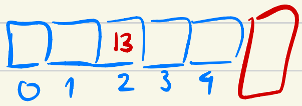
int [a=5]

array → [5, 10, 15, 20]

```
main (){
    ~
    int arr[5] = {} ← 0      // ค่าขยะ
        arr[2] = 13
      * arr[5] = ระเบิด
}
```



string ✓
strlen → ✓ O(n)

sz : 1 2 3 4 (5) → O(n)

TORZY '\0'
0 1 2 3 4 5

```
for (i : 0 → ∞){
    if(str[i] == '\0'){
        break
    }
    sz += 1
}
```

โจทย์ที่มี < สิ่งที่เขาออกกัน

```
string str
(1) * for (i = 0 ; i < strlen(str) ; i++){      → O(n × n) = n^2
        // do sth ← O(n)
    }
(2) for (i = 0, n = strlen(str) ; i < n ; i++){   → O(n)
        //
    }
```

TLE (Time Limit Exceed) → 10^8 คำสั่ง 1s

$n = 10^4$

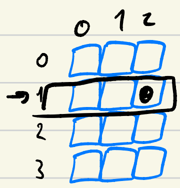
(1) → 10^8 → แตก TLE

(2) → 10^4 → ไม่ติด TLE

100 (1)/(2)
1000 (1)/(2)
10,000 (2)
>10,000 (2)

Array 2D

arr[ ]



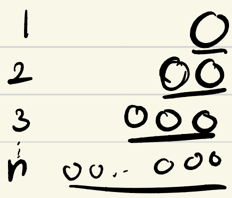
arr[1] [2]
แถว หลัก

Sort → เรียงจาก น้อยไปมาก

	$n = 10^4$	$n = 10^6$
ค่าย 1	$O(n^2)$ ✓ ✗	
ค่าย 2	$O(n\log n)$ ✓	✓

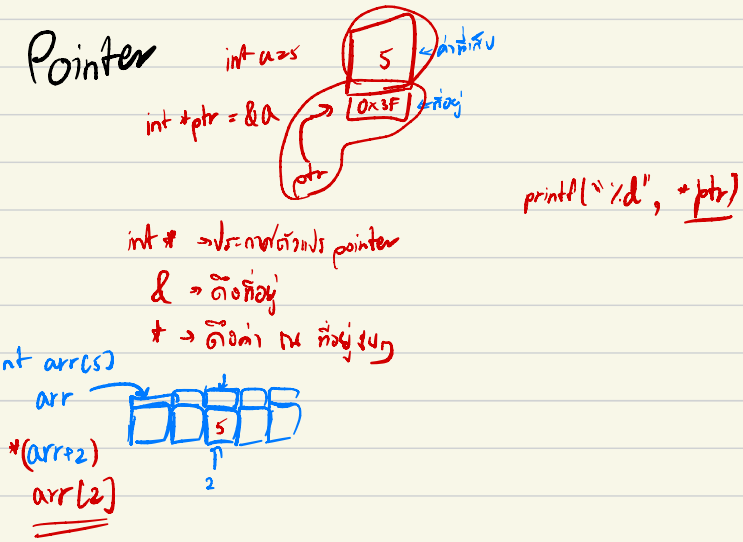
→ Bubble Sort

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



pointer
function → recursive
struct

Pointer



Function

ชนิด ชื่อ (ค่าที่ส่งมา (Parameter)) {

return

}

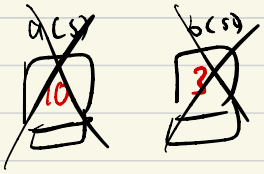
```
int add(int a, int b){
    return a+b
}
x = add(3,5)
```

```
void print(int a, int b){
    printf("%d %d\n", b, a);
    return;
}
```

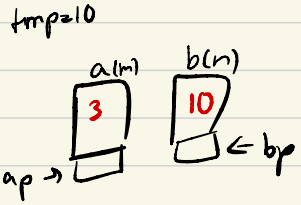
3,5 → 5,3

print(3,5) ← 5 3

```
void swap(int *ap, int *bp){
    int tmp = *ap
    *ap = *bp
    *bp = tmp
}
```




```
main
    a = 10
    b = 3
    swap(&a, &b)
```



factorial

sum 1...n

fibonacci

Recursive Function

factorial → n!

0039 → Permutation

f(n) = n!

f(3) = 3! → 3 × (2!) → 2 × 1!

f(3) = 3 × f(2)

f(2) = 2 × f(1)

f(n) := n × n-1 × n-2 × ... × 1

→ $f(n) \begin{cases} 1 ; n=0 \\ n \times f(n-1) ; n>0 \end{cases}$

```
int fac(int n){
    if(n==0) return 1
    return n x fac(n-1)
}
```

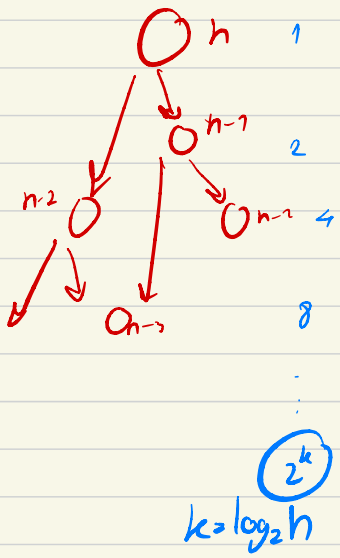
fibo(n) 1, 1, 2, 3, 5, 8 ...

nth 1 2 3 4 5

$fibo(n) \begin{cases} 1 ; n=1 \\ 1 ; n=2 \\ fibo(n-1)+fibo(n-2) ; n>2 \end{cases}$

```
int fibo(int n){
    if( n==1 || n==2) return 1
    return fibo(n-1)+fibo(n-2)
}
```

$O(2^n) < 30$




```
fibo[n+10] = {}
base case ; fibo[1] = fibo[2] = 1
    for(i=3 ; i≤n ; i++){
        fibo[i] = fibo[i-1] + fibo[i-2]
    }
```

O(n)

O(logn) Matrix exponentiation

gen-subset

recursive function

Bitmask

$S = \{1,2,3\}$

gen → { }
{1}
{2}
{3}
{1,2}
{1,3}
{2,3}
{1,2,3}

input : 3
output : _
1
2
3
1 ∪ 2
1 ∪ 3
2 ∪ 3
1 ∪ 2 ∪ 3

	3 2 1
_	0 0 0
1	0 0 1
2	0 1 0
3	1 0 0
1 ∪ 2	0 1 1
1 ∪ 3	1 0 1
2 ∪ 3	1 1 0
1 ∪ 2 ∪ 3	1 1 1

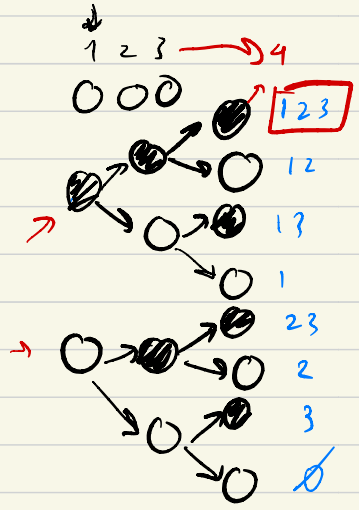
i-th

5 - 101

n

if((n & (1<<i)) != 0)
// i-th bit = 1

5 → 00 101
00 100 ✗



1
recur(2) →

Trick → เอาออกทีหลัง

gen subset

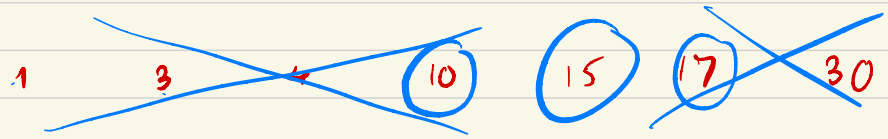
```
int pick[5] = {};

void recur(int cur_lv, int lim){
    if(cur_lv == lim+1){
        for(i=1; i<=lim; i++){
            if(pick[i] == 1)
                printf("%d", i);
        }
        return
    }

    pick[cur_lv] = 1
    recur(cur_lv+1, lim)

    pick[cur_lv] = 0
    recur(cur_lv+1, lim)
}
```

Binary Search



Recursive

Iterative → int arr[0...n-1]

```
l=0, r=n-1, ans=-1
while( l<=r){
    int mid=(l+r)/2
    if(arr[mid]==val){
        ans=mid;
        break
    else if (arr[mid]<val){
        l=mid+1
    }else{
        r=mid-1
    }
}
if( ans==-1) → Not found
else found at ans
```

Find 15

$l=0, r=6, mid=\frac{(0+6)}{2}=3$

$l=mid+1=4, r=6, mid=\frac{(4+6)}{2}=5$

$l=4, r=mid-1=4, mid=\frac{(4+4)}{2}=4$

n

$O(\log_2 n)$

2 ใช้ → ① ลองหาค่าที่น้อยที่สุดที่มากกว่า ~~17~~ 4

② ลองหาค่าที่มากที่สุดที่น้อยกว่า

↳ f(9)=4

f(22)=17

O(logn)

1 3 4 10 15 17 30

①
```
l=0, r=n-1, ans=-1
while (l<=r){
    int mid=(l+r)/2
    if( arr[mid] > X){
        ans=arr[mid]
        r=mid-1
    }else{
        l=mid+1
    }
}
print(ans)
```

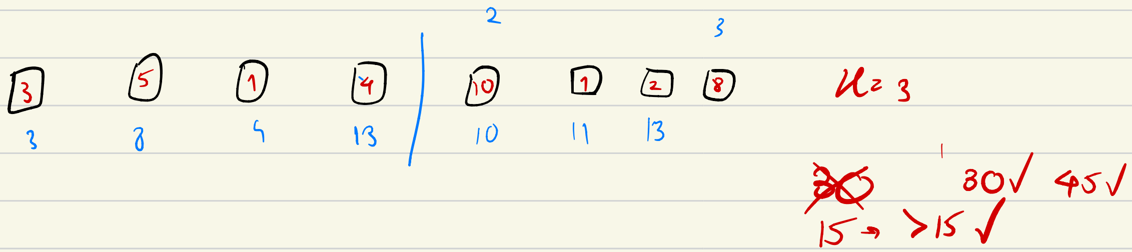
②
```
l=0, r=n-1, ans=-1
while (l<=r){
    int mid=(l+r)/2
    if( arr[mid] < X ){
        ans=arr[mid]
        l=mid+1
    }else{
        r=mid-1
    }
}
print(ans)
```

B search บนคำตอบ

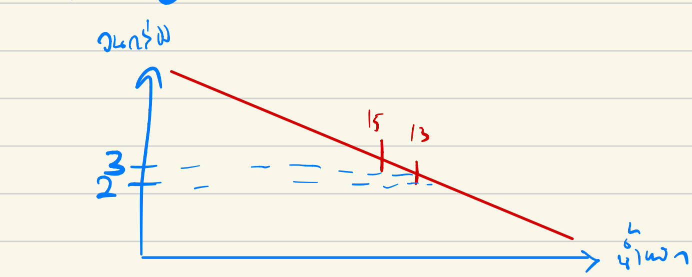
จงหาเวลา/เงิน/ sth ที่น้อยที่สุดที่ทำให้เงื่อนไขทางอย่างเป็นจริง

มี ของ n ($1 \le n \le 10^5$) ชิ้น เรียงต่อกัน โดยของแต่ละชิ้นมีน้ำหนัก w_i ($1 \le i \le n$, $1 \le w_i \le 10^9$)

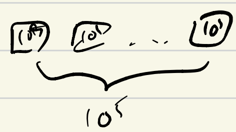
ต้องใส่กล่องตามลำดับ โดยใช้กล่องได้ไม่เกิน K ($1 \le K \le n$) ใบ จงแบ่งให้น้ำหนักที่มากสุดของกล่องให้น้อยที่สุด



monotonic



$n = 10^5$, $W = 10^4$, $K = 1$



$= 10^{14}$

```
l=0, r=10^14, ans=-1
while (l<=r){                  <- O(log2 n·w)
    long long mid=(l+r)/2      <- O(1)

    if( chk(mid) ){            <- O(n)
        ans=mid                <- O(1)
        r=mid-1                <- O(1)
    }else {
        l=mid+1                <- O(1)
    }
}
print (ans)
```

$O(n \log_2 n \cdot w)$

```
bool chk(int mid){
    sum=0, cnt_crate=1
    for(i=1->N){
        if(weight[i] >mid)
            return false
        if(sum+weight[i] >mid){
            cnt_crate ++
            sum =0
        }
        sum += weight[i]
    }
    return (cnt_crate <= K)   -> true
                              -> false
}
```

Sieve of Eratosthenes → หา prime number

prime number 10 → 2 3 9 5 ... 9 → 10 ไม่เป็น prime $O(n) \rightarrow O(\sqrt{n})$

```
for i in (2, n-1):
    if (x % i == 0)
        not_prime = true
```

10 → 2 3 → 10 ไม่เป็น prime $O(\sqrt{n}) \rightarrow O(\sqrt{n})$

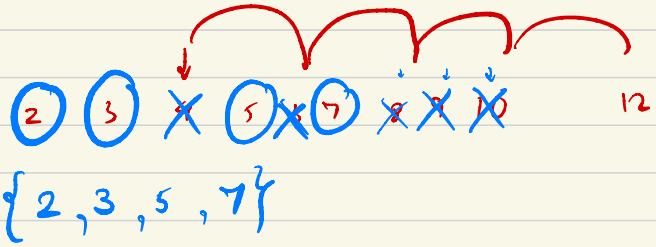
```
for (i = 2, lim = sqrt(10)+1; i <= lim; i++){
    if (x % i == 0)
        not_prime = true
}
```

9 → 3.3 $\sqrt{9} = 3$

10 → 2.5 $\sqrt{10} \neq 3$

$O(n \log n)$ → หา prime ทุกตัว ตั้งแต่ [1, n]

{1 2 3 4 5 6 7 8 9 10} → {2,3,5,7} $O(10 \log 10)$



{2,3,5,7}

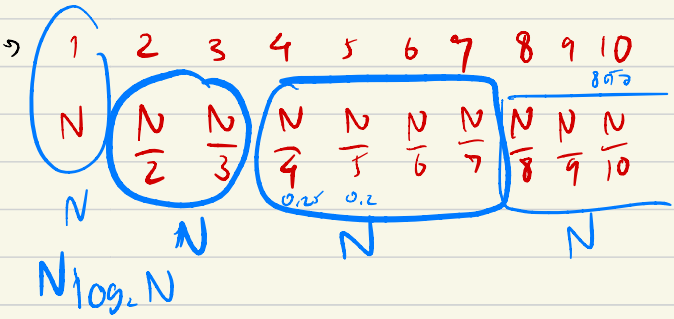
~~bool prime[N]~~ ↳ 1 byte = 8 bit, N byte

bitset<N> prime ↳ 1 bit, N bit ≈ $\frac{N}{8}$ byte

```
void sieve(){
    for (i = 2; i <= N; i++){
        prime[i] = true
    }
    for (i = 2; i <= N; i++){
        if (prime[i] == true){
            for (j = i+i; j <= N; j += i){
                prim[j] = false
            }
        }
    }
}
```

2 3 5 7 11 ...

$\frac{N}{2} + \frac{N}{3} + \frac{N}{5} + \frac{N}{7} + \frac{N}{11} + \dots$



STL

sort, reverse

vector (dynamic array) - begin/end, rbegin/rend, front, back
[-1]
- push, pop
- size
- insert/erase
- vector<int>:: iterator it → auto it
- vector<int> (10,5) → "5" × 10 slot

queue - front
- push, pop
- size

stack - top
- push, pop
- size

pair/tuple - get<0>
- tie

set (AVL) - insert/erase
- begin/end, rbegin/rend
- size

Left heavy → $H_L - H_R > 1$
Right → 3,2,1
Left-Right → 3,1,2
Right heavy → $H_R - H_L > 1$
Left → 1,2,3
Right-Left → 1,3,2

pq (heap) - top
- push, pop
- size

insert left-to-right → heapify up
delete replace root with the latest element → heapify down

auto [ ]: map ← map / unordered_map (hash table)

Link list

STL → Standard Template Library

→ Function / Data Structure

→ อยู่ใน bits/stdc++.h

- sort, min, max, reverse
- Data Structure

vector (Dynamic array)

list (Linked List)

queue

stack

set (AVL tree)

map (AVL tree)

unordered_map (hash table)

priority_queue (heap)

pair, tuple → เก็บข้อมูลหลายอย่าง

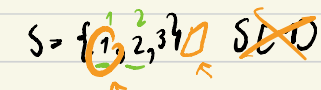
Set / Map

set

S = {1, 1, 2, 4} = {1, 2, 4}

- ไม่มีตัวซ้ำ
- เรียงค่าจากน้อยไปมาก

S.insert(3) → O(logn)
S.insert(1)
S.insert(2)



S.erase(3) → O(logn)

O(log n)
1, 2, ✗, 4, ✗, -3

O(n) → หาค่าที่น้อยที่สุดลำดับที่ k ; k ≤ n

print(S.size()) → O(1)

```
for (int &s : S){
    printf("%d\n", s)   // 1
    s = 5               // 2
}                       // 3
```

iterator → pointer ของ stl

```
for (set<int>::iterator it = S.begin(); it != S.end(); it++){ → เรียงไปมาก
    print(*it)
}
```

S.rbegin(); it != S.rend(); it++ → มากไปน้อย

```
for(auto it = S.begin(); it != S.end(); it++){
    print(*it)
}
```

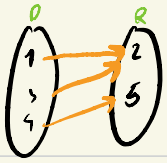
```
for (auto it : S){      // it → int type
    print(it)           // 1, 2, 3
}
```

set<int> S = {1, 2, 3} หรือ set<int> S

insert(x) } O(logn)
erase(x)

size()
begin()
end()
rbegin() → reverse begin → *(S.rbegin()) = ค่าที่มากที่สุด
rend() } O(1)

Map



print (map[1]) → 2
print (map[3]) → 2
print (map[4]) → 5

key value

mp = {(1, 2), (3, 2), (4, 5)}

map<string, int> fav; //เรียงตามตัวอักษรให้อัตโนมัติ

fav["ants"] = 5 print (fav["ants"]) → 5
fav["elephants"] = 2
print (fav["ant"]) → 0

// {("ants", 5), ("ant", 0), ("elephants", 2)}

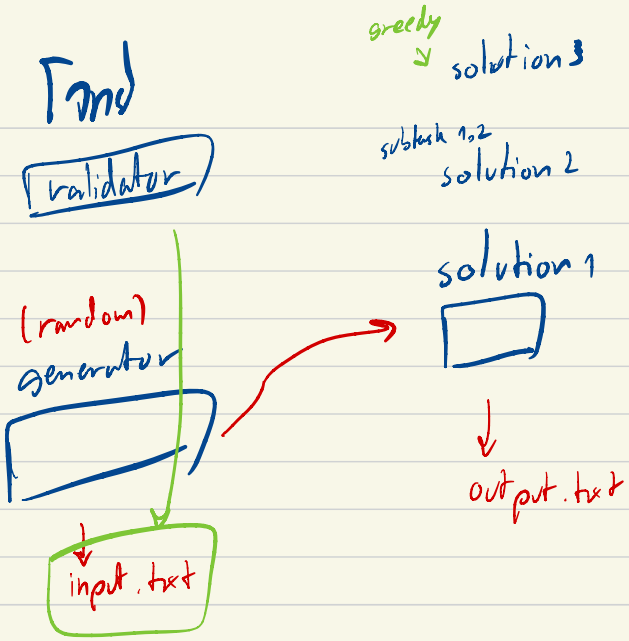
```
for (auto &[key, val] : mp){
    print (key, val)
}
for (auto it = mp.begin(); it != mp.end(); it++){
    print (it -> first) //ants
    print (it -> second) //5
}
```

(*it).first → ("ants", 5)
(*it).second

mp.erase ("ants")

map <int, int> mp
add key O(logn)
erase key O(logn)
size()
begin()
end()
rbegin()
rend()
} O(1)

Gen Tmd



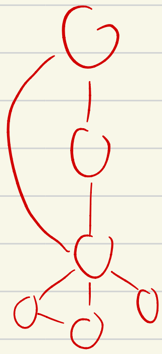
subtask 1 → $N \leq 100$
2 → $N \leq 10^4$
3 → $N \leq 10^5$

Parallel B search

weight
รอบ dfs ใน undirected G → visit / parent ของทางเดิน tree
กับ directed G

```
if(v==p)con
if(!vi[v]){
    dfs(v,u)
    lo[v]=min(lo[v],lo[u])
}else{
    low[v]=min(lo[u],disc[v])
}
```

Top down (Iterative)
Bottom UP (Recursive)



Push
Pull

DFS tree → Bridge
Arti → 2ccs
SCC? (ไว้ก่อน)

Fen / Seg

Matrix Expo

QS
Knapsack
LIS
LCS
MCM
Partitioning (K-subarray)
Digit DP
Bitmask
DAG

1. What is dp? ✓
2. Recursive Vs Iterative ✓
3. Push Vs Pull ✓

Slime
Mixture

1. Stair ✓
2. Coin combination ↗ Double Counting ✓
3. Wine line (2, 4, 6, 2, 5) ✓
5. Frog ↗2 ก้าว ↗k ก้าว
4. Grid ✓
6. MCM

state space

	6	3	4	7	5	6
bfid	-1	-1	2	3	3	5

mxp: ~~6~~ 3, 4, ~~7~~ 5, 6
idx: ~~1~~ 2, 3, ~~4~~ 5, 4

DP 2D ✓
LCS ✓
LIS → 1151, cat, orchid
MCM / Range DP
Knapsack → max(dp(i-1, wei), dp(i-1, wei - w[i]) + v[i])
Coin Change ✓
Grid ✓
Island ✓