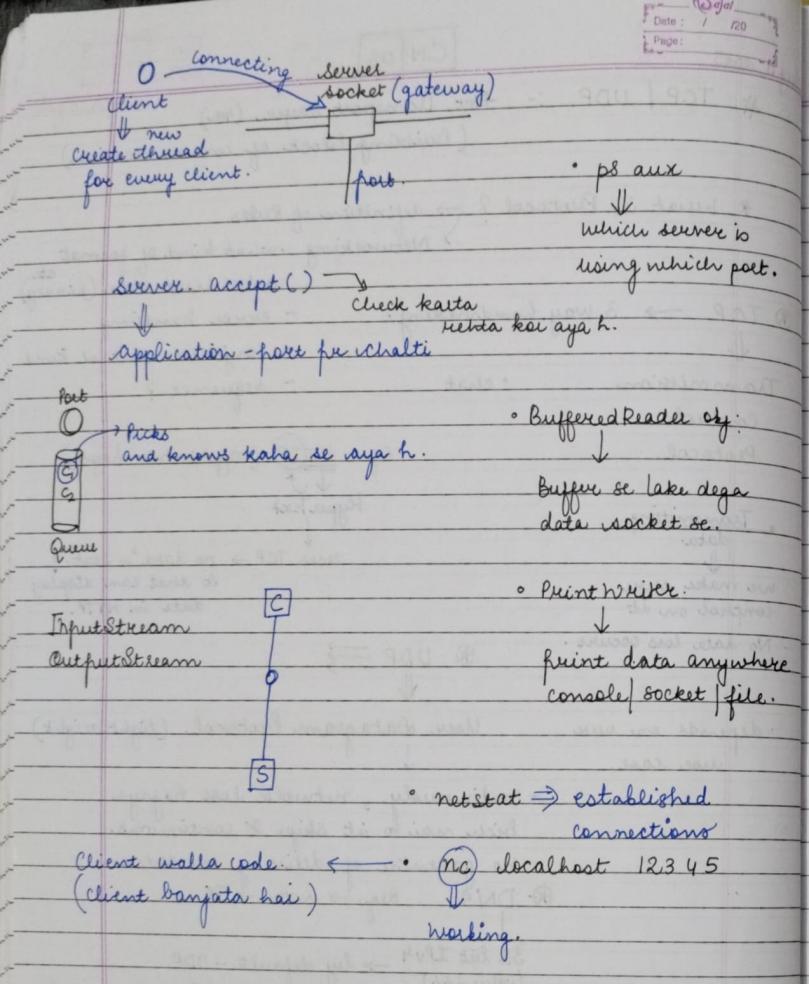
⊗ DNS Reg. → Data → IP

↓
32 bit IPv4
(value ↓↓)

→ by default - UDP

cases if UDP fails continuously
↳ TCP connection .

• java → socket
→ datagram } frameworks .



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Problem Solving

Aug 12, 2025.

jar file in java → like zip file containing classes.

Checkstyle

- java -jar [path] -c google-checks.xml file.java
- configuration or sun_checks.xml.

* cpplint → by google, made open source.

* curl
* scp

④ Stack | Queue → correction

- if Array is only 1/4th full i.e. 3/4th empty.
 - Reduce it by half.

Priority Queue Implementation

↓

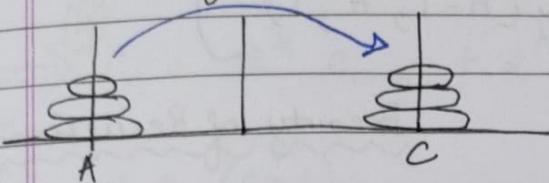
1-based index → just following for cleaner code.

- are at bottom of binary tree, till child > parent we are going for exchange.
- [n--] forget about it.
- int - basic data type ← delMaxC()
- if object has so we would set it to null for Garbage Collector.
- sink → take larger of the 2 ch
 - if left child > right child → j++

C | Linux

Aug 15, 2025.

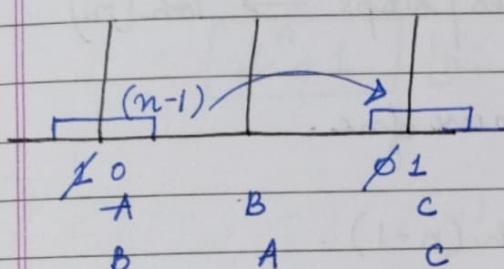
Tower of Hanoi.



- solve
- tedious.
- count the steps

- only one pick
- longer disc can't be placed on smaller at any time.

from To Auxiliary

$$\text{Toh}(n, A, B, C)$$


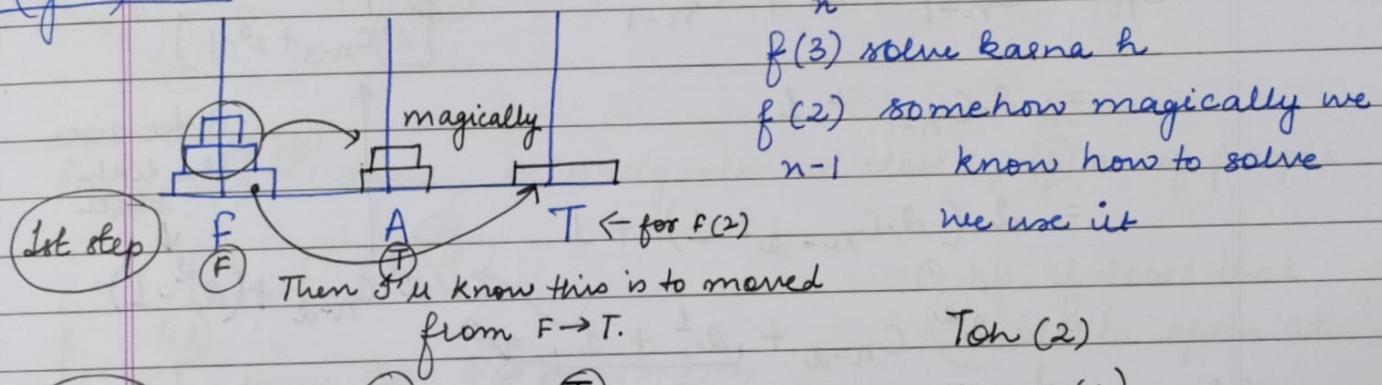
$$\begin{aligned} f(n) &\checkmark \\ f(n-1) &\checkmark \end{aligned}$$

if ($n == 1$) {
move (A, T)}

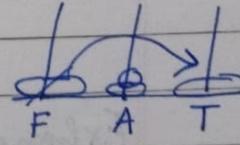
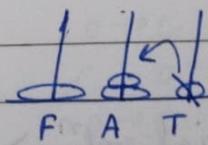
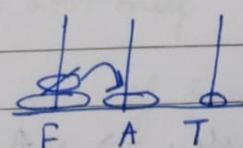
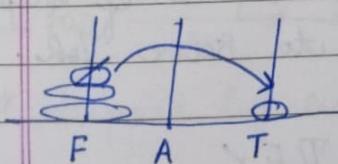
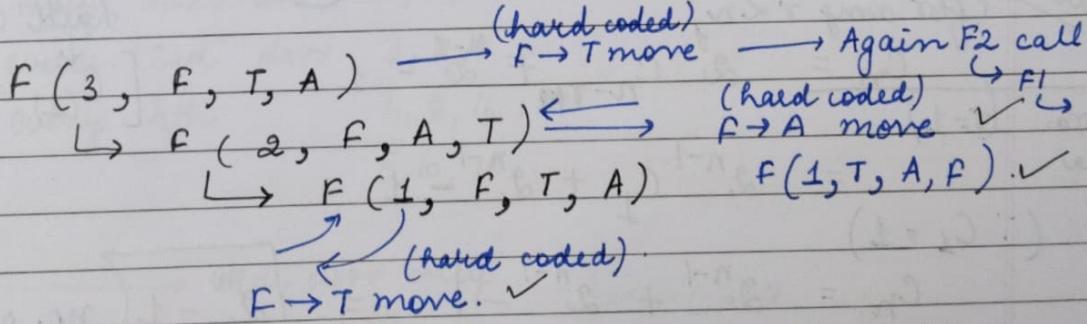
$\text{Toh}(n-1, F, A, T);$
move (A, C)}

$\text{Toh}(n-1, A, T, F);$

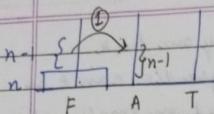
(Again)



(2nd step)

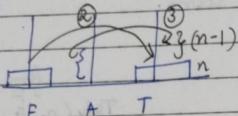


....



$T(n-1, F, A)$
move (F, T)
 $T(n-1, A, T)$)

Soln.



Beauty of Recursion

(Min no. of moves) $\rightarrow T(n)$

Now tell how many moves/steps $\rightarrow T(n)$
global variable count in move func.

It is calling recursively $T(n-1)$.
move again

$$C_n = C_{n-1} + 1 + C_{n-1}$$

(say) pattern dikhega.
 $[2^3 C_{n-3} + 2^3 - 1]$

$$= 2 C_{n-1} + 1$$

$$= 2 (2 C_{n-2} + 1) + 1$$

$$= (2^2) C_{n-2} + \underline{2^1 + 1}$$

3 ka aise
bhi likh
take

$$= 3 \text{ or } (2^2 - 1)$$

only knows
hard coded value.
 $C_1 = 1$

Ptn soln
(for any $r < n$)

$$C_n = 2 C_{n-r} + \underline{2^{r-1} - 1}$$

$C_1 = 1$

$$\leftarrow \text{dubara likhe hai}$$

$$= 2^{n-1} C_1 + 2^{n-1} - 1$$

$$(\because C_1 = 1)$$

$$C_n = 2^{n-1} + 2^{n-1} - 1 = \boxed{2^n - 1}$$

no. of steps
to solve $T(n)$.

Exponential solⁿ \rightarrow costly \rightarrow n[↑] so TLE

$\hookrightarrow O(2^n)$

if $n=3$; no. of steps $= 2^3 - 1 = 8 - 1 = 7$

$$\textcircled{*} \Rightarrow C_n = 2^r C_{n-r} + 2^r - 1 \quad [\text{where } r = n]$$

dubara
kriya

$$r = (n-1)$$

$$C_{n-(n-1)} = C_1$$

$$= 2^{n-1} C_1 + 2^{n-1} - 1$$

$$= \boxed{2^n - 1} \quad [\text{min no. of steps}]$$

↓
dec. hora $\textcircled{2}$

$$2^3 (2 C_{n-4} + 1) + 2^3 - 1$$

$$2^4 C_{n-4} + 2^3 + 2^3 - 1$$

$$\text{now } 2 \cdot 2^3 = 2^4$$

$$2^5 C_{n-4} + 2^4 - 1$$

Puzzle: eq. 100
 $\textcircled{1}$ doors, initially all are closed, $\textcircled{2}$ no. of people



$\textcircled{1}$ every door flip 1, 2, 3, 4, ...

\hookrightarrow 2 every other door 2, 4, 6 ...

\hookrightarrow 3 every 3rd door 3, 6, 9 ...

\hookrightarrow 4 every 4th 4, 8, 16 ...

\hookrightarrow 5 5, 10, 15 ...
!

\hookrightarrow 99 99th door only

\hookrightarrow 100 100th door only

100
 $\textcircled{2}$ No. of doors that
will be open at
end.

$$C \rightarrow 0$$

$$0 \rightarrow C$$

$$C \rightarrow 0$$

$$0 \rightarrow \underline{C}$$

* Flipped by even no. of people

* odd no. of people access here \rightarrow wo hi open karege.

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even $\rightarrow 0 \rightarrow c$.

$x_1 \times x_2$
 $x_3 \times x_4$

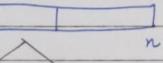
$6 \rightarrow 1, 2, 3, 6$.
 6×1 closed Rabha as even no. of people still touch doors.
 2×3

(odd) $\rightarrow x_1 \times x_2$
 $x_3 \times x_4 \rightarrow 2 \times 2$ perfect squares.
 3×3
 4×4 odd no. of factors.

eg: 16
 1×16
 2×8
 4×4

Merge Sort \Rightarrow Not in sorting algo, it is merging algo.

$f(n)$ ✓
magically know how to sort $f(n/2)$

n 

$n/2$ $n/2$ Magically sort Kardya Insertion sort for eg.

Now we should know only how to merge.

$1 \ 2 \ 3 \quad | \quad 4 \ 5 \ 6$

only 1 step \rightarrow know how to sort as its sorted.

merge sort (n) ?
if ($n = 1$)
return
 $mid = n/2$.
mergesort ($0, n/2$)

merge sort ($n/2, n/2$);
merge ($0, n/2, n/2+1, n$);
(yahi main as merging algo)

in dense mai se cuota aux move

only calculating mid

log n steps *

comparisons: $\leq 3n/2$

comparing & merging.
 $\log n + n \log n \approx O(n \log n)$

splitting merging

	Selection	Bubble	Insertion	MergeSort
TC	n^2	n^2	$\leq n^2$	$n \log n$
SC	1	1	1	\approx need same size of array
Caching	Not very good	V. V. good	V. good.	not very good

Merge ho sakta h. $\rightarrow [] | []$
5th ele compare

$[] | []$
10th ele compare

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Selection	Bubble	Insertion	Merge sort
X	✓	✓	✓

stability

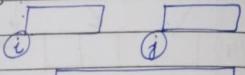
sweep

array boundary
 \downarrow
 merges(a, l, R, aux) {
 if ($L == R$)
 return;
 mid = $(L+R)/2;$

mergeS(a, l, mid, aux);
 mergeS(a, mid + 1, R, aux);
 merge(a, l, mid, R, aux);

(merge 2 sorted arrays)

merge(a, l, mid, R, aux) {
 $i = 1$



$j = mid + 1$
 for ($k = L \rightarrow R$)

i exhausted. if ($i > mid$) {

j ki hi ele. \leftarrow aux[k] = a[j++]; j

j exhausted. \leftarrow if ($j > R$) {
 aux[k] = a[i++]; i

i & j valid else if $a[i] < a[j]$ {
 i in less \leftarrow aux[k] = a[i++];

j in less else {
 aux[k] = a[j++]; j

fun ($k = L \rightarrow R$)

$a[k] = aux[k]$ move back to org array from aux array.

n log n (movement
 of data, technically
 no sweeps.)

Inversion Count. \rightarrow array given.

have to tell kishe misplaced, how far from
 sorting?

4 3 2 1
 \downarrow
 3 2 1

④

for $i = 0 \rightarrow n$

$O(n^2)$ for $j = i + 1 \rightarrow n$
 $a[j] < a[i]$
 $c++;$

Better soln.
 assume sorted
 compare main arr
 \rightarrow 4 3 2 1
 \rightarrow 3 4 1 2 Imagically
 \rightarrow 3 4 1 2
 \rightarrow 1 2
 $I = 0$

$j = 1$ if $3 > 1$
 so subsequent ele > 1 ✓
 $I = 2$

$j = 2$ if $3 > 2$
 so subsequent ele > 2 ✓
 $I = 2$

$4 + 3 + 1 = 6$
 \downarrow
 1 1

\Rightarrow same as merge sort.
 just return type c.

n log n approach.

Puzzles :- ① Aeroplane 100 seats, 100 passengers $1 \rightarrow 100$, come in same order.

1st person \rightarrow mad, kahan thi baith jaega. $\frac{1}{100}$ prob.
 2nd \rightarrow 100 \rightarrow normal, apne seat. \rightarrow agar 2nd ki occupied wo mad ho jaga $\frac{1}{99}$ prob.

find Pic of 100th person \rightarrow his own seat i.e. 100 no. seat.

② knockout tournament.

2ⁿ players.

\hookrightarrow e.g. 32, 64, 128, 256.

2nd best
team?

B/C ya
kaun.

\downarrow constraint. \rightarrow ck player

A ne jisse
match khela

wo consider for 2nd best.

\downarrow
Unka tournament hoga.

③ 5 track, 25 horse.

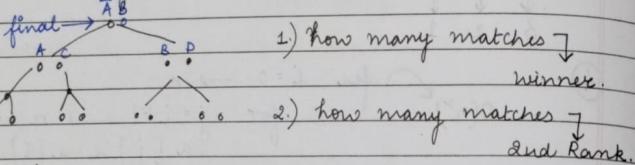
In how many races we would have to conduct

④ Dark room, ∞ no. of white & black hats in Room.

one by one come out & randomly come so dusso ki
hat ka color dusso ka dekh sakte, kudh ka nahi

\downarrow
Cond'n: ke clear boundary b/w white & black. (anything)

[Google code]



OS/CN

O/distro.

Rehing Sire.

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83
Aug 18, 2025

Ques: We are working in a company that is branch of Walmart. They have mechanism - hot product. N no. of products on page \rightarrow relisting / deleting products (like customer Product Name = Unique key. \rightarrow ne relist).

- o Max relisted
- o Min relisted

④ Constraint \rightarrow Bina product ke call nahi karenge.

\rightarrow 2 log ki same value ho gai to \rightarrow ?

\searrow Priority Queue (log n)

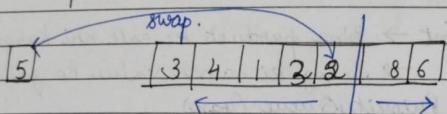
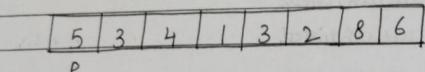
\searrow TreeSet (log n)

$O(1) \Rightarrow$ doubly LL.

Aug 22, 2025.

Quick sort → $n \log n$
 → worst n^2 (ordered) / asc or desc

- not stable
- not good use of cache, jumps
- swaps $n \log n$.



unordered arr



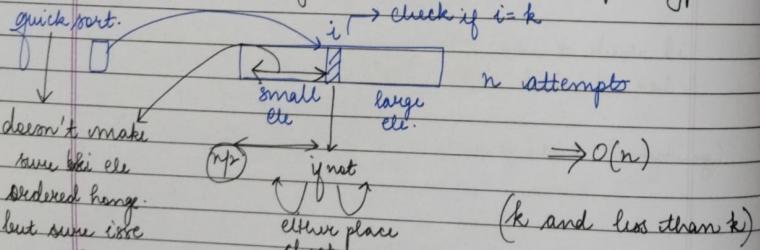
top k smallest ele

① max heap → $n \log n$ (built minheap) $k < \log n$
 (min heap) (decreas minheap)
 (comparable.)

② selection sort → kn . (faster).

* Google Ques

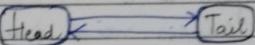
No indexing, unordered data, top 10 cgpa.

search criteria ko half, k k milie exit

Aug 26, 2025

 $O(1) \rightarrow$ Stack, array, linked list.

All One's Ques.



Node:

int freq;

Node next;

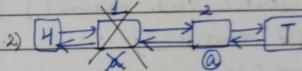
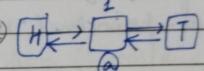
Node prev; (no duplicates, $O(1)$ complexity)

set <String> productNames

① a - x

→ a - 1

② a - 2



③ b - x

→ b - 1

④ c - x

→ c - 1

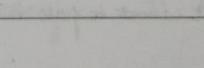
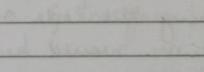
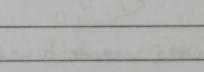
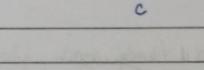
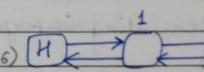
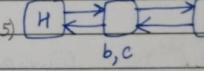
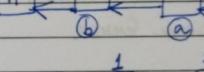
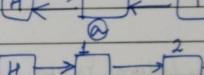
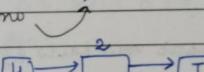
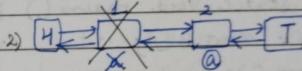
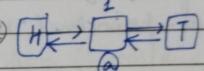
⑤ b - 2

→ b - 1

⑥ c - 2

→ c - 1

delete as no use



Problem Solving

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Interface

1) ↳ **Interface I** {
 public void foo(); → abstract methods
 public void bar();
}
3 class B implements I {
 B() {
 }
 public void foo() {
 System.out.println("Hello");
 }
 public static void main() {
 B b = new B();
 b.foo();
 }
 } → public void bars {} [have to implement]
}

Output ? ↳ Compilation Error
 ↳ Runtime Errors
 ↳ Hello.

Ans:- Compilation Error.

Class B is implementing interface but not overriding bar().

Java → Strongly typed language.
↓

Errors → u would want to catch them before shipping the code out
Runtime would be expensive if u won't want to pass this to customer.

2) ↳ interface I1 {
 public void foo();
}
3 interface I2 {
 public void bar();
}
3 class B implements I1, I2 {
 public void foo() {
 S.O. println("Hello");
 }
 public void bar() {
 S.O. println("World");
 }
 public static void main() {
 B b = new B();
 b.foo();
 }
}

Output :- Hello

3) ↳ same ques.
 just in main() ↳ obj of class B
 I1 b = new B();

Output :- Hello

Polymorphism → obj can take many shapes.

- 1) class
- 2) Base class
- 3) Interface

→ can't create obj of Interface I1 b = new I1();

1) → same fues
 public static void main () {
 Ia b = new B ();
 b. foo (); ←

as Ia doesn't know foo();

Output :- compilation Error.

* Class can extend only one class.

* Class can extend as many interfaces.

Object is parent class for any class in java.
 2 methods

equals hashCode

5) → class B {
 public void foo () {
 S. o. p ("In Base");
 }
 }

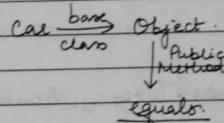
class D extends B {
 public void bar () {
 public void foo () {
 S. o. p ("In Derived");
 }
 }

public static void main (String [] args) {
 Data type of base class
 B b = new D (); ← obj is of derived class
 b. foo ();
 }
 }

Output :- In Derived.

* Polymorphism hai although datatype B.
 since obj of type D → In derived (always associated with obj, method will be called of class of which obj has been defined)

6) → class Cat {
 int size;
 int color;
 Cat (int size, int color) {
 this.size = size;
 this.color = color;



7) →
 public static void main (String [] args) {
 Cat c1 = new Cat (6, 8);
 Cat c2 = new Cat (6, 8);
 S. o. p (c1 == c2);
 S. o. p (c1.equals (c2));
 }

7)

Output :- false
 false.

- c1 never created, it is basically an address where obj is stored.
- c1 & c2 are diff obj & diff address lying at diff. places

• equals method, if not overridden it also creates the addresses.

• have to override to compare attribute values.

→ (Object class)
 public boolean equals (Object o) {
 Cat c = (Cat) o;
 }

Java → operator overriding \otimes
C++ \ominus

if (`c.size == this.size && c.color == this.color`)
return true;
return false;

Comparable Interface:

↳ has to
method → `compareTo()`

Classes → Integer, Double by default implement it

Priority Queue Generic Implementation

generics → can't compare 2 items using operator.

- less than → negative
- equal → 0
- greater → positive

- of type Object
- Typecasting to Item

(generic
 x/y)

Only method.

`(Comparable<Item>) pg[i].compareTo(((Item) this))`
`pg[j])`

Typecast to comparable
interface.

- Ques code Car → Runtime Error as Car doesn't
implement Comparable Interface.
Car will PQ code → can define `compareTo()` according to our
own requirements.

- ① Item → Template
↳ are instantiating Integer / Car while in main.
Define → `compareTo()`

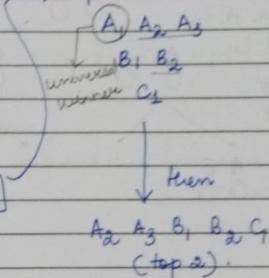
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C/ dinux

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Top 3 contestants

1	A ₁ ... A ₅
2	B ₁ ... B ₅
3	C ₁ ... C ₅
4	D ₁ ... D ₅
5	E ₁ ... E ₅
6	A ₁ , B ₁ , C ₁ , D ₁ , E ₁



② Flat Problem

① Aeroplane.

$$P_{100} = 100 \text{ people \& First is crazy}$$
$$= \frac{1}{100} \times 1 + \frac{1}{100} \times (P_2) + \frac{1}{100} \times (P_{100})$$

(less known
Hence 2 → P₁ = 1
hardcoded → P₂ = 1
Mathematically → 2 → 3rd person)

$$\dots + \frac{1}{100} P_2 + \frac{1}{100} (P_1)$$

$$P_3 = \frac{1+P_2}{3} + \frac{P_1 \times 0}{3} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{1}{3} (1 + \frac{1}{2} + 1)$$

(ager
apni jagah pr
bach gaya)

$$= \frac{1}{3} \times 1 + \frac{1}{2} \times \frac{1}{3} + \frac{1}{3} \times 0$$
$$= \frac{1}{3} \left(\frac{3}{2} \right) = \frac{1}{2}$$

$$P_4 = \frac{1}{4} \times 1 + \frac{1}{4} \times P_3 + \frac{P_2}{4} + \frac{1}{4} \times 0$$

$$= \frac{1}{4} + \frac{1}{4} \times \frac{1}{2} + \frac{1}{4} \times \frac{1}{2} + \frac{1}{2} \times 0 = \frac{1}{2}$$

[.. all still
P₄ will be $\frac{1}{2}$]

③ Knockout tournament Simulator.

given → better player | jo jira wo hamisha jitega.

∴ will return whoever has better rank.

if winner

whenever A has

defeated in

previous

stages



0 0

1.

2nd Best



long n stages



0 0

B D

0 0

2

4

8

16



0 0

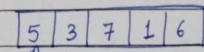
so on.

HashMap of each Player Id.

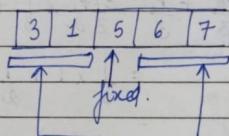
for ek knockout tournament firse kardiya.

Quick Sort

if we have ordered array.



Pinot.



left & right array will be
magically sorted.

it pick a value
(typically left most)
called pivot.

it takes pivot place
it correct position.

only 1 ele sort in 1
pass.

left boundary right boundary

$Q(a, l, r)$

if ($l \geq r$) return; (exit cond.)

$p = l$

$i = l + 1$

for ($i = l + 1 \rightarrow r$)

Inclusive.

Swap (i, j)

if $i = j$ nothing

else swap

original position of my first



if ($a[i] < a[l]$)

swap (i, $l + p$) \rightarrow found at least 1 ele lesser

swap (i, p) (pivot fixed)

Qsort (a, l, p-1); (not sort these boundaries)

- Q(a, 0, 2)

$p = 0$

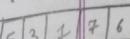
$l = 0$

$R = 1$

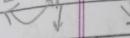
- Q(a, 0, -1).

- Q(a, 1, 1).

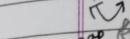
after 1 pass:



L if R

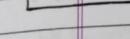


pi.



↑ ↑

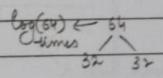
No swap fixed



RTC \rightarrow at each stage, $(n-1)$ comparisons.

as dividing ele in half-half, $\log(n)$.

$\therefore n \log(n)$



8

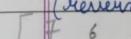
4

2

1

Problem:- If array was already sorted.
 \rightarrow for loop will run, swap would be
called, won't do anything.

(reversely sorted).



swaps

n attempts

↓

1 | 6 | 5 | 3 | 2

↓

imbalanced tree

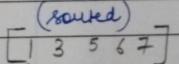
or $(n-1)$

n attempts

to reach bottom
of tree

↓

Quick sort = $O(n^2)$



7

5

3

2

1

↓

5

3

2

1

↓

ordered
array

Random
Array

→ To solve this problem, will take middle ele as pivot.

$m = (l + R)/2$; Swap (l, m); after end in q-sort.

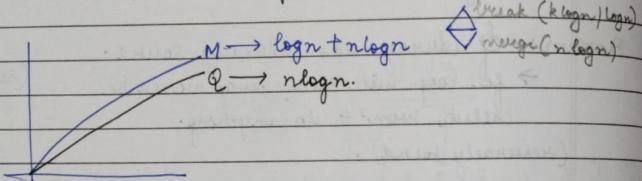
(May/may not work)
if middle is smallest
 $O(n^2)$.

5 3 7 1 6
↓
3 5 1 7 6

→ Take random nos. b/w L, R. → Pseudocode for $O(n^2)$.

$s = \text{random}(L, R)$;
Swap (s, l).

Time → $[n \log n / n^2]$
Space → $O(1)$, no extra space.



Stability → Not stable, very random access.

2 1 1' 3 5 7
L ↑ R

1' 1 ② 3 5 7

Swapped ($1' < 1'$)

→ better fix jaldi se dubara, sort kara, leket gyada slow

Caching → Not as good as bubble/inversion, but better than merge.

No. of swap → $(n-1)$ swap every time $[n \log n] = \text{Merge sort.}$

compare Merge Sort & Quick Sort.

Ques) k^{th} smallest? → ① Minheap → $n \log n$
k log n

② Selection Sort → $k n$

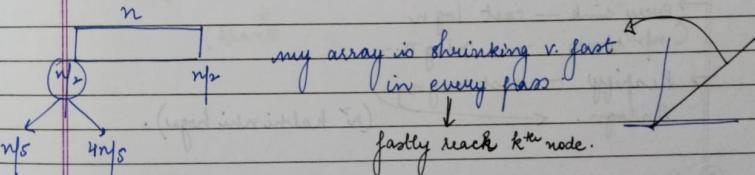
③ Quick sort → Quick Select.

* for unordered data all top smallest k
→ can search like in file/db with no indexing.

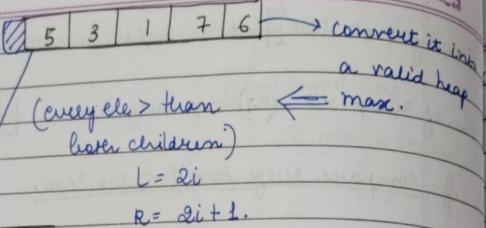
Select * from t
where id <= 10

(Agar yeah sorted chahiye toh nahi work hogya)

instead of Swap (L, p) outside for loop.



* Heap Sort:

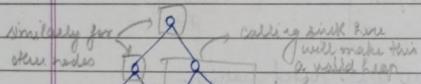


largest, to find other ele $\rightarrow O(n)$ nhi pata could be
2nd/3rd largest anywhere.

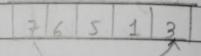
O(1).

① heapify (max heap)

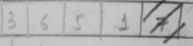
② n times call delete max.



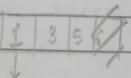
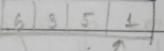
for ($i = \frac{n}{2} \rightarrow 0$)
sink(i)



swap last ele &
forget abt it.



sink(3) = $log(n)$



sink(3):

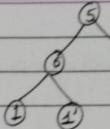
① RTC

every sink - cost $log n$
(n times $\rightarrow n log n$)

\rightarrow heapify - cost $n log n$
 $2n log n$ \leftarrow (n^2 kalsi hoga).

② Space $\rightarrow O(1)$ no extra space.

③ Stable. $\rightarrow X$



④ Caching $\rightarrow X$

⑤ Swap $\rightarrow n log n$

* Comparison \rightarrow why we don't use heap sort?

stability matter
where we use? \rightarrow no extra space

can use heap sort. (Heapify $\rightarrow n log n$).

Select * from t where id $\leq k$ ordered by id;
(in sorted order).

Merge $\rightarrow n log n$
Quick $\rightarrow n log n$
Heap $\rightarrow 2n log n$
Slowest out.

consistent

Problem Solving

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Sept 2, 2025.

- If an obj is using Comparable so its imp that its class implements Interface.

- diff users \rightarrow diff preference \rightarrow Comparable func.

only once (if we define
feel size, can do for
size only.)

\downarrow to lose this restriction -

- define default way

\leftarrow Comparator func.
(Interface)

- can specify explicitly
which way to go rather than
default.

\downarrow
can define 'n' no. of comparators.

Dept 5, 2025

Topic 1

$n \rightarrow$ power. (have to find if number is power of 2 or not).

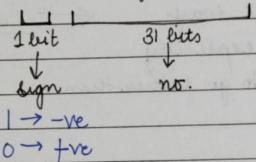
$$\rightarrow 8, 16, 64.$$

① if $n < 0$
 $n = -n$

$$n \& (n-1) == 0 \rightarrow \text{then true.}$$

② $n \& -n == n$

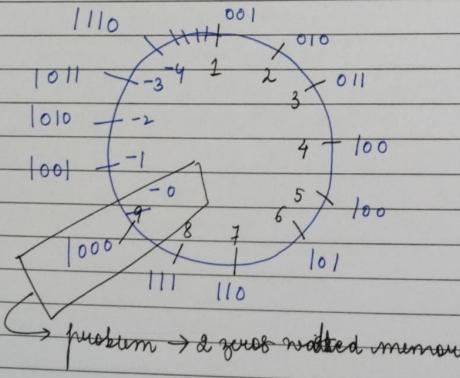
-ve nos. \rightarrow 32 bit system



\rightarrow Now if 4 bit number system

$$1 = \underline{\underline{0001}}$$

$$-1 = \underline{\underline{1001}}$$



- Date : / / 20
Page : ..
- 1) what is 0000, 1000, \rightarrow 2 zeros : memory wasted
2) Basic arithmetic doesn't work here. : computer will SUFFER a lot.

$$\begin{array}{r}
 3 & 0011 \\
 -2 & 1011 \\
 \hline
 & 1110
 \end{array} \rightarrow \textcircled{6} \text{ incorrect.}$$

Soln:

\rightarrow 2's complement \rightarrow add 1 to 1's complement
1's complement = \sim

$$\begin{array}{r}
 -n = \underline{\underline{\sim n + 1}} \rightarrow 2^s \text{ complement.} \\
 \downarrow \\
 \text{1's complement}
 \end{array}$$

Benefits \rightarrow 1. Completely Reversible both ways.

$$n = \sim(-n) + 1$$

2. All arithmetic operation work.

③ $3 = 0011$

$$-3 = 1100 + 1 = \boxed{1101}$$

$$3 = 0010 + 1 = 0011$$

④ $3 + (-3) = 0011$

$$\begin{array}{r}
 1101 \\
 + 0000 \\
 \hline
 0011
 \end{array} \rightarrow 0$$

no place for it (as + bit system)

⑤ assuming 8 bit no. system.

$$16 = 00010000 \rightarrow$$

for a no. to be 2^n
only 1 bit will be set.

Counting no
of one bits

① while $n > 0$

$$c + n \& 1$$

$$n = n \gg 1$$

return $c = 1$.

② 16 00010000

15 00001111

(2ⁿ) → 0

$$n \& (n-1) == 0$$

(with work
ve k dekh)

$$n \& (-n) = |n| \rightarrow (n < 0)$$

$$16 = 00010000$$

for 2ⁿ

$$-16 = 11110000$$

(+ve)...000010000...

$$16 \rightarrow 00010000$$

(-ve)...111110000...

also be written as

$$n \& (n+1) == n \quad (0 \text{ exception})$$

2 puzzles:

- 1) There is a magician in a big hall on stage, show a file of 52 cards. Random bande se random card, magician ko chdke sako dikaya, put back & shuffle & pick 4 cards. Audience goes back, now friend who was standing outside who has no knowledge, 4 cards are handed over to other friend. He will see & tell what was card picked by audience.
- Make strategy how?

Boolean algebra logic (decided)
color coding (magician)

Eq. K

as it is horizontal

0 →

1 →

2 →

3 →

(decided)
face up
↓
 $K = 1101$

↓
face down

Let 2 cards mai

↓

mai

Tough.

2) We have 100 cards instead of 52, square shaped

Nes hai bars → 1, 2, 3, 4, ..., 98, 99, 100.

Magician → 4 person from audience w

↳ All 4 people will pick Random cards

1 → 100 mice
2 → back 99

Audience ko dikhenge, wapas & shuffle (4 apas mai hi)

Now Magician will pick a card after seeing from

96, 5th card → top per rakna.

Magician find ke hand over → batadiya, kisne kesa
(5 cards ke dekhne) card nikala.

OPERATORS

0 & 0 | 0 ^ 0 ~ 0 >> 0 << 0 !

$$1,1 = 0$$

$$1,0 = 1$$

$$0,1 = 1$$

$$0,0 = 0$$

↓

guest ate → tea or coffee

↓

should be tea ^ coffee

diff and

flip the list

$$1100 \rightarrow 0011$$

$$!(15) = 0$$

batata

if it exists

or not

$$!(-15) = 0$$

$$!0 = 1$$

$$!(\text{anything apart from } 0) = 0$$

right shift

$$0.1100 >> 2 = \dots \leftarrow 1 \rightarrow | 2$$

$$0.0001100 << 3 = 0011000 \rightarrow * 2.$$

left shift

$$01 * 2 = 10 * 2 = 100$$

Q1) $-643 >> 31$

-n >> 31
→ ?

Q2) 8 bit >> 7

assume $\overline{1111}$

$$\begin{array}{r} 10010100 \\ \downarrow 2s \\ 01101001 \end{array} \quad \begin{array}{r} -108 \\ /2 \\ \overline{+1} \\ \hline 00000001 \end{array} \quad \begin{array}{l} \text{as any -ve} \\ \text{no/0 can never be +ve} \\ \text{so -ve rakhna hi hai} \end{array}$$

$$\begin{array}{r} 11001010 \\ \downarrow -54 \\ 00110101 \\ \downarrow +1 \\ \hline 00110110 \end{array} \quad \therefore$$

★ Right shift krene
but preserving 1's logic
-ve no hai toh 11 aane do
+ve no → 0. same do

★ left shift mai KOI DEMAG NHII LAGANA, 0 add karta raha.

↳ $-1 \infty / 2 \rightarrow \textcircled{1} \text{ hi raha.}$ ★

Q.) $-643 >> 31$

any -ve no.

$\boxed{1}$

(31)

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31 shifts.

Any -ve no. $>> 31$

$\boxed{1} \rightarrow \text{last mai parhanch jayega.}$

Aur \pm hi delta raha.

$$32 \rightarrow \begin{array}{r} 1111 \dots \end{array} \quad \textcircled{1} \swarrow$$

$$\begin{array}{r} 000 \dots \\ \downarrow \\ \hline +1 \\ \hline \dots 0001 \end{array} \quad \textcircled{1}$$

-16	$\boxed{12}$
-8	
-4	
-2	
-1	
-1	
-1	

Any -ve int $\infty / 2 \rightarrow -1.$

swap ($*i, *j$)

$$t = i$$

$$i = j$$

$$j = t$$

t not allowed.

Risk if $i \& j$ 2 ke ass pass (overflow -ve ban jaega)

$$i = i + j$$

$$j = i - j \rightarrow \text{only work.}$$

$$i = i - j \quad i + j \propto 2^{31}$$

No overflow.

Solution of this $\rightarrow \text{XOR.}$

$$i \wedge 0 = i \quad i = i \wedge j.$$

$$(i \wedge j) \wedge 1 \quad j = i \wedge j.$$

$$i = i \wedge j \quad i = i \wedge j$$

$$(i \wedge j) \wedge 1 \quad j \wedge 0 = j$$

$a \wedge 0 = a$
$a \wedge a = 0$

find

$$\begin{aligned} \text{TC} &\rightarrow O(n) \\ \text{SC} &\rightarrow O(1). \end{aligned}$$

Ques) all nos are in pair 1 is alone

1	2	3	1	2	[XOR all ele.]
---	---	---	---	---	----------------

Ques) same $\text{ele} \times n$ $\text{ele} > 0$

Ques) Same but in triplets with constraint

1	2	1	3	1	2	+ 2
---	---	---	---	---	---	-----

for ($i = 0 \rightarrow n$)
 $a[\text{mod } a[i]] * = -1;$

for ($i = 0 \rightarrow n$)
if ($a[i] \neq 0$)
reverse i;

$i = 0$	0	1	2	3	4	5	6
$a[1] \rightarrow$	1	3	5	1	3	4	4

five
2* done
new aya

Problem Solving

Gaurav six

Sept 9, 2025.

HashMap

use cases :-

① Database

RNo.	S. Details

key-value pair

eg. ↓ ↓
student student details
Roll.

• we don't want to compare key1 to key2.

Each key is an independent identity & doesn't depend on other keys.

↓
No relation b/w
key.

↳ C++ → Unordered Map

↳ Java → HashMap

↳ JS / Python / bash → Dictionaries.

- key1 < key2 \otimes

• Case → No key/value pair (not needed abt associated value).
↳ HashSet.

Implementation

1000 key / value pairs.

Goals : → Efficient Insertion
→ Efficient Deletion

↓
create array of 1000 size.

Insertion $\rightarrow O(1)$	k_1	v_1
$O(n)$	k_2	v_2
each	.	.
	.	.
	.	.

problems in
this implemen-
-tation

- ① $O(n)$ $\rightarrow O(n)$
- ② $O(n^2)$ $\rightarrow O(n^2)$ each

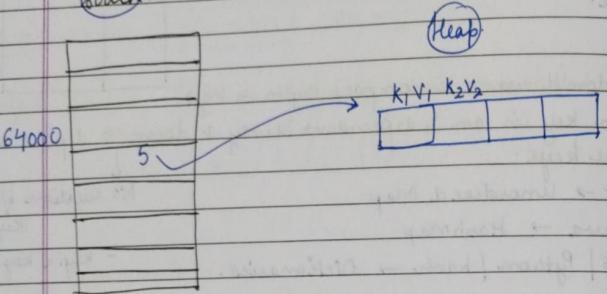
③ Millions / Trillions of entries. $\rightarrow [an \otimes size]$ (Space efficiency)
↓
done wanna

(not too
much
combc
ach-
-ived)

④ Real world problems \rightarrow everything obj. \therefore key \rightarrow obj \rightarrow No.
value

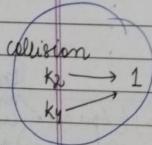
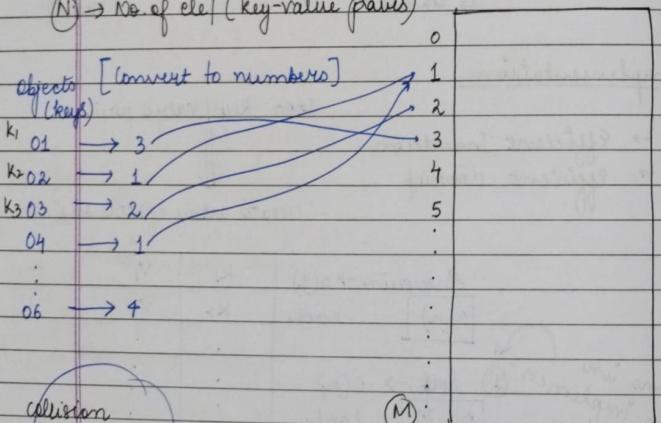
- Duplicate values not allowed.
- objects store total make primitive data types.

Stack



(N) → No. of ele / (key-value pairs)

arr



So how will you handle collisions?

↳ Hashing is a way to do Sharding.

① Data → Uniformly distributed.

If each storage indices have multiple entries.

↳ equally distributed.

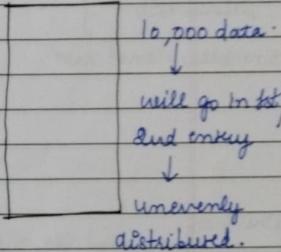
All must have N/M .

Cg. all-

0	~	→ $N/10$
1	~	→ 4
2	~	→ 1
3	~	→ 1
4	~	→ 1
5	~	→ 1
6	~	→ 1
7	~	→ 1
8	~	→ 1
9	~	→ 1

↳ last 4
first 8 characters
as index.

X
bad hashing
231099 → 0
231010 → 1
 $O(N)$
etc.
main kaff etc.



[www.google.com]
DNS → IP] ← Hashing

Hashing is the concept of connecting keys / objects into numbers.

Keys / objects → Hashing → Numbers

→ Basic one (Most often used for usual use cases.)

→ hashCode → object class

↳ class overrides.

memory address where obj is stored.

equals

Java contract.

$$o_1, o_2 \rightarrow h(o_1) = h(o_2)$$

equal obj.

desirable hashcodes are equal.
Required.

$$\rightarrow o_1 \neq o_2$$

$h(o_1) \neq h(o_2) \rightarrow$ Not Required but desirable.

- hashCode() implemented in Java such that it returns value of Integer itself.

String:

#

{ public final class String

"ab"

len=2

public int hashCode()

[0] = i

hash = 97 + 0;

[1] = i

hash = 98 + 3 * 97; $\frac{3}{3}$

\downarrow

This is how hash value of a str

$O(\text{length of String})$

consists created

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Cached:

$O(1)$

int hash = 0;

for (int i=0; i < length(); i++) {
 hash = s[i] + (31 * hash);

$\frac{3}{3}$

return hash;

prime no.

data - uniformly distributed

near handle collisions.

o1 {
 int 5
 int 7
} \downarrow
y

o2 {
 int 9
 int 15
} \downarrow
y

equals overridden.

false

\downarrow
hash code = 3
done ka same

(2 diff. obj. have same hashcode)

Cache..

class Foo { \Rightarrow This is how we create hashCode()
 x x;
 y y;
 z z;

public int hashCode() {
 int hash = 17;

$\frac{3}{3} \star$
 hash = z.hashCode() + hash;

$\text{hash} = y.\text{hashCode}() + 31 * \text{hash};$
 $\text{hash} = z.\text{hashCode}() + 31 * \text{hash};$
 return hash;

(Space efficiency level jao).

Even if $M = N$, there would be multiple instances with same hashCode.

goal → minimize (though they are bound to happen)

01. equals(02) → true \Rightarrow 01.hashCode() == 02.hashCode()

01.hashCode() == 02.hashCode() $\not\Rightarrow$ 01.equals(02) = true.

*Collision → & unequal object hashCode.

1st implementation

Separate Chaining

Typically $\rightarrow M \approx N/4$.
↓
closer to

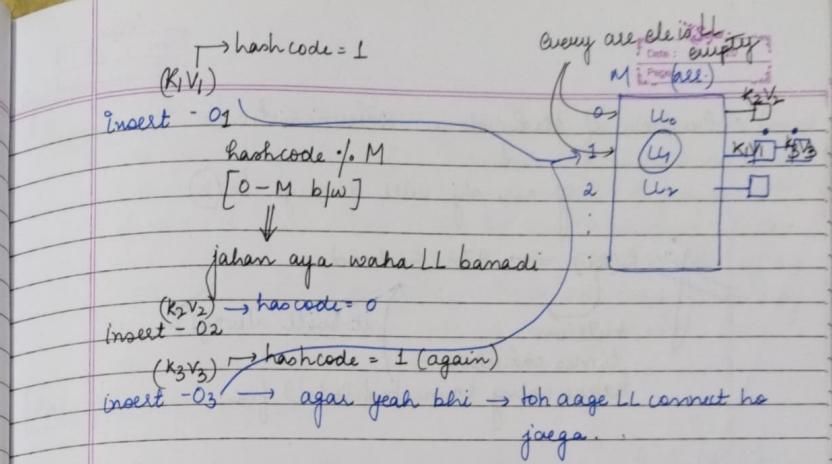
$M \rightarrow \text{size of array}$

$N \rightarrow$

resize.

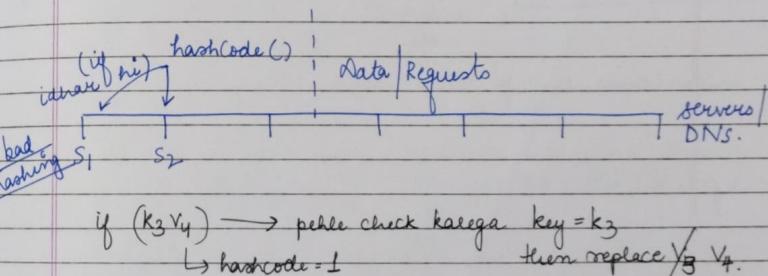
$\uparrow \rightarrow (\frac{1}{2} \text{ size}) M = N/2 \rightarrow M = N/4$

$\downarrow \rightarrow (* \text{ size}) M = N/8 \rightarrow M = N/4$



jahan par match kr jaegi wo return karo.
(pehle hashCode le denge aur fir usmai LL mai dhundenge).

→ size of LL = 5, if



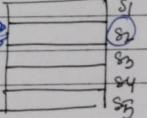
Java

String implementation of hashCode → uniform distribution

Badly designed

DOS

all requests



• Creation of hashCode is deterministic.
of an obj will always be $\text{② } x$

e.g. $h(k) \rightarrow 973$ hashCode.
million times calculate
hence using same hashCode() func.

it will always be.

September 12, 2025

Puzzle Prisoner to (total), you are one of them. one box \rightarrow white & black caps. Random cap is put on your head. last (10^{th}) can see caps of 1st of people. 9th of first 8 and so on till 1st set can't see any. jailor will come & tell 10th person to tell the color of his hat. He will start from 10th & ask everyone one by one to tell their hat color, if wrong shoot. Save max people.

Aus: Magician Puzzle II.

A B C D → (Consider in ascending sorted order) $\rightarrow 3, 5, 15, 97$

code

1 2 3 4 $\rightarrow \text{①}$

2 1 3 4 $\rightarrow \text{②}$

How many ways
can u shuffle these no?

$4! = 24$

[1, 2, 3, 4]

if also
5, 3, 97, 15

2 1 3 4
5 3 15 97 $\leftarrow \text{③} \text{ mukha ho.}$

Now what if yeah combination.

30 / 24.

5 ho.

25 \rightarrow 48 slot uthega.

30

9 1 25 49 73

← yeah nikala issi order
mai aise saare hint kaed
for 1st combination tak.
100 put kaedenge

[Ans: Purple]

probability hai

→ Raat ko strategy: aage aage kar boldega.

Mm → 5 (guarantee).
Max → 10 bach jaenge.

→ 2 types operators

$+1$
 $\ominus 1$
 \otimes

→ Result bologa

10th → +1 → 9th value -1 → 8th → Including
me * -1
here.
chahiye.
Save.

for 8th ke patako ke uoke
aage - hoga chahiye & so on blab blab ...

Max ⑨ save.

Puzzle Variant

① 3 color hats - Black, white, Red.
(10 people)

② Generalise ⑩ color hats (10 people)

③ Generalise ⑩ no. of people.

Triplets, lone.

Q)

[1, 2, 3, 1, 2, 1, 2].

$n \rightarrow 2^5 \dots$

$n_1 \rightarrow$ 1st position mai kitna ka sum 1

$n_2 \rightarrow$ 2nd " " " " " sum 2 lastt. $O(2)$

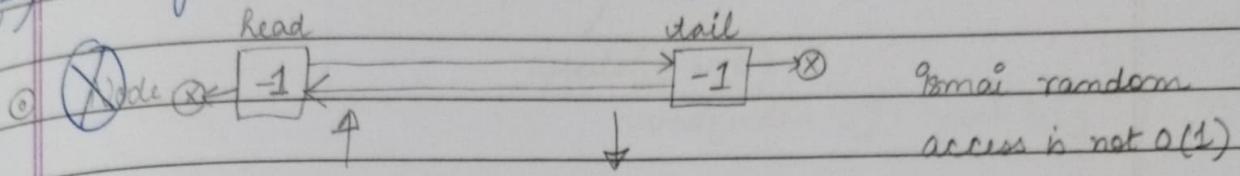
32 integers

ny pe jo sum aega o. 3 $\xrightarrow{3}$ 0 ← lonely no. ke
(3 pair) $\xrightarrow{1}$ is bkt position
pe yehi hoga

$O(n \times 32) \leftarrow T_c$

$O(32) \leftarrow S_c$

September 15, 2025.

Q1: Change $O(1)$ To Randomized Set.ArrayList, HashMap (val, index).RandomizedSet() \rightarrow ArrayList

HashMap

Random.

5

insert(5) \rightarrow true

7, 2

insert(6) \rightarrow true

3, 2

insert(3) \rightarrow true

6, 1

insert(5) \rightarrow false

5, 0

getRandom() \rightarrow ⑥

0	1	2
5	6	3

Index=1

lastIndex=2

remove(6) \rightarrow trueinsert(7) \rightarrow trueremove(1) \rightarrow false. [5, 3, X]

① I just used remove on ele while removing it from array but then $O(n)$ shift occurred & index not updated in map.

② for $O(1)$ swap kinda with last ele & remove the last ele.

eg:

nums1 = [0]
nums2 = [1]

$i = m-1 = -1 \geq 0 \times$
 $m=0 \quad j=0$
 $n=1$
 \downarrow
while ($j \geq 0$)
 $\quad \text{nums1}[index--] = \text{nums2}[j--]$

(Q8) Merge Sorted Array.

(Q8) \rightarrow nums1 = [1, 2, 3, 0, 0, 0] $m=3$ $i = m \times j < n$
 nums2 = [2, 5, 6] $n=3$

remain put [1, 2, 2, 3, 5]

(using as max change happen)

input change happen
 $i \downarrow$
 nums1 = [1, 2, 3, 0, 0, 0] $m=3$
 nums2 = [2, 5, 6] $n=3$

index = $n+m-1$

$\times \textcircled{3}$

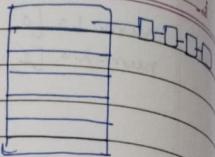
$i \downarrow$
 $j \uparrow$
 $f \uparrow$
 $f \uparrow$
 nums1 = [1, 2, 3, 5, 6]

fill to this ✓

Sept 16, 2025:

Separate Chaining : →

$$M = N/2$$



hash → uniform distribution.

Linear Probing : →

$$M = N$$

hash(k_1) → 2

hash(k_2) → n-1

hash(k_3) → 3

hash(k_4) → 2 → See there is

already present.

\downarrow
next location

$k_4 \neq k_1$ (hai present)

$k_4 \neq k_3$ (age bade).

get(k_4)

$k_1, k_4 \neq$

$k_2, k_3 \neq$

$k_4, k_4 =$

Completed.

Datatypes

1	(Key, Value)
2	(k_1, v_1)
3	(k_2, v_2)
4	(k_3, v_3)
5	:
N-1	(k_2, v_2)
N	

Recursion

foo() ?

once assigned $x = 5$ / $foo(1) / foo();$
Modified only 1 place
 $y = x$

If have to change do in another variable.



Tail Recursion

(Java, Python X)

(C, C++ supported)

Most of Functional

Programming lang

foo() {
 foo()
}

September 18, 2025.

Clinix

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2 lonely Nos [1, 2, 3, 4, 2, 1]

for $n \rightarrow$
XOR of all
 $x = 3^{14}$

for $\rightarrow 32$

2 categories 1/0

011100010100
↓
mask
8th bit

000001000

→ Divide array into 2 sub arrays. $S_1 = [1, 1, 3]$
 $S_2 = [2, 2, 4]$

for $i = 0 \rightarrow n$
 $x = x \wedge a[i]$

for $i = 0 \rightarrow 32$
if $x \wedge 1 = 0$ break
 $x = x \gg 1$ (will find 1st set bit)
mask = 2^i or $1 \ll i$

(Virtually make S_1 & S_2) a_1, a_2

for $i = 0 \rightarrow n$
if $a[i] \wedge \text{mask} = 0$

$a_1 = a_1 \wedge a[i]$

else

$a_2 = a_2 \wedge a[i]$

return a_1, a_2

Puzzle

3 hats:

B = 0

W = 1

R = 2

function sum(hats) // 3;
 $10^{\text{th}} = 1$
 $(9 \text{ hat sum}) // 3$

$\Rightarrow (a+b+c) \% m = (a \% m + (b+c) \% m) \% m$

$9^{\text{th}} \text{ person } (a_1 + a_2 + \dots + a_9) \% 3$

① 10th ne bataya → 2

③ 9th man → then meera definitely ①

② top 8 ka mod → 1

September 26, 2025

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Page:

Using Buffer → Thread Safe.

list < Integer > l = new ArrayList <>();

Thread t₁ = l.add(1);

Thread t₂ = l.add(2);

Thread t₃ = l.add(3);

Possible koi (if don't care abt order, bars all 3 rows) Think no need to
bari thread public → [1, 2, 3], [3, 2, 1], [1, 3, 2] bari thread safe.
add kardegi

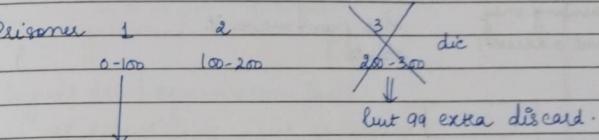
Possible kya? → [1], [2], [3] but possibility
of override
 $i = i$

thread over add (int i) {
 index = this.length;
 a[index] = i;
}
 a[i] = c
 if index < 0
 exception.}

↳ Readers-Writer Problem.

if R₁, R₂, R₃ are reading, no w
if W is writing, no R₁, no W.

purple King. He has 1000 barrels of wine. After 1 week, party in his kingdom & he has to drink all of them. Spy of enemy country, he knows if he add poison to barrel king will die. Jisse hi 1 barrel mai dala, pakde gaya, betadaya only 1 barrel mai dala & then died poison so hard ke 1 drop se kill in 1 week (time lagega). Soldiers have 1 week till party to figure out, have 10 prisoners to test. Need to find that 1 barrel in 7 days. King greedy 999 chahiye.



isko 50 yaar 85 ke set
mai bhi divide kar sakte.

[bottle no. karne, prisoners ko line up]
combinations

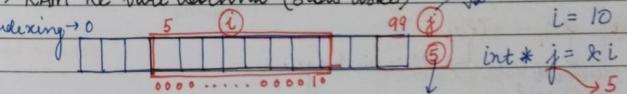
like bottle 49 → 1, 5, 8 but is combination ko
like bottle 9 → 1, 5 ko ✓ sing ek barrel no.

↳ 2¹⁰ combinations.
↳ 1024 10 → 1010
∴ every barrel no. unique combination. 11 → 1011
[unhi banda ko pilega]
80 jo majaenge -1, jo zinda -0 [80 jo no
banega library mai wo barrel poisoned].

Pointers

(&i, *i)

↳ RAM ke bare sochna (slots use)



5

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⑤
pointing to something at loc. 5.

float $i = 10.0$
float $*j = &i$

double $i = 10.0$
double $*j = &i$

[but my type is student (size = 50B)]
* → Integer.
always go to 5th loc. read 50B & j will be a valid int just tells slot from where it starts]

counting only (just address).

Struct $*j = &i$
 $i = \text{str} \{ \text{Cassine int 50B}$
float char

5 $10 \leftarrow i$

④ In C, pointer (*) just a location in RAM (virtual address space that is mapped not physical address space).
→ To understand think like a RAM.

10 5 $\rightarrow j = &i$

10 $\rightarrow k = &j$
(pointer of pointer).

⑤ If I have 4GB RAM \rightarrow 32 bit OS
4 Byte Integer.

ismai 8GB lagadiya toh waste, thi counting until hi nhi 4GB ke upr.
Now 64 bit OS

⑥ IPv4 IPv6
almost exhausted.
this is huge.

4 Byte [for machines aagaya]

In C \rightarrow int a = [10]

a[0]

[a is pointer pointing to 1st loc. in RAM.]

1025

a[5] \rightarrow 20 byte beyond this

a[-1] \rightarrow legal in C (gets one step back)

could be junk data / segmentation fault.

(∴ C is not robust lang., also chizon ka dhyaan rakhna, whereas in Java/High level lang., array is a class / wrapper over this array implementation)

C \rightarrow faster \rightarrow yeah sab check nhi karna pata, directly RAM.

(kisi se puchna nhi)

1024

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a[-1]
a[0]

a[5]

RAM.
Python \rightarrow net strongly typed,
(slow, lookup karta)

a {} \leftarrow (list)

int a[] = {1, 2.0, 1.5, "Ritesh"};

a[3]

object is just 2.0 a pointer

Ritesh

(lookup bana a = { Q Q Q }
liya ek talab)

(stores pointers in arrays)

size pata hi nhi (?)

internally
pointer

Java: Object \rightarrow Hashcode
(lookup x, class majeena).

Python → Data Science

↳ Numpy (list/array mai ek datatype ka).

Eg: To implement strcpy (char *s, char *d) {

 while ($d[i] = s[i] != \text{\'\0}'$)

$i++;$

 }

 while (*d = *s != \text{\'\0}') {

$*d += 1$

$*s += 1$

 } \rightarrow char pointer move by 1
 tak next char pr chalya jaga
 in RAM.

 while (*d += *s++) {

$*d += 1$

$*s += 1$

 }

 }

Q.) Simulate how OS does memory management.

OS → access to RAM.

P₁ → 2 byte mangta

P₂ → 20 byte

P₃ → 1 byte

Implement malloc & free

allocate (int n) { @ return pointer to space.

y

free (int i, int size) {
 by

(background) → chances of fragmentation / defragmentation

scattered hogi
tak waste.

20 Byte
First Fit

Best Fit slot \leftarrow size closest

→ So what Data Structure?
linked list

Initial FLL = [0, size] → null.
4GB

All = null

[0, 2 Byte] → null

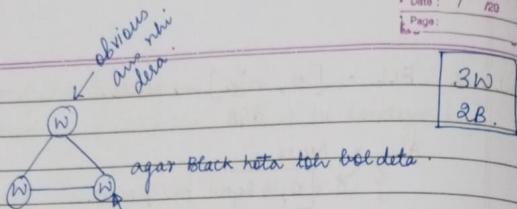
Puzzle:

rich cap merchant, he wants to hire smartest person on earth to work in his shop. Research → found 3

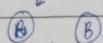
Bataya → box — 2 white caps, 2 black hats, 3 people are shown this, then blindfolded, then ke six per surf white hat (only we know, they don't). 10-15 min baad ek band kehta white hat is on his head. What logic? Bande Δ mai khade. baki 2 dikhe agne nhi.

October 3, 2025

Purple Ans:



case 1
agar 1 black hai obvious.



case 2



agar 2 black hote

→ toh yeh boldita.
nhi hota toh A ko
pata chalgay ki mera
white hai

case 3



jab dono confused kuch nhi hore.

→ matlab ispr white hi hai.

Memory Management (OS)

- n byte of free space (calloc / malloc)
- r. fast in freeing the allocated space

(free)

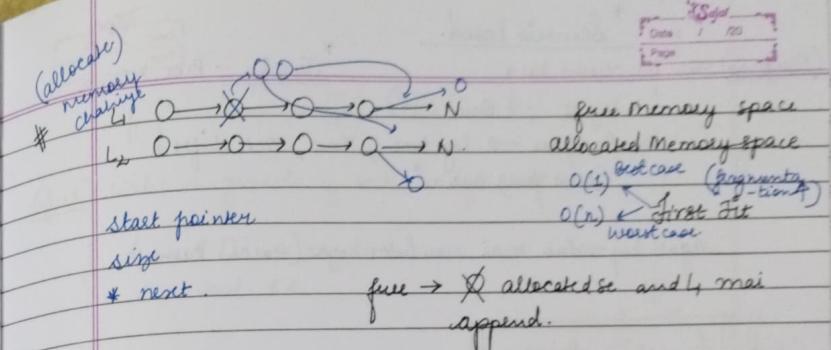
- make sure in background

Non blocking defragmentation

* Very fast & accurate.

↳ never give same memory space to more than 1 process

Design Discussion Question.



for accuracy → If parallel calls are coming ← Race Condⁿ. (non recoverable problem)

↓
Sohn have to synchronise

④ Multi-threaded hai → toh apply locks.

will store a
down a
list

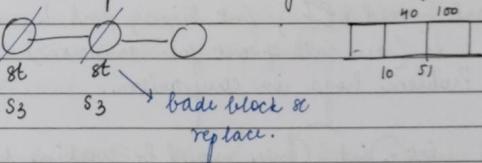
Best fit → slow

→ pointer dalna padega, aux puse
scan karna padega, better mitigate
toh more pointer.

(every search opr) TC

↳ Adv. → fragmentation ↓

→ Defragmentation per leni lock lagana chahiye.



BST → comparator based on size (allocation fast)

comparator based on initial pointer.

Defragmentation cost oya da BST, better for Best Fit Approach.

* Scenario based.

(Design) SQL DB choose kara

↳ MySQL → fine (✓)

↳ PostgreSQL → log time, slow, OLA shifted
(also fine) but ↑

agar key-value mai use hoga (search kaene)

Function Pointer

↳ C → callbacks.

Genetic programs.

qsort (int [] a, int size, int L, int R)

Now

what if I have to sort double / string?

Struct student (→ sort this on based of id.
id)

\equiv $\begin{bmatrix} s_1^* & s_2^* & s_3^* \end{bmatrix}$

[void ** a]
a

↳ qsort (void ** f, int size, int L, int R)

↓ (can call qsort for any now)

Ab Problem hoga in comparison.

int (<) int (only would be working for numeric.)
different from this void * all, have to pass func
pointer for comparison.

qsort (, int (* comp) (void *, void *))

* Justify - Pros & Cons

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if (a comp (a[i], a[j]) < 0)

swap func also generic

Ques) Make a generic qsort, merge-qsort.

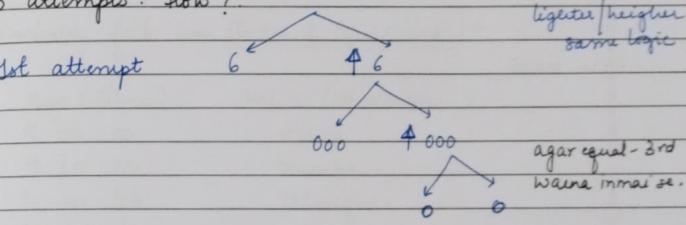
{ char * [] → char **
i.e. void **

its func signature.

swap (void * a, i, j)

Puzzle ① 2 sided天平 scale

12 coins / balls identical → unmai se ch galat hai (helka h)
Find which is counterfeit coin / ball in not more than
3 attempts. How?



Puzzle ② 10 bag → ∞ no. of coins identical (10 gm)

1 bag gadbad → all coins unmai counterfeit hai
(10.1 gm)

Given normal electronic weighing scale → tell counterfeit
(↑ scale, sare bhi sarek sarek) bag.

Single use.

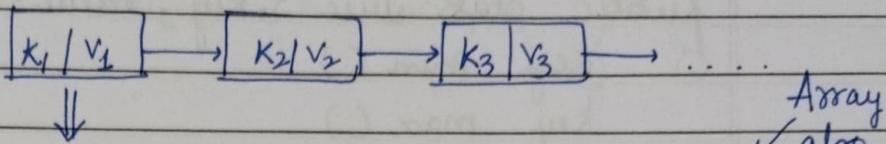
Puzzle ③ Variant of ② . We don't know heavier/lighter hai
Boaki sab same.
countfeit coin.
(defect kya h).

October 6, 2025.

Problem Solving

- Stack \rightarrow LIFO, Queue \rightarrow FIFO.

- linked list



TC for searching if using LL $\rightarrow O(N^2)$ also $O(N)$ for 1

- Priority Queue \rightarrow Max key / Min key.

- HashMaps \rightarrow if implemented correctly, near $O(1)$ performance for search $O(N)$.

HashMap fails in Ordered Operations :-

Source \rightarrow Cnd.

Eg:	Keys (Times)	Values (Destination)
	9:00 : 00	Delhi
	9:10 : 00	Mumbai
	10:30 : 45	Srinagar.
	10:45 : 30	Goa
	11:00 : 00	Bangalore.

if I implement hashmap

so if I give key [10:30:45] exactly \rightarrow Srinagar.

Query what flights [b/w 10:00:00 & 10:50:00] \leftarrow can't do using hashmap.

\checkmark for 1 $\rightarrow O(N)$ \leftarrow PQ / LL / Array
 \checkmark $N \rightarrow O(N^2)$.

which flight going out

of Cnd [before 10:32:00 AM]

also tell time.

floor, ceil. \rightarrow (next)

[$N \log N \rightarrow$ linear arithmetic]

Data Structure Designing \rightarrow BST / Balanced ST

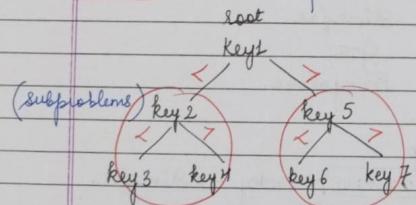
```
public class Tree { Key, Value > {  
    Key min()  
    Key max()  
    Key floor(Key)  
    Key ceil(Key)  
    Key get(Key)  
    Key put(Key, Value)  
    void delete(Key)
```

Operation we would wanna implement in optimized way.

T N^2 N $N \log N$ ($\text{v. close to linear & better than quadratic.}$)

(see referential DS)

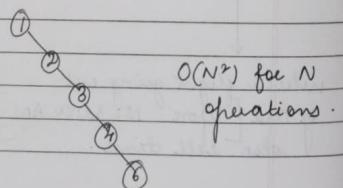
Trees



```
class Node {  
    Key key;  
    Value val;  
    Node left;  
    Node right;
```

Order of Operations:

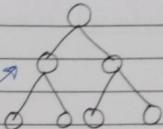
- put(1)
- (2)
- (3)
- (4)
- (5)



$O(N^2)$ for N operations.

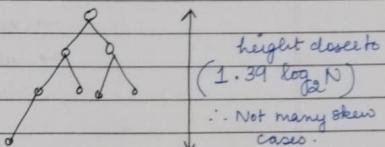
wanna have kinda balanced.

(BST doesn't guarantee this kinda structure)



In real world Data \rightarrow as long as Delete operations are not involved.

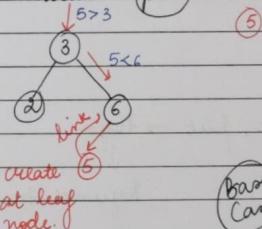
then we could use BST



but asal mai can't risk right/left skew \rightarrow

∴ use Balanced ST (Performance also comparable to BST).
(Doesn't bring much performance implications)
($\log N$ operations)

Implementation: put



(5)

```
private Node put(Node x, Key key, Value value) {  
    if (x == null) {  
        return new Node(key, value);  
    }
```

Base Case

(like student table override address)

duplicate, so override

```
int cmp = key.compareTo(x.key);  
if (cmp == 0) x.value = value;
```

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```

else if (cmp < 0) x.left = put
    (x.left, key, val);
else x.right = put(x.right, key, val);
return x;

```

y.

Tree kahan use? → DB

→ key value DS hai

→ all crud operation in balanced tree → logn

Array → LL → Stack | Queue
 (fast, random (no contiguous) (LIFO) (FIFO))
 access, but
 contiguous)

Binary Search → Tree | BT.
 (a lot in commerce & sale)

update fast search ✓

insertion, deletion, X

Implement → get, put → logn
 ↓
 keyunkt hne layer.

Q Why extends & not implements Comparable?

java → generics ← extends ✓ ∵ extends
 implements ✓ → × grammatically sati.
 (dhundega kya kera but kuch nhi kera
 child hai bas)

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key → class, but interface wali properties parent-child wali

BST < Integer, String>



any comparable.

* del(k) → ① k.left == null

return k.right

② k.right == null

return k.left.

③ l = min(k.right)

l.right = delmin(k.right);

l.left = n.left.

October 10, 2025.

Puzzle

12 coins Problem ii

→ brute force

→ attempt mai
hogaega.→ Representations of Combinations etc.
ternary no. ka concept

L Heavy = + 1

have to keep same no. of

R Heavy = - 1

coins.

equal = 0

$$\hookrightarrow 1 = 1 \times 3^0 + 0 \times 3^1 + 0 \times 3^2$$

$$\hookrightarrow 2 = -1 \times 3^0 + 1 \times 3^1 + 0 \times 3^2$$

$$\hookrightarrow 5 = 9 - 3 - 1 \\ = 3^2 - 3^1 - 3^0$$

$$\hookrightarrow 7 = 9 - 3 + 1$$

10	11	12										$3^2 A_3$
5	6	7	8	9								
5	6	7	8	9	10	11	12					$3^1 A_2$
2	5	8	11		1	4	7	10	11			$3^0 A_1$

↓
Not balanced.→ Exception ⑨ ultra bolenge
• kyunki jagah change kedi

off 1st → 0

2nd → LD

3rd → LD

(12)

lighter

9	7	11	12									
11	5	6	12	2	3	4	7					

(5 → LLR)

7	2	5	8									
7	2	5	8	1	4	10	11					

testing

↓
aur koi no. yeh pattern nahi bana saka.

→ Assume ⑤ heavy.

$$1st \text{ Attempt} \rightarrow LD - 1 \times 3^0 + -1 \times 3^1 + 1 \times 3^2.$$

$$2nd \text{ Attempt} \rightarrow LD = +5.$$

$$3rd \text{ " RD}$$

→ Assume ⑪ lighter.

1st → LD

$$(-1) \times 3^0 + (+1) \times 3^1 + (+1) \times 3^2$$

2nd → RD

$$= +11$$

3rd → RD

$$\begin{cases} + \text{heavy} \\ - \text{heavy} \end{cases}$$

heavy normally but exception light

(Q) discuss ③

$$0 \times 3^0 + \pm 3^1 + 0 \times 3^2 \\ = ③$$

strongly
typed

(WebKit
Dynamically
typed)

[JAVA] why Java? - comparison c/c++.

- Away from hardware compared.
- GC → memory management nahi karen.
- Robust Multithreading
- being open source → web frameworks
- Robust language - lot of things caught (memory management) stops doing mistake. nahi at compile time / runtime.
- pointers → security
- (complex task / not robust.) Mai aisa nahi hota.

Java as a whole → 99.1% OOPS.
(Valid OOP ✓ can't do anything without class.)

small (ka koi parent primitive data types nahi karta) turn trust karo
code acha likhega.
(can't build, have to use classes)

- but as Java supports Primitive.

all class child of Object, parent by default extends Object

(at least 1 parent). Mention nahi karta as Y hi extend karsakar
Java → double inheritance tak support karta.

equals() → override ho raha hai.

GC → bg mai low priority ke sare chale hote, tab zyada active job memory full.
finalize() → not paka but GC ke GC chalya

C → hardware → OS se terminal mange [asking for memory]

Linux fix
Yeah func na
to kee our name
so nahi hog.

(Java mai JVM kaha does for us)

c
main()
func()
getMemory()

Big Endian, Small Endian

write &
compile
Code
OS | AC | F9
Big
Small (bit manipulation aasan for OS).
JVM is always Big Endian

Big
Endian mai!
different
format
Byte code, code share ✓
.out file
seln
.jar
get PDB

write compile
class
Java
(Big Endian)
sent to
small
Endian.
process name
Java / JVM hi hai
Small → Big ← JVM manipulate
These conversions
JVM does for u.

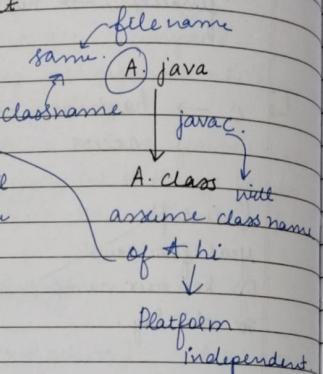
* JRE → Java RunTime Env.

doesn't have compiler

* JDK → Java Development kit

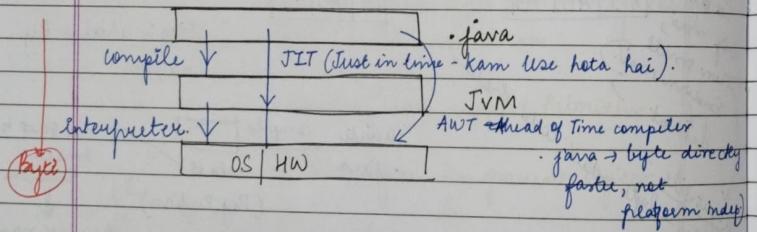
has compiler + JRE

if not
(Java runtime pur fail
nhi hota, class name
doesn't match)



JDK ka path:
javac ko chaladega.

A. class → first few classes (Random Selection)
caffebabe ← fix
to identify * class hai.



Byte

fringloot ki tarah)

Micromant → AWT ka use keta.
ek framework.

java A ?

hello. ←

compiled file

class A

PSVM

=

search(A)

search(B)

folder kabhi & dhunde corn.

JVM.

Object Pool.

String Pool

Class Pool

3 types of class loader.

Class Path, cur
directory

App class loader
make ka parent

B
ismai
dhundega.
cur ka parent.

External class loader
age magi ka parent.

tom
RT.jar
found file
return; if not
for exception know)

Java → follow

Delegation
Principal

koi kaam nhi
kaena chalta.

deduce:
By chance hote
(RT.jar)

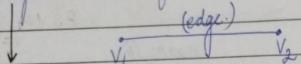
October 13, 2025.

Problem Solving

GRAPHS.1

1) Undirected graph.

Graph \rightarrow set of vertices connected by edges.

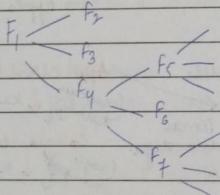


∞ applications

helps mimic a logical process (flow)

④ Facebook Networking / Connection

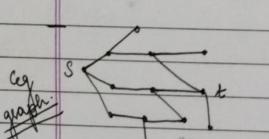
⑤ Computer Networks



(so many paths, still reach Source \rightarrow Destn.)

⑥ Data structures.

(Sequence of steps - directed graph as path like binary search tree jaega).



- 1) Is there path b/w s and t?
- 2) What is shortest path?
- 3) Cycle (Problems we need to avoid)

e.g. designing a curriculum.
 1) Discrete Algebra \rightarrow 2) C Python \rightarrow 3) DSA
 \rightarrow 4) C Python \leftarrow 5) Data Science.
 cycle (not nice)

4) Connectivity (Computer Networks)



⑦ Designing Graph class.

public class Graph {

graph(int v). \rightarrow No. of vertices. (create empty graph
 $\quad \quad \quad$ (2 vertices) with v vertices)

public void addEdge(int v, int w). \rightarrow lot of
 $\quad \quad \quad$ adjacent vertices.

public Iterable<Integer> edges(int v). \rightarrow gives no. of vertices

int e(). \rightarrow gives no. of edges.

g

How to design? \rightarrow

- 1) Adjacency Matrix
- 2) Adjacency list.

⑧ 2D Matrix \leftarrow v (No. of vertices)

	1	2	-	-	v
1	T	F	F	F	F
2	F	T	F	F	F
1	F	F	T	F	F
1	F	F	/T	T	F
1	F	F	F	F	T
v	F	F	F	F	F

\rightarrow Initially all would be false
 \rightarrow both sc connected so diagonals = true
 addEdge(4, 3)

Adv \rightarrow TC \checkmark (no traversal, just go to row & do useful).

\rightarrow But graph ka size hoga $4 \uparrow \uparrow \uparrow \uparrow$
 \downarrow (complexly complex real life networks.).

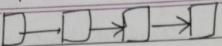
1) $V \rightarrow$ very very high

2) Sparse Graph.

(No. of edges from 1 V to another \downarrow
 \downarrow as compared to size of graph).

\therefore practice \rightarrow Adjacency List.

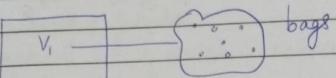
V1



(Can have)

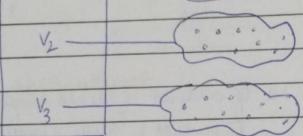
- Linked list
- Hashmap
- Array
- (problem dekh ke
we have to think
what makes sense)

V2



bags

V3



bags

- Performance slightly slower than adjacency matrix.
- But we save a lot of space.

(Can't have)

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Rohit Sirohi

Date : / /20

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CN|OS

October 14, 2025.

Caching

fast, in memory
usually.

geolocation

DNS

Cache

Root to like face book, calendar,
etc. time → have a lot of hits
(time & effort save).

DB call - very heavy operation (I/O op)

* (Storing info near u, so that don't have to
call DB / do networking again & again)

* CDN

(Content Delivery Network)

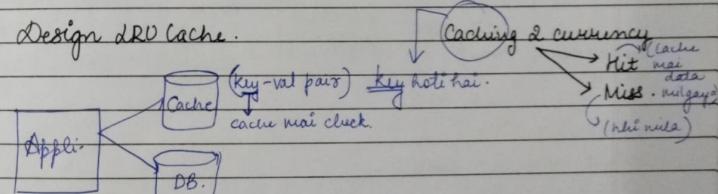
Actual Source

Whenever u use caching,
disadvantage ?
↳ INCONSISTENCY.

(Report my show - UI mai update nahi hua (DB mai tharam ho gaya)
payment karna jaab tak cancel → not available)

(Unfollow someone - kuch se ke hand dikha h → as Read from
cache & Write in DB).

Ques) Design DRD Cache.



Q.) What is the matrix of Cache ? List kisi
(so so requests de) kisi kisi

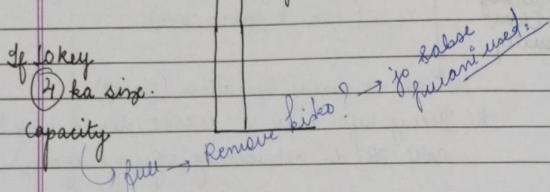
hit / miss is nice.

(But can be disadv if DB is getting frequently
updated, cache se inconsistent ubi kesa chahiye)

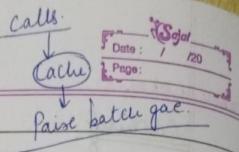
[DynamoDB → AWS NoSQL DB].

↓
about currency → acc to read
write

LRU → Least Recently Used.



Kam se remove karke head/tail → Linked List.
+ Hashmap.



October 27, 2025

C/dimz.

Compiler

④ Code → to something
JVM understand

⑤ JVM translates
to Machine
language.

Package com. chitkara.
import com. chitkara.A
class Test {

public static void Main (String [] args) {
(platform independent)

3
3

.class
Magic No.

= (import, static &
field val etc.).

Java Test
PCB

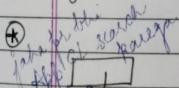
(top) and.

JVM has
component

1. Java finds Test.
2. Loads Test if find A also needs to be loaded
3. Find A & loads it.
4. String class
5. Object

Class loader.
(follows
delegation
principle - kudh
kaam nahi karna,
deligate work to parent.)

(Instead of
searching in
classpath
of parent ↓
parent is ext
ext CL
↓ JavaCL
→ Root CL → rt.jar



⑦ if we import set.

Java
↳ utils
↳ set.

it works to
select, run
JRE
↳ lib
↳ ext.

(typically lib
folder mai
Rota bata).

✓ Ab root CL ko st. jar mai nahi miliga toh Exception throws karega

✓ Ext CL also exception throws karega

Milega toh thik maina exception throws.

Agar mai set banalun apne current dir mai wo kabhi load nahi hogा as Opp CL X

↓
↓
root CL → rt.jar

class Path

x.jar x.vc.jar y.jar.

(Hence do any reason some class named h inside package name, so under jo milega wo load kardige)

[JAR HELL] → production mai kabhi chalta h kehte h
(developer ko duryam rakhna hoga kya as Java nahi bataega).

→ Class A {

final static int i = 10;
int j; → instance / field / non-static variables

A a1 = new A();

A a2 = new A();

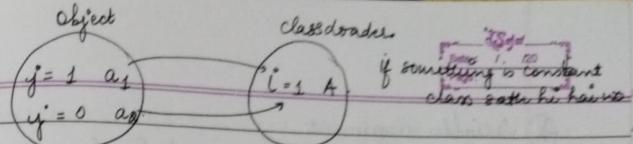
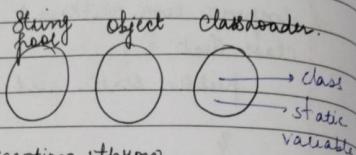
a1.i++

a2.i++

print

a2.i = 1

a2.i = 0



→ automatic type casting

int i = 10; → 32 bit

long j = i; ✓
↓
64 bits ← 8 bits as akta alarm

long i = 10;

int j = i; X → typecast
↓
if no. out of int → range data loss.

range data loss.
programmer ↓
ki responsiblity ke int j = (int) i;

int ki range
computer ko sare daat nahi.

→ JAVA = Auto Widening

class T { public fil mai scan hakee finds best fit, deon't matter phele ya badmash)

→ public void print (long i) { } [matter phele ya badmash]

→ public void print (int i) { }

→ public void print (float i) { } [now best yeah.]

→ t.print (10);

→ Polymorphism → Overriding

Overloading (have to make sure arguments are diff., return type doesn't matter) name same.

→ public void print (Integer i) { }

t.print (10);

Wrapper class.

Auto Boxing

Auto Unboxing

agar (int i) fnc lehi hai toh best fit dekhiga.

print (int i);

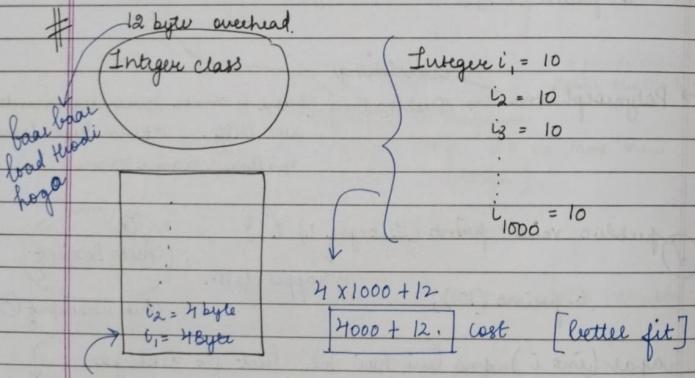
t.print (Integer)

④ Variable argument

public void print (int... i) { (agar nahi mila toh
S.e. pln (i[0]); Variable argument
3 walla choose
t. print (10, 20, 30); (agar nahi mila toh
t. print (10); iske case mai satth mai
still best fit) still best fit
java null still best fit public void print (int i) {
best fit.

public void print (int... i) {
public void print (Integer i) {
public void print (long i) {

t. print (10); → Ab Kisko choose
karega ???



heap

long → 1000 long → 8000 cost · auto widening
zyada space lega

Java Architect → int... → set preference.
hata mai Integer → 2nd
Long → 3rd

HISTORY

- * auto widening → 1st version of JAVA
- * auto boxing / auto unboxing / varargs → 5th rev. of JDK

Always backward compatible.
(as pehle bana, java ke apni
gandagi sakni padti hai).

1st preference → long
2nd → Integer
3rd → int ...

→ long wrapper class X ← Auto widening & Auto boxing done nahi
[No] karega.

OOPS.

1.) Polymorphism → Overloading
→ Overriding

2.) Inheritance → • Interface
• class

*) abstract class A { } instance X
→ B extends A { } child ✓ How to create
use abstract
method implement
karna padega.

abstract method.
(jiski implementation
nhi hai)
fail at compilation
as ase
Issue aa
sakta h.

Interface ke andar vali abstract method hai
Sabko implement karna padega
no instance

faked Multiple Inheritance (diamond problem logi ki
nhi as no implementation)

Java → confusion ko avoid karta hai.

Date: / /
Page: / 20

Date: / /
Page: /

class Car {

class Maruti extends Car {

g
chalta

g

✓ parents f1
✓ override f2
✓ method f3
Car c1 = new Car(); ✓
Car c2 = new Maruti(); ✓

Maruti m1 = new Maruti(); ✗

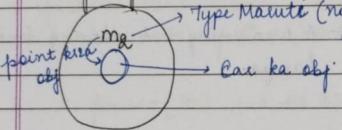
Car c1 = new Car(); ✓

Car c2 = new Maruti(); ✗

Maruti m2 = new Car(); ✗

Maruti m2;
m2 = new Car();
At compile time still allocated.

Object pool.



lets assume

Car → methods → f1 f2 f3
Maruti → methods → f1 f2 f3

fatega ← At runtime.

so net
allowed.

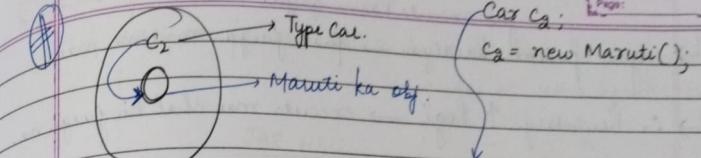
f1 ✓ f2 ✓ f3 ✗

as obj to
Car ka hai.
(Maruti ka
nhi).

variable
time

* Type
decides
scope
(would have all
features of type class).
Mujhe kya beta point
pu kiske point
karao.

Date: / /
Page: / 20



Car c2;

c2 = new Maruti();

iske baad.

C2. f1(c)

C2. f2

C2. f3 → Car Type f3 nhi
hai so compiler allows

m2 ko m1 name diya
new obj nahi ban raha yaha.
Maruti class ka obj hai.

[Compiler kind of disclaimer ke
C Car type beli has aksa hai but
ab tumhari sardari]

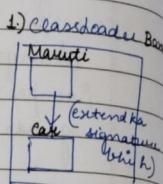
Maruti m3 = (Maruti) c2

m3. f3 ✗

Maruti ka obj

tum chaitaega.

(Make sure
new obj nahi ban raha yaha.
Maruti class ka obj hai).



peti class hooge
hoga.
obj baad mai
banega.

* Car () {

protected f() { } ✗

g

Maruti extends Car {

protected f() { } ✗

protected f() { } ✗

(guess) Child class visibility ↑ kar sakta

Visibility → can make
private, public / default.

mauti m = new car() → ✗

car c = new Maruti(); → ismai

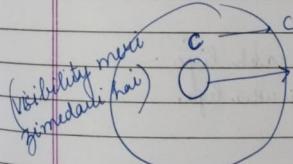
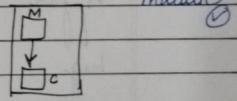
child class can change
visibility → can make

private, public / default.

Truth car c = new car() ✗

mauti m = new Maruti() ✗

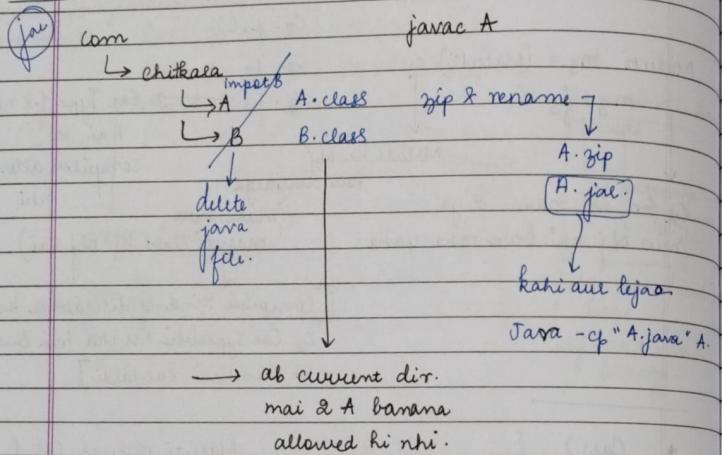
confusion



c.f() → compiler toya nahi means
(protected ki range mai se chalaii code)

Runtime pr → as visibility + ho jai.
 jab execute kaene gaya.

→ agar private kaadiya → phat jaega. runtime mai
 ∵ boundary ↑ hogi → execute mai chal hi jaegi na.



→ but jar ke case mai & A banadi | copy. → ab karna A

Jar - cp "A.jar" A
 Jar - cp "*" A

uthaega
 ↓
 koi bhi
 no logic

A.jar A-VI.jar

bug
 ↓
 versioning (fix)
 kisi bande ne done rakh liye.
 Ab classloader koi bhi utha lega.

aisi lot of places ho sakte

↑
 ab class path pr bhi hai, Ajar bhi hai so classloader ander se utha lega ke kahi pata nhi chahga.

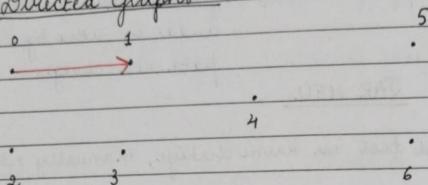
JAR HELL.

jhunge build tool use karne chahiye, manually nhi karne chahiye

Problem Solving

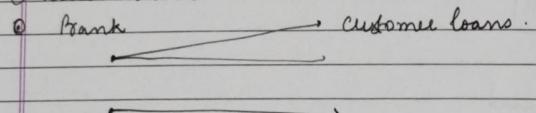
November 3, 2025.

Directed Graphs.



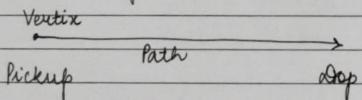
Many Many Applications :-

① Read Network.

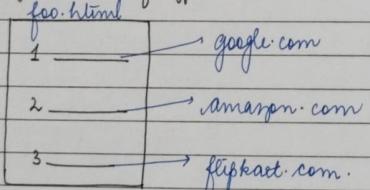


bank would give loan to customer.

② Uber | OLA trips

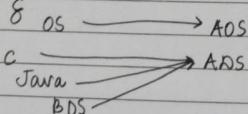


③ Web page (A lot of hyperlinks)



web crawler implement:

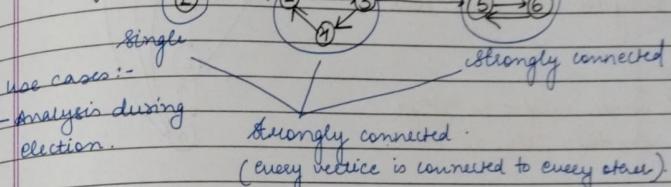
④ Scheduling



Implementation of programming languages.

Problems :-

- Is there a path from $s \rightarrow t$?
- What is shortest path b/w $s \rightarrow t$?
- Is there a directed cycle.
- Topological sort.
- Strong connectivity.



6. Transitive Closure.

7. Page Rank.

↳ Directed Graph Implementation

↳ BFS

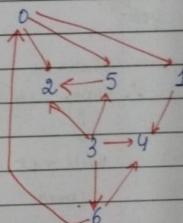
↳ DFS

↳ Web crawler \rightarrow uses BFS.

↳ Topological Sort.

e.g. Courses

- algorithms
- Complexity Theory
- AI
- Basics of CS
- Cryptography
- Scientific Computing
- Advanced Programming



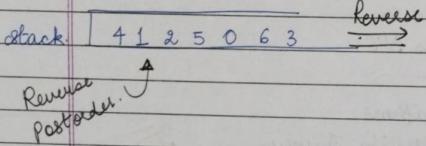
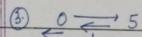
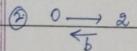
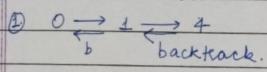
Note: There can't be any cycles.

3 6 0 5 2 1 ↑

If there are directed cycles, no topo sort.

There might be other feasible solns as well.

→ we will do DFS



∴ There is proof, if no directed graph cycle then topo sort is feasible.

well not cover



Nov 4, 2025.

Cache System

- ① LRU - least Recently Used.
- Map → key, value (generally).
- maximum capacity → 10 / 10000 / 1000000...

store on RAM itself. (cache limit kaam hoti)

DB → Disk ph hi karta h

purpose - system survive a bigger load.

Eg: Amazon → order history base base check → cache.

Disadv. → stale data (ORIGI)

ACID

consistency → SQL (ensure)
(miss ho saka).

NOSQL
Cache else

② TIL

Time to live.

↓
Cache

TTL → 10 min

- hit rate (entey aai, nahi hotsuk)
- miss rate (for bhi 10 min 10 min stale, for mai haat jana) delete hojega.

These are SD problems / query.

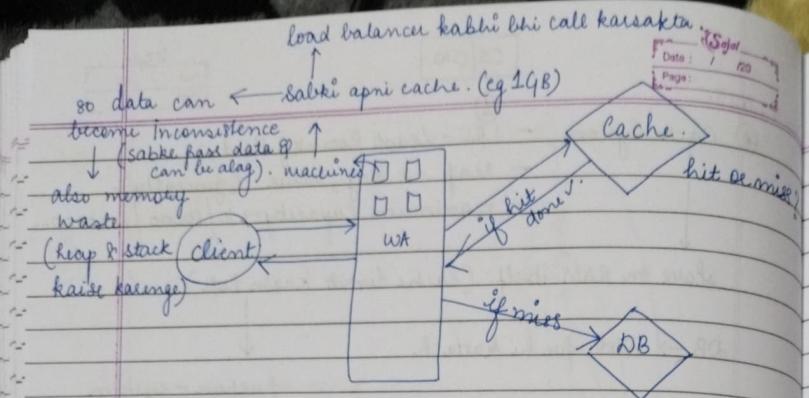
(cloud ↑↑↑ — kitna hi RAM dedenge)

Horizontal Scaling v/s Vertical Scaling

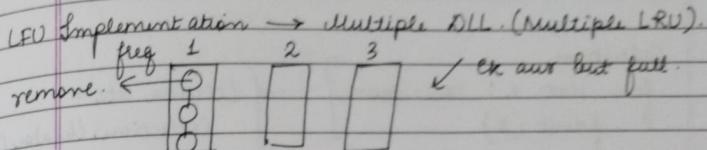
↓
addr more machines / servers to distribute load.

↓
load balancer.

inc. power (CPU, RAM) of a single machine.



Better → LFU + TTL.



(like application).

Distributed Cache → Cache deploy kardiya → sab nodes same data store karengne → consistent data ke liye.

Parameters on Cache Design → traffic hit/miss rate algo cache size what existing soln / framework

→ LFU → least Frequently Used.

↳ slightly more complex than LRU.

if multiple pages/keys have same frequency → LRU.

Disadv. → K6 aya → new one 2, 3 calls but less freq.

K7 agaya → K6 remove but its new & could (hack) agar K8 → 2 lakh baal kabhi cache se come again jaega ki nhi.

eg: Amazon → Mdi hai, 10-12 lakh product dekhi fir aai hi nhi 2-3 maline teh itne time thode cache mai rahega

October 7, 2025.

Iterable → for each loop
 Iterators

Collection
 for int x : collection
 print(x)

Iterator ite =
 Collection.iterator()
 while ite.hasNext()
 print(ite.next());

Collection implements Iterable.

public Iterator iterator() {

y

④ Iterable returns Iterators

must have → hasNext()
 first → next()

Eg: class LL {
 private static class Node {
 data, next;

y

private Node head();
 insert();
 delete();
 search(key);
 update(index, key);

iterator();

→ public Iterator iterator()
 return new LLIterator();

public LLIterator iterator

t = head; hasNext → t is not null.
 next()
 t = t.next.

Nov 10, 2025.

Graph

→ What info does graph store?

↳ DS responsible for storing relationship b/w 2 entities

→ Insta follow.

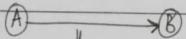
Graph → Directed (relationship is not uniform)

Undirected (relationship info u & holding is same b/w 2 nodes)
uniform.

→ Facebook friends.

↳ Edge.

→ How do we store that information?



connection is also information

(as if 2 nodes exist we have no idea there is relationship b/w them).

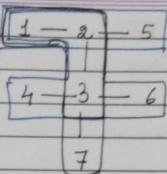
↳ int[][] matrix // n*n → easier to use, can easily check matrix[a][b]
 $O(1)$ TC just mapping.

↳ dist < int[] edges // new int[] { } → space better,
we would have to search through the entire list
 $\frac{n(n-1)}{2} \rightarrow n^2$ complexity.

↳ Map < Integer, Set < Integer >



→ of all the connected nodes.
 $O(1)$ complexity.

Print Paths

1 - 2 - 5

1 - 2 - 3 - 7

1 - 2 - 3 - 4

1 - 2 - 3 - 6

leaf nodes.

(Jaha se aee h uske
alawa aur koi node na
hota.)

Nov 11, 2025.

cycle → we just have to find the present node
for which na jise

November 14, 2021.

- Self Balancing BST
- Red Black Tree
- AVL Tree
- Comparison

Solve CRVD problems →

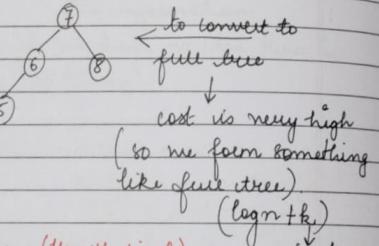
Good for $\log(n) <$ CRVD. for all operations

LL
Stack
Queue
PQ
BST

only problem → worst $O(n)$
(Skew trees / Right/left leaning trees).

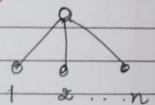
* full tree

cost is always
 $\log(n)$



1) RBT

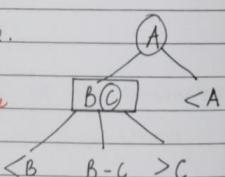
n-way Tree (Hypothetical).
2-3 Search Tree.



Follows the concept of

2 way Tree / max 3 way Tree.

some nodes are red, some black.



↳ Minimise Red nodes in a path, red to count red hasta.
↳ Somehow avoid 2 consecutive reds.

Node S

V value

K key

Node left

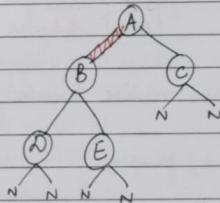
Node right

3 boolean color (B=false, R=true) (only 1 type)

Rules

- ① every node is coloured either Red or Black.
- ② Root is Black.
- ③ nulls are black (leaves).
- ④ New node is Red.
- ⑤ A Red node will have both black children.
- ⑥ Every path from root to any leaf have exactly equal number of black nodes.

$n \log(n) + c$.



→ Valid RBT.
(No. Black nodes from Root → leaf are same at all paths).

↳ left leaning Red Black Tree.

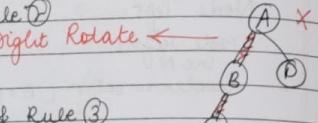
→ left for those leaning allowed hope, right for strict hope.

→ if right node is always black.

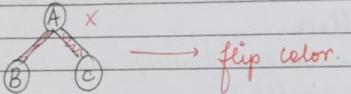
Rule :- 1) Right node → if $r.\text{right} == \text{Red}$ & $r.\text{left} == \text{Black}$
 Violation of Rule ①.
 left Rotate ←



2) left is Red & left grand child is also Red
 Violation of Rule ②

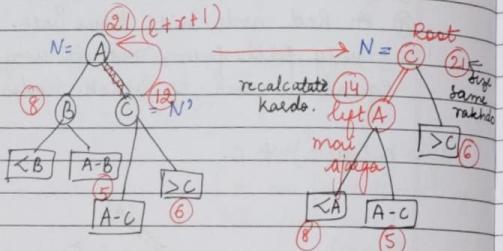


3) been Red
 Violation of Rule ③



→ flip color.

1) Left Rotate



size of n. ↴ ko lehi revise karna padega.

this $\cdot N$

Node leftRotate (Node A) {

 Node G = A.right;

 A.right = G.left;

 C.left = A;

 C.color = A.color;

 A.color = Red;

$O(1)$

C.N = A.N;

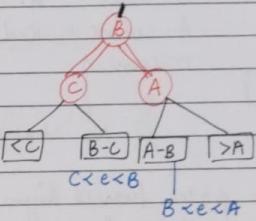
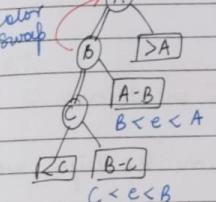
A.N = 1 + size of (A.left) + size of (A.right);
 return 'C';

3

jisme lehi call kijo tha uska child is now C
 and now not A.

2)

right rotate



Node rightRotate (Node A) {

 Node B = A.left;

 A.left = B.right;

 B.right = A;

 B.color = A.color;

 A.color = Red;

 B.N = A.N;

 A.N = 1 + size of (A.left) + size of (A.right);
 return B;

3

right Rotate is mirror of left-rotate.
 toas left \leftrightarrow right (varma same code).

3) flip color.



Node FlipColor (Node n) {

```
B . color = A . color;
C . color = A . color;
A . color = Red;
return A;
```

↓

No change in nodes whatsoever.

O(1) runtime
cost

→ do path travel kijo insert karne ke liye, wahi path
par check karao.

Net more than $\log(n)$ scans

→ More 3 operations can be done on 1 node.

just worst manner ↓ as ek node par max 3
operations ho sakte hai
(chaar node par not possible).

→ only called these operations on insertion & deletion

constructor(K, V) {

← of Node { }

this . K = K;

this . V = V;

this . left = null;

this . right = null;

this . N = 1

this . color = RED (true);

(order of data)

1 → 2 → 3 → 4 → 5

Date : / / 20
Page :

Proof

worst case eg:

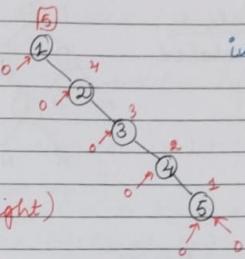
height (T) = 5

CRUD = O(height)

in this eg:

= O(5) = O(n)

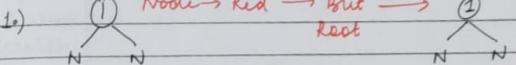
↓
not desirable.



int height (Node n) {
if (n == null) return;
return

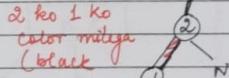
1 + Math . max (
height (n . left),
height (n . right))

LL RBT.

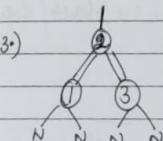


Rule 1
violated
∴ left Rotate.

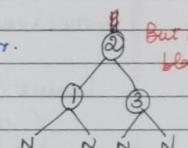
1. right = Insert (2)



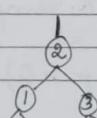
Path from R → N
(2 Black)
- R, N also Black.

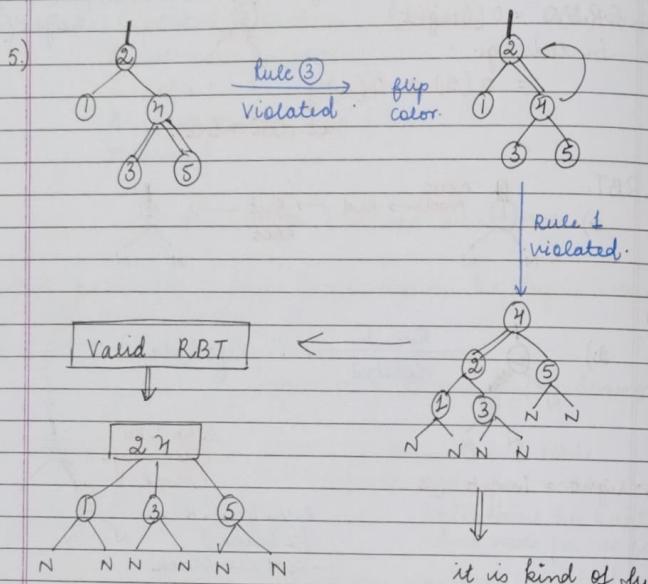
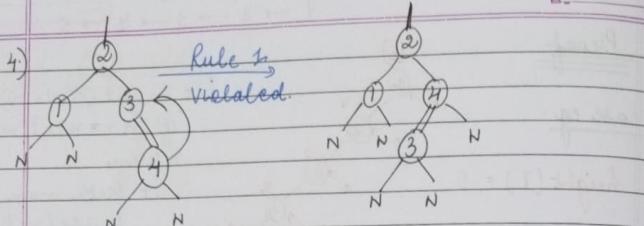


Rule 3
violated
∴ flip color.



But Root
Black

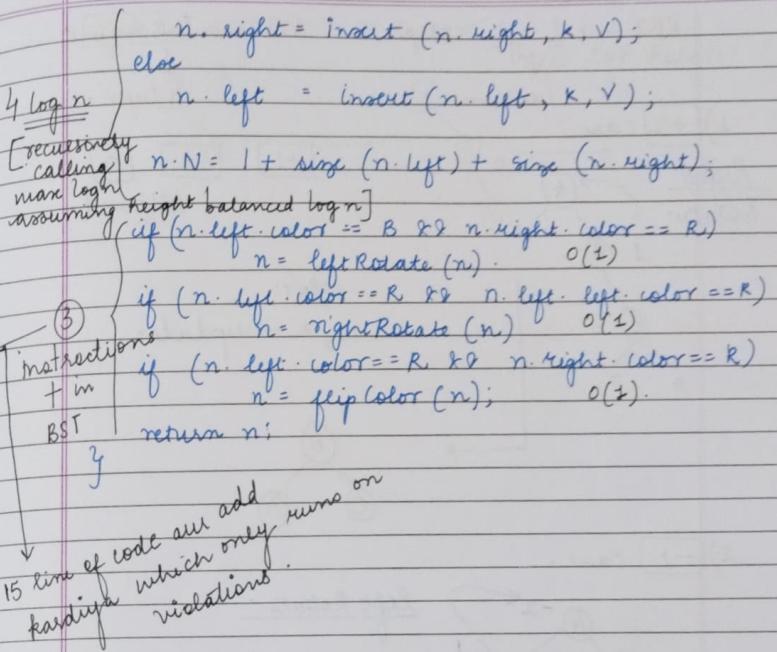




root = insert (root, k, V);
root . color = B;

```
insert (Node n, k, k, V v) {
    if (n == null) return new Node (k, V);
    int cmp = k . compareTo (n . k);
    if (cmp == 0) update value;
    else if (cmp > 0) return n;
}
```

Sujal
Date : 1/12/20
Page : 1

4. 

n. right = insert (n. right, k, V);
else
n. left = insert (n. left, k, V);

[recursively calling max level assuming height balanced log n]

if (n. left . color == B && n. right . color == R)
n = leftRotate (n); O(1)

if (n. left . color == R && n. left . left . color == R)
n = rightRotate (n); O(1)

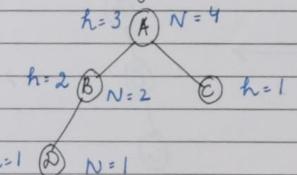
if (n. left . color == R && n. right . color == R)
n = flipColor (n); O(1).

instructions + in BST
return n;

15 line of code will add only runs on
handling violations.

AVL

has node ka height maintain karte challenge.
(fix calculation of height jo O(n) hote hai BST/RBT mai wo already maintained in each node)



RBT \rightarrow 1 lyde extra

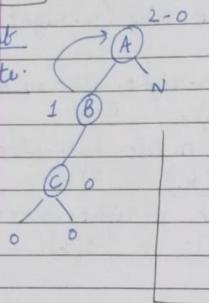
balance.

AVL \rightarrow int height

1 lyde.

1.) $+2$ case.

Right
Rotate.

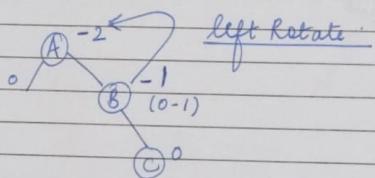


$+1$ -1 0
allowed.

color.

$n, n \rightarrow$ update.

2.) -2 case.



3.) Special case

case 1

$+2$

-1

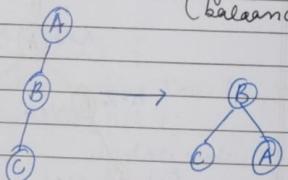
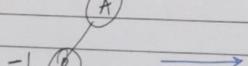
0

① left Rotate

(straight krange)

② right Rotate.

(balance).

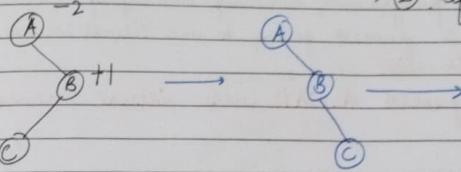


Case 2

\rightarrow 2 steps

① Right Rotate

② left Rotate



Problem Solving

November 18, 2023

Ques) 16 GB RAM, nothing else running, a C printf 'Hello World' program, running on laptop. Nothing else so is this process going to use Virtual Memory or not?

Ans) Yes it will (not selective)

Every process ALWAYS uses virtual memory.

If your system has been all processes have to use it).

For certain use cases, car stereo system, microwave, chip to see temp.

here we know what process, what kind of memory is to be used.

↓ System will use cache.
No need of Virtual Memory.

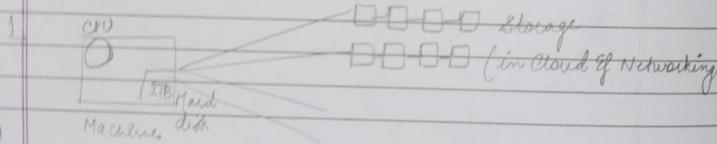
Concept of Virtual Memory:-

→ One of the top 10 ideas ever proposed in CS history.

4) 32-bit OS] → need size.
64-bit OS]

↳ 64-bit OS → 2^{64} addresses

$$2^{32} \text{ bytes} = 1000 \text{ PB.}$$

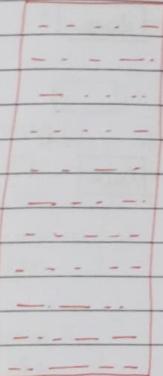


Concept, Not tangible

Virtual Memory

↳ What problems does it solve?

1)



(as a developer with
only working
virtual
addresses)
RAM

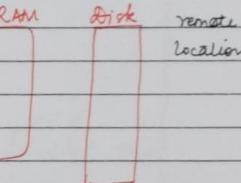
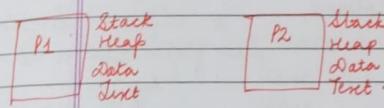
How does everything fit?
VAT generated by → RAM (if full) → Page
table update
disk.

16 ExB

(Runtime / OS system)

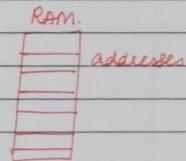
2) What goes where?

oblivious
to it



3) Programmers

↓
We don't worry!
Manage what is
going to which address.



VM → Protect:

↳ Process don't
write to same
address

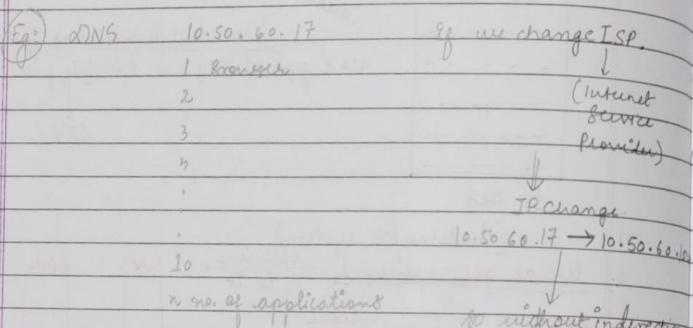
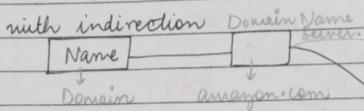
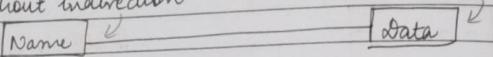
override / hacker reading
sensitive data

How to Protect?
(Shared library code)

How to Share?

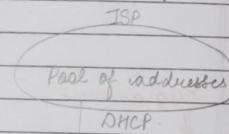
Indirection

without indirection



with indirection

- only mapping has to change
- enterprise DNS change e.g.
- call centre e.g. Range of IP not static is available

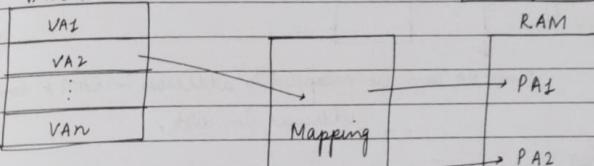


our laptop has an IP, shut down, pool may avail, has to be taken.

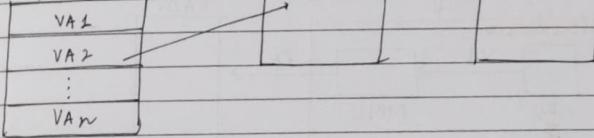
Virtual address

How indirection is happening in OS?

Process 1



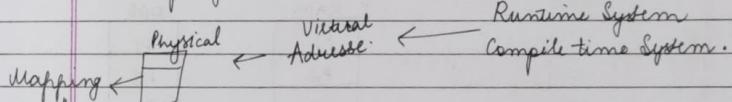
Process 2



① Every process → Made to believe.

Same the whole memory to themselves.
16 EXB.

don't have to
worry about which Memory address
as a programmer.



Page Table → How many Page tables? 1 page table per process
themselves are stored in RAM.

Page Table

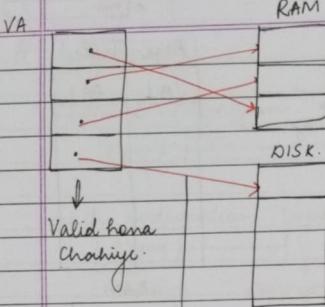
VA1 PA1

RAM

PA1

PA2

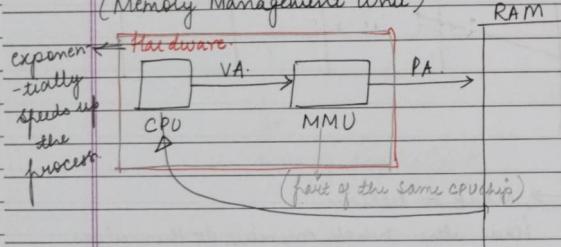
Runtime System
Compile time System.



④ A Virtual Address can be mapped to physical memory (RAM) or disk.

Some VA can be mapped to addresses in RAM & some to addresses in disk.

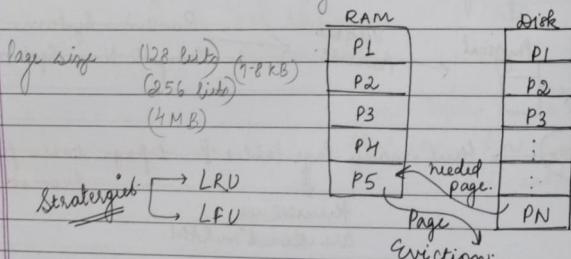
MMU VA \rightarrow PA $\xrightarrow{W/R}$ get data \rightarrow return to CPU
(Memory Management Unit)



CPU \rightarrow VA \rightarrow MMU \rightarrow PA \rightarrow RAM \rightarrow R/W data \rightarrow return to CPU.

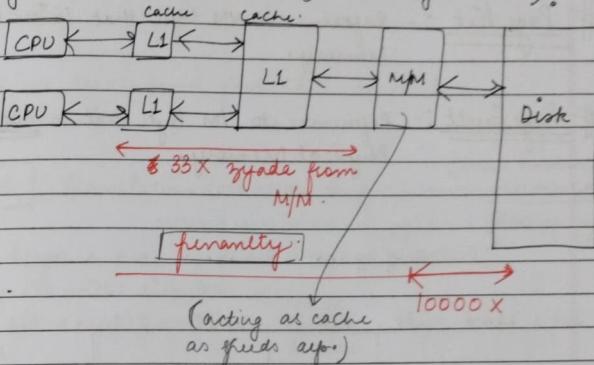
Transferring data \rightarrow X byte by byte

✓ Page



* CPU will only read data from physical memory, & not directly from the disk.

Why do we need RAM (not direct disk access)?



Address Translation

(either no data or no data)

valid in RAM, in disk

✓ NOT IN RAM

✓ IN RAM

null

1

1

0

1

0

0

1

RAM (4 page size)

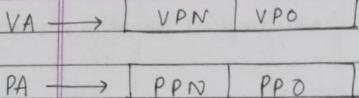
VPL
VP2
VP7
VP4

not contiguous to each other

Disk

VPI
VP2
VP3
VP4
VP5
VP6
VP7

will have all the pages



Page Hit :- Reference to VM byte that is in Physical Memory.

Page Fault :- Reference to VM byte that is not in Physical Memory.

SUP → 1 → can be read by User Processes

→ 0 → only by System Processes.

Valid	SUP	WRITE	EXEC	PPN	Bits in page table.

Summarizing:

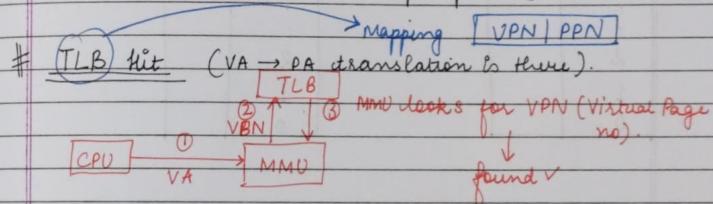
November 18, 2025.

(6) Page Not found → Returns Exception → Page Eviction Algorithm.

(7) CPU can't directly talk to Disk, data needs to be moved to RAM.

CPU → MMU → jaata hai check keta - takes time

TLB (Translation look aside Buffer) → Hardware (small hardware cache)
 ↓
 it keeps a map of VA → PA but very smaller.
 only 128 - 256 entries. ↗ Total entries in itri
 it is across processes. Page table → per process not per process.



TLB Miss — TLB Misses are Rare. (application's using some portions of data nearby)
 Principle of locality → Imp for any Cache.

Cache Replacement algos are used in TLB.

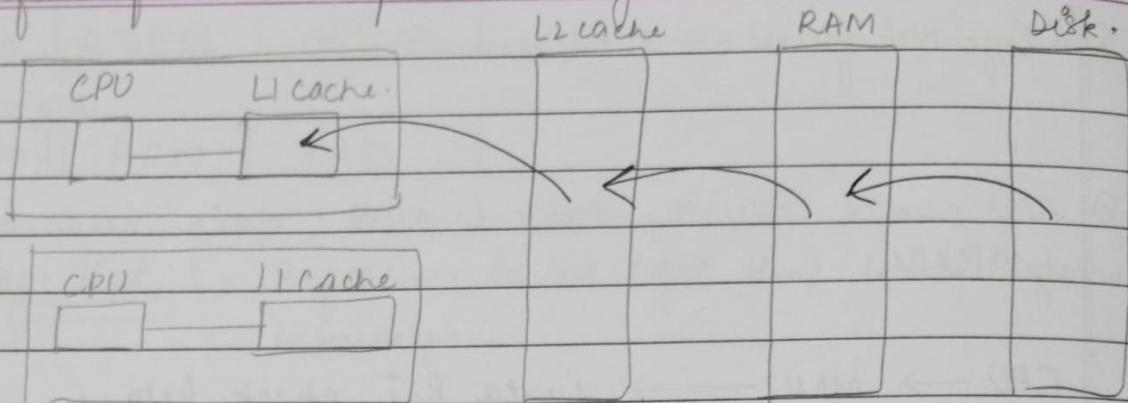
TLB faster → as present in CPU chip.

→ as it is v. smaller (smaller cache, faster it is)

④ Page Tables are in software & not in hardware.

Sajal
Date : / /20
Page:

flow of data to TLB | cache in general



(directly nahi ho sakta)

↳ Context switching in TLB kaise?

Eg

V			P	
$2^{14}-1$			$2^{12}-1$	
:			:	
2			2	
1			1	
0			0	

→ Bit architecture is decided by OS actually
(Physical Address).

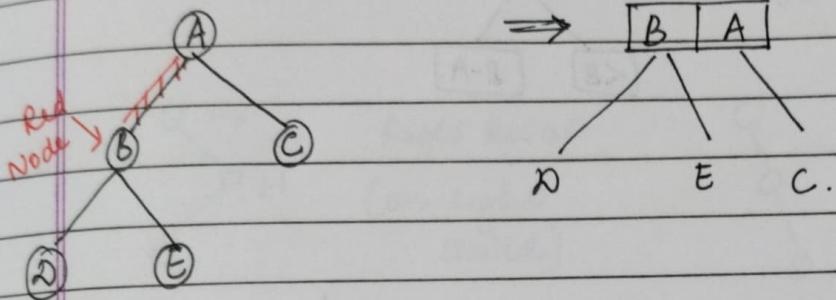
November 21, 2025.

Red Black Tree

↳ Self Balancing

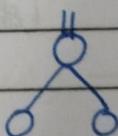
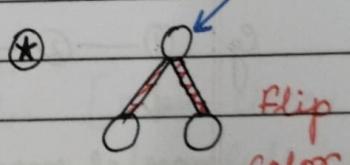
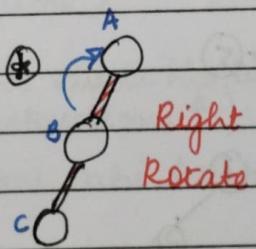
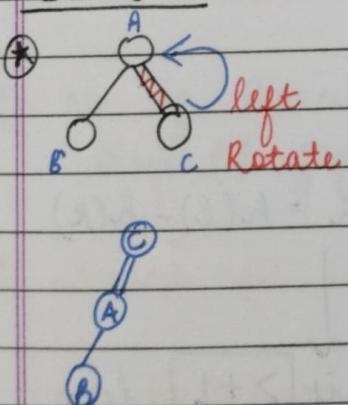
→ 2-3 search → 2 way or 3 way Search Tree

(as theoretically Red Node ko ignore / merge keta h).



Rules / Properties : -

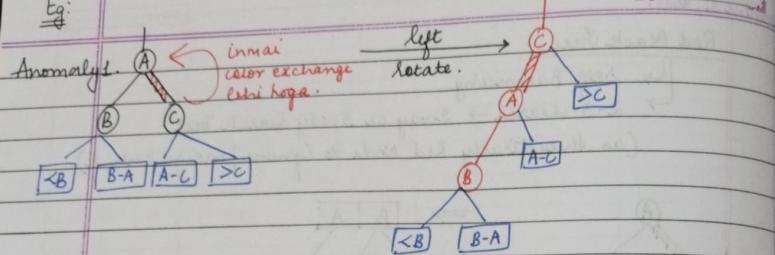
- Root is Black.
- New is Red.
- null is black.
- Root to any null (leaf) - No. of hops will have exactly same no. of black.

LL RBT.

⇒ this we will do at every stage of our recursion.

tree \leftarrow CRUD \rightarrow cost $\rightarrow \Theta(\log(n))$ \downarrow
O(height) \downarrow
Height of balanced tree.

Eq:



AVL Tree.

- works on concept of diff. of height / size.
- height gap zyada mhi hona chahiye.

$$\Delta h = \pm 1, 0 \quad \text{height gap.}$$

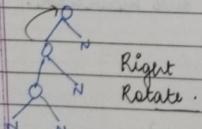
balance karne ke liye → left/right rotate O(1)
 insertion cost → $O(\log(n))$

eg: ① - ② - ③ - ④ - ⑤

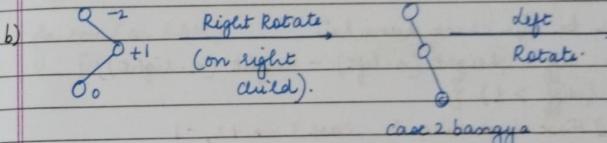
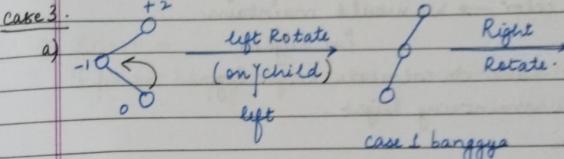
↓
normal mai → (skew)

$$\Delta h = h(l) - h(r)$$

$\Delta h = >+1$ left leaning.

Case 1
(+2)

Case 2



Difference b/w AVL v/s RBT.

- ① Memory footprint of RBT is low. (small device / RAM kum hai → RBT).
- ② RBT → 1 byte v/s 4 bytes. ← AVL.
 (boolean) (int)

- ② No. of Rotations (instructions ↑) → AVL. [more closer to a full tree]
- ③ search cost is better ($\log n$ hi but slightly less) → AVL.

DB prefer → RBT

space optimisation
 search is not that slow (a few instructions hi zyada se zyada CPU mei bhejne padegi).

code:

An

- ↳ instead of color → we would maintain int height.
- ↳ we don't have to calculate height logn as we are maintaining height.
- ↳ insert mai $n.H = 1 + \max(\text{height}(n.\text{left}), \text{height}(n.\text{right}))$
- ↳ AVL ke liye check karna hai
int diff = [height(n.left) - height(n.right)];
if (diff > 1) {
 // First check kina h case 3 → +2, -1
 if (getDiff(n.left) == -1) {
 n.left = leftRotate(n.left);
 }
 n = rightRotate(n);
}
else if (diff < -1) {
 // case 3 → -2, +1
 if (getDiff(n.right) == 1) {
 n.right = rightRotate(n.right);
 }
 n = leftRotate(n);
}

Networking → Wireshark.

TCP → 3 way handshaking, see no (o kyu nhi? - kaise pata chala connection se jattu wala o, last hogaya buffer size, ACK, SYN)

C | dinux

Sajal
Date: / / 120
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ICMP =

IP packet bhi jega → Dekhega → Error bhi jega + source apne ICMP bhi jega

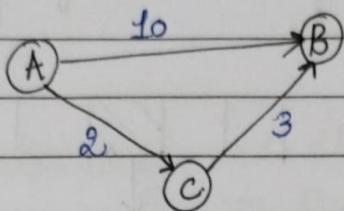
BufferedReader

↓
faster (as RAM)

.close() → internally calls flush()

ember 24, 2025.

* single source (jab ek source se distance find karna h).



You will use Dijkstra.
only when \rightarrow no negative edges.

without any aleg, observation.

Shortest dis $\begin{matrix} A \rightarrow A & \rightarrow 0 \\ B & \rightarrow 5 \\ C & \rightarrow 2 \end{matrix}$

using BFS. \rightarrow saari edges nikalli

A	B	C
∞	$\cancel{\infty} 5$	$\cancel{\infty} 2$

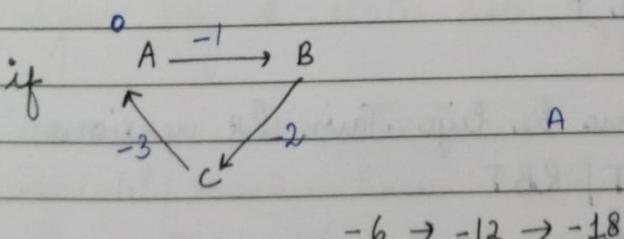
table single source of truth.
(compare kete hte hai).

$\boxed{A} \rightarrow B$ is $10 \times$
10 already
existing
dis.

$\begin{matrix} A \\ B \rightarrow x \\ C \rightarrow x \\ B \rightarrow x \end{matrix}$

$\boxed{A} \rightarrow C$ is $2 \times$ current dis. (prev. dis ko add krite.)

$\boxed{C} \rightarrow B$ is $5 \times$ current dis.



A	B	C
∞	$\cancel{\infty}$	∞

-1
 -6
 $-6 \rightarrow -12 \rightarrow -18$

kabhi shortest dis nahi \rightarrow ya a loop
 \rightarrow ya wrong ans.

November 28, 2025.

Hashing → concept of bucket.

↓
Dynamic array of linkedlist $R(\text{key}) \% \text{ curr_bucket_size}$ ↓
It will tell where to put value

O(1) time we can reach bucket.

CRUD cost $\Rightarrow O(k)$

Size of largest bucket.

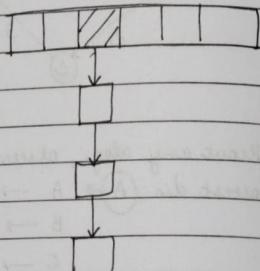
if v good hashing tech. → use k const.
(less collision factors, dynamic array)Cost of Rearranging $\rightarrow O(n)$

Shuffling

no. of ele.

Shuffling ↓ kte
job size ↑

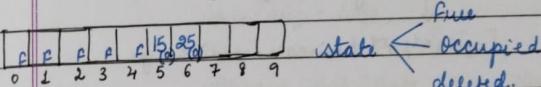
iss cost ko bache ke liye Java ls versions changed LL → BST / RBT

RBT. CRUD $\rightarrow \log(k) \ll k$.

* Separate Chaining → we have a hash code to find location internally location \rightarrow LL / BST
collision here too LL grows - separate chaining for each of every bucket.

* Open Addressing: → linear Probing
→ Quadratic Probing.
→ Double Addressing

1) Linear Probing.



Insert
Hash function = $H(\text{key}) \% \text{ size}$
linear probing = $(1 + \text{idx}) \% \text{ size}$.
 $(+5) \% 10 = 6$.

$$\begin{aligned} 15 \% 10 &= 5 \\ 25 \% 10 &= 5 \\ 35 \% 10 &= 5 \end{aligned}$$

fnc pr
(1+6) \% 10.
depend karega
1/2/k kuch goes on job take occupied aega.
lehi rakh sake.

Delete

delete (15) \rightarrow 15, 5 pr h \rightarrow 15%

State of that bucket will be deleted.

agar suff & states hote, \rightarrow ① → delete krkr \rightarrow ②

elut agar states ②, ele can be somewhere else for update / search - have to do linear probing

① → occupied but not search value, linear probing,
start & end point same. saara search keliya, doesn't exist.

① till the time we reach free, we do linear probing:

$$(k + h) \% \text{ size}$$

linear
probing
factor

Benefits LP :-
1. easy to implement.
2. caching \rightarrow easy to

2nd/3rd bhi cache mai honge.

Disadv. LP :-
1. clustering zyada, search cost $\uparrow \rightarrow X$
optimised addressing.

2) Quadratic Probing:

$$h = f(\text{square})$$

fix na
ratio

$$h = \text{key \% size}$$

$$h = (h + i^2) \% \text{ size}$$

variable.

1, 4, 9, 16, ...

\rightarrow ok in clustering, \rightarrow ok in caching
 \rightarrow leiche ki chiz.

3) Double Addressing:

$$h = (h+1) \% \text{ size} \quad \hookrightarrow h_0 = \text{key \% size.}$$

$$(h+1 \% \text{ prime no \% size}) \% \text{ size}$$

$$h = (h + \text{key \% prime No}) \% \text{ size.}$$

public class OpenAddressing {

private enum State {

Free, Occupied, Deleted;

}

private Node[] data;

private final int size;

public OpenAddressing (int size) {

this.size = size;

data = new Node [size];

Arrays.fill (data, new Node ())

}

private static class Node {

private Integer key;

private State state;

public Node (Integer key) {

this.key = key;

this.state = State.Occupied;

}

public Node () {

this.key = null

this.state = State.Free;

}

private int hashfunction (Integer key, int h) {

if (h == -1) return key \% size; // 1st time (f)

return (h+1) \% size; // linear Probing (o)

}

```

public void insert (int key) {
    int h = hashFunction (key, -1);
    int orgH = h;
    while (data [h]. state == State. Occupied) {
        h = hashFunction (key, h);
        if (h == original H)
            throw new RuntimeException ("Overflow");
    }
}

```

```

public boolean haskey (int key) {
    int h = hashFunction (key, -1);
    int orgH = h;
    while (true) {

```

```

        if (data [h]. state == State. Occupied) {
            if (data [h]. key == key) return true;
        }
    }
}

```

```

if (data [h]. state == State . Free) {
    return false;
}

```

```

h = hashFunction (key, h);

```

```

if (h == orgH) return false;
}

```

3

```

public boolean search (int key) { }
public void delete (int key) { }

```

continued...

Problem Solving

Date : 1 / 120
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December 2, 2025.

Ques1) you have a website which is currently running on a single web server on PostgreSQL database. Web server, application server & DB are installed on the same Virtual Machine (8GB RAM, 100 GB HD, 4 core). It was serving around 10000 users per day. In holiday season you expect that number to go to 1 million per day. How would u scale your web application?

Ques2) How would u check if there is latency in the network & it is causing a bottleneck?

December 2, 2025.

JOINS

Cross

1.) Natural Join.

A)

A1	A2
1	2
5	6
7	8

B)

A2	A3
2	3
5	7
6	8

SELECT A.A1, A.A2, B.A2, B.A3.

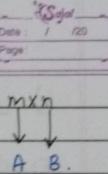
FROM A CROSS JOIN B;

→ cartesian product
(every row of A with every row of B).

Result → A.A1 | A.A2 | B.A2 | B.A3.

1	2	2	3
1	2	5	7
1	2	6	8
5	6	2	3
5	6	5	7
5	6	6	8
7	8	2	3
7	8	5	7
7	8	6	8

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2.) Natural Join .

SELECT A.A1, A.A2, B.A2, B.A3.

FROM A

NATURAL JOIN B;

* Matching values ✓

A.A1 | A.A2 | B.A2 | B.A3..

1	2	2	3
5	6	6	8

→ not explicitly telling which col to join, so join will happen on cols with same name in both the tables.

others are discarded.

- Not Recommended (if colname change hogaya so).
- explicit join is preferred.

3.) Inner Join .

SELECT A.A1, A.A2, B.A2, B.A3.

FROM A INNER JOIN B

ON A.A2 = B.A2; → kis col pe join karna hai?

4) OUTER JOINS. @ left Outer Join

SELECT A.A1, B.A2, B.A2, B.A3.

FROM A

LEFT OUTER JOIN B

ON A.A2 = B.A2;

→ all rows from left +
only matched from
right

A.A1	A.A2	B.A2	B.A3
1	2	2	3
5	6	6	8
7	8	null	null

(constraint ka dhyaan
sabka h - who lagake
ya koi nhi kehna k A, B
mai all val should be
not null)

② Right Outer Join → complete
opposite

A.A1	A.A2	B.A2	B.A3
1	2	2	3
5	6	6	8
null	null	5	7

③ Full Outer Join → UNION of left OR and right AT.

A.A1	A.A2	B.A2	B.A3
1	2	2	3
5	6	6	8
7	8	null	null
null	null	5	7

Query Optimisation

- FROM section - processed first. ← Need to make sure.
- lot of optimisations done by SQL compiler itself.

→ Intermedia result / table should not go high.

Latency:

overall slow na ho ja.

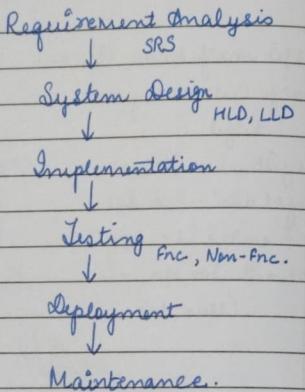
December 5, 2025.

Wildcard Genetics:

History of Software Development:

→ Waterfall Model:

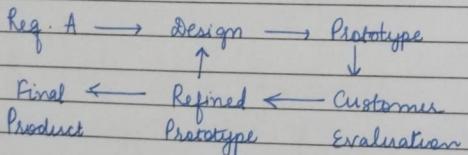
- at every stage we are assuming previous stage ka work is perfect. (6 months) (baad mai dikhat hogा)
- because mustek as puri cycle fix chahi
- No feedback.



→ V-Shaped:

Verification Phase → Validation Phase

→ Prototype Model:



→ Spiral Model:

Theoretical, ⑤, Risk Analysis

→ Agile

- limited features, sprint, incremental, numerous iterations.
- defect thik karna easy, quicker recovery
- feedback ✓
- Management easy → lot sprint (some staff) ↓
- kaam kaan defined. ↓
- (accurate) forecast update ← live/remanage sprints, karpaega (1 sprint = 1 month, 6 features → 6 months). kum time so hoga.

3 weeks eg. Deployment (can't take 8 weeks, 5 min hona chahiye) Testing (fast time & type tool, current - manual (n-1) sprint bhi test ke such defect na hoga)

[Agile - Base min Setup]
(AUTOMATION)

(automated script) → (automate)

CI/CD → Continuous Integration Continuous Deployment (Automation)

- Jenkins (will check build; Pipeline) coding standards
- sonarQube extension dekkha

chahi non-production.

puppet - grub bhi koi company koi VM / Machine acquire keri ↑ - setup (JDK install, upgrade).
Setting up infrastructure.

→ Ansible. (sari machine pr kuch install nhi karna, agent bhi nhi, SSH se kaam chala leta)

Puppet - install - agent.

→ Chef.

- Bande wala coding ki apni machine ke hisaab se (Ubuntu) → deploy windows → phat gaya
- Developer doesn't have control ke kis infra.

we'll decide base & swap kare infra.

Docker.

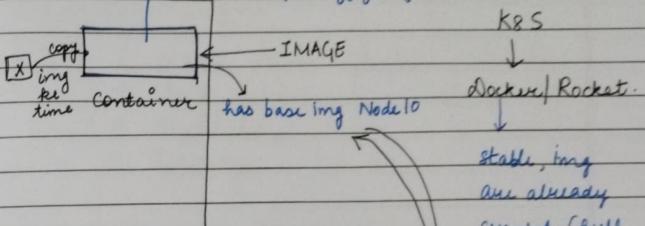
Container = code + infrastructure

[quasi virtualized - swap]
(host machine)

Dec 6, 2015

C | Linux.

(as if it's a new machine / kuch hoga so apne andar ke search karta / diff filesystem) Kubernetes



K8S

↓
Docker / Rocket.

stable, img
are already
created (pull
from docker
hub), free,
community support

alpine (lightweight, no X,
already installed nhi - security issues nhi)

Image mai likha hogा → from centos 7
(node10).

apt-get install node
apt-get install npm

!

- Docker → launching & destroying a container (ms of work).
- mapping - humans. containers
(Port forwarding) 8080 → 8081

December 13, 2025.

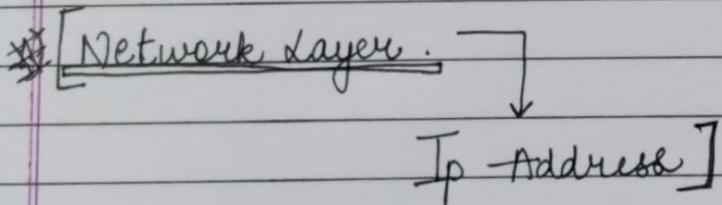
Load Balancing

- Benefits :-
1. Load Distribution
 2. Fault Tolerance.
 3. Scalability
 4. Security

Layers of OSI → Application
 (7) Presentation
 Session
 Transport
 Network
 Data Link
 Physicals.

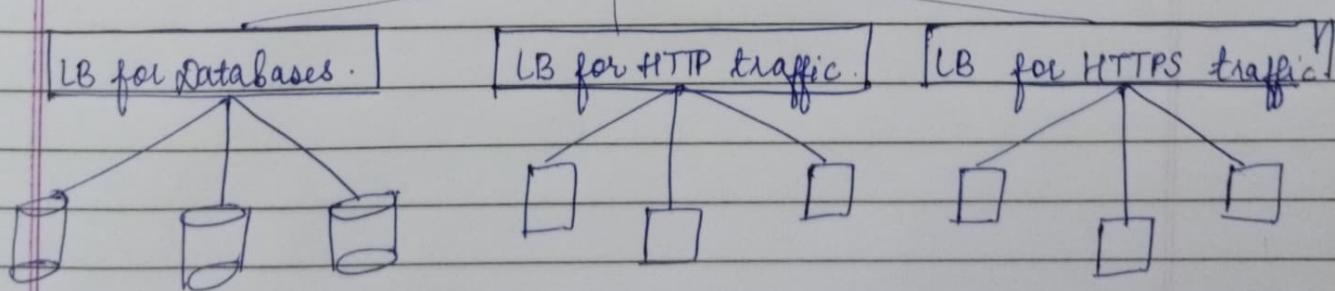
Q.) What layer does load balancer operate upon ?

Layer 4 (Transport)] (depending on type).
 Layer 7 (Application)]



1.) LB at Transport Layer:

[Load Balancer]



2) LB for application layer.

Static Methods

- Round Robin
- Hash
- Weighted Round Robin

Dynamic Methods

- Least Connections
- Resource Based
- Least Response Time

→ Sticky Sessions

→ Path Based Routing

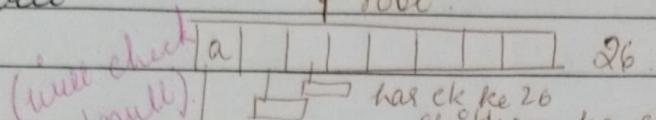
December 18, 2025.

Trie

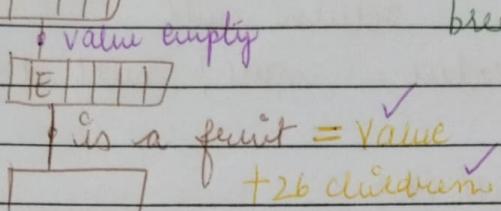
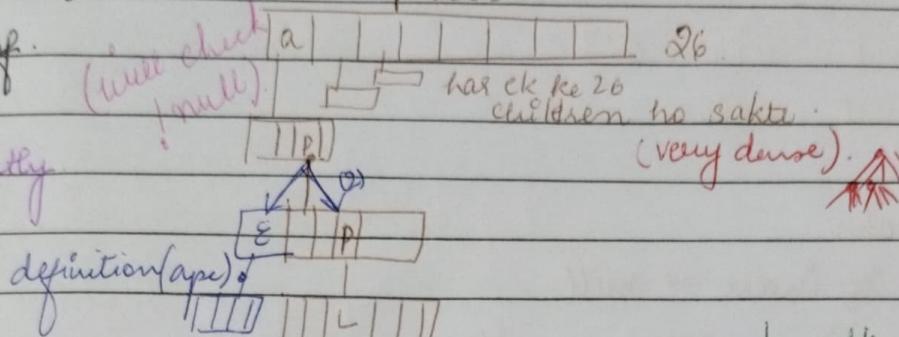
Sofal
Date: / / 20
Page: (search)

(high level).
26 search tree

kind of:



Not exactly



breadth MT

cost → height

$O(h)$

for eg. → English dictionary → longest valid word.

Memory Mai dikkat

- can store using Java serialisation / deserialisation
- but Mem. Mai load karna padega!
- RAM fast hona chahiye.

Root par → Array ka size → 26

1st layer → her ek ke 26 ho sakte → 26^2

English dict /

valid



but agar kuch bhi

kam dense loga

random banana toh

(Saare occupied nahi

kuch bhi comb. ho

longe)

isakta.

apple (have word starting with this)
(but not valid) Node { Null if not word }

Null if not word

Definition

Sudo code

class Trie

root: Node

object value;

Node[] children;

↳ insert (String key, String value) {
 t = root;

for $c \rightarrow \text{key}$
 $t[c - 'a'] \rightarrow \text{new Node}$
 $t = t[c - 'a']$
 $t\text{-val} = \text{value}$

(\hookrightarrow) search:

If $\text{index} == \text{null}$.
return null.
 $t\text{-value} == \text{null? null: } t\text{-value}$

(\hookrightarrow) startsWith (k)

for $c \rightarrow k$. ?
 $\text{index} = c - 'a'$
if ($t[\text{index}] == \text{null}$)
return false; ?
return true;

(\hookrightarrow) delete \rightarrow soft delete (not optimised) \rightarrow would need
hard delete \rightarrow to handle
either fnc.

deletable nodes \rightarrow jiske pass value whi hai
has no children.

use parent delete

ka dega \rightarrow null mark ka dega

True ko kahan wa \rightarrow starts with, search;
kaise sake?
auto complete, browser search
if prefix check - subnet

Negative point \rightarrow high memory footprint.

CRUD = startwith : cost = $O(\text{length of max valid key})$

December 20, 2025

Java Stream API

\rightarrow we have a list $\text{list} < \text{List<Integer>} = [4, 3, 2, 5, 4]$.

\rightarrow we have to do following

- 1) Filter even. $- [4, 2, 4]$
- 2) Double $- [8, 4, 8]$
- 3) sort $- [4, 8, 8]$
- 4) distinct unique $- [4, 8]$
- 5) Return a list or print. $- [4, 8]$

(anonymous func)

Java \rightarrow COP, need of functional programming

Scala (on top of Java)

Java 8 \rightarrow lambda supports functional programming (lambda func)

streams = stream

$S_1 = S \cdot \text{filter}(n \rightarrow n \% 2 == 0)$ \rightarrow input immutable. $\&$ fab jarur
 $S_2 = S_1 \cdot \text{map}(n \rightarrow n * 2)$ \rightarrow multiple
 $S_3 = S_2 \cdot \text{sort()}$ \rightarrow intermediate func

$S_4 = S_3 \cdot \text{distinct()}$ \rightarrow terminal kinda stream
 $\text{List<Integer>} \text{output} = S_4 \cdot \text{collect}(\text{Collector. toList}())$
ya sidha print the S_4 stream.

$\text{List<Integer>} \text{output} = \text{Input: InputStream(). filter}(n \rightarrow n \% 2 == 0)$

$\cdot \text{map}(n \rightarrow n * 2)$

$\cdot \text{sort}()$

(Stream closes at end)

$\cdot \text{distinct}()$

$\cdot \text{collect}(\text{Collector. toList}())$

\rightarrow ika baad I can operate on S_1
but if I try to operate on $S \rightarrow$ error [Stream closed]

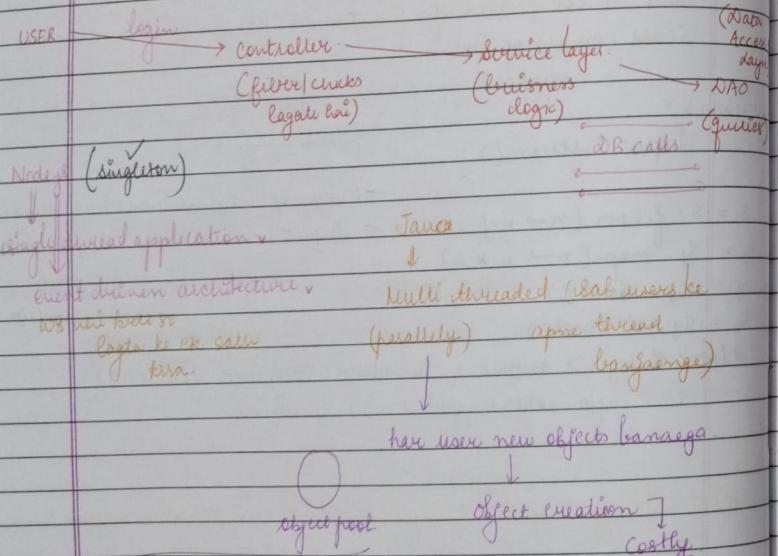
(space baaki whi
as ek stream open,
previous closed.)

Functional Programming

- Benefits
 - Auto close
 - I on use
 - Chaining

Singleton

Need ??



Isko saare kone ke liye first controller obj]

every thread will have same obj, every thread will execute their code

will have instructions only no state

class xyz {

f1()

f2()

→ new xyz()

← spring se
manga

}

last developer hi likhe sab ka
new xyz() × 50 → 50 obj

↓
Singleton classes ← No obj creation Idea fail

↑
for instance / per form only 1 object is created.

public class xyz {

private xyz() {

→ at new xyz() nahi
hai paega

public static xyz getInstance() {

return inst;

developer

}

private xyz inst = new xyz();
= null;

→ Eager loading

↓
Lazy loading

if instance banega
abhi banega

ek bhar hi:

↓
public static xyz getInstance() {

if (inst == null) (if 2 threads aata toh
inst = new xyz, jaldi new 2 obj)

3 → 2 → 1 → 0 →

return inst;

nation hua toh b

↓
allega

↓
Ab different Multithreading

↓
Iske liye synchronization

↓
1000 threads aac, 999 wch
(critical section) → bade kar
Crista

RAM, Cache [Not Sync]
 Date: / /
 Page: / 20
 (t1 → RAM, Cache instance → volatile kar sake.
 t2 → cache update
 (jo cache whi hota
 ya agar hote deh RAM
 se sync ✓)
 old data

```

    ↗ public static xyz getInstance() {
      if inst == null
        1. sync() { (critical section)
      2. if inst == null (double check)
        1. inst = new xyz()
        ↘
      ↘ return inst;
    }
  
```

Coding Ques.

Sum = 7 [2, 3, 7] → 2, 2, 3
 ⑦ Min length
 subsequence.

Combination sum form smallest len subsequence.

Recursion - Take | Not take

```

public List<Integer> findSum(int target, int[] a) {
  if (target == 0)
    return [];
  if (target < 0)
    return null;
  for (int i : a) {
    List<Integer> r = findSum(target - i, a);
    if (r != null)
      r.add(i);
    if (r != null)
      if (res == null || res.size() > r.size())
        res = r;
    if (res == null)
      res = new ArrayList();
  }
  return res;
}
  
```

