

key	value
S	→ 10
g	→ 10
8	→ 10
0	→ 10
3	→ 10

hm < Integer, Integer >

↓
~~9 5 5 9 8 5 5 8~~
~~0 3 1 8 9 7 1 0 3~~
 6 5 9 1 1 8 0 2
 4 2 9 1 5

a1 → [5 5 9 8 5 5 8 0 3] 0(∞)
 a2 → [9 7 1 0 3 6 5 9 1 1 8 0 2 4 2 9]

9
 0
 3
 5
 8

e in a1
 hm.put(e, 1)

e in a2
 contains key (e)
 88 get(e) == 1
 print
 put(e, 0)

$1 \rightarrow 210$
 $2 \rightarrow 321$
 $3 \rightarrow 1$
 $5 \rightarrow 10$

$a1 \rightarrow$ $\textcircled{1}$ $\textcircled{1}$ 2 $\textcircled{2}$ 2 3 $\textcircled{5}$
 $a2 \rightarrow$ $\underline{1}$ $\underline{1}$ $\textcircled{4}$ $\textcircled{5}$ $\textcircled{2}$ $\underline{1}$ $\underline{2}$

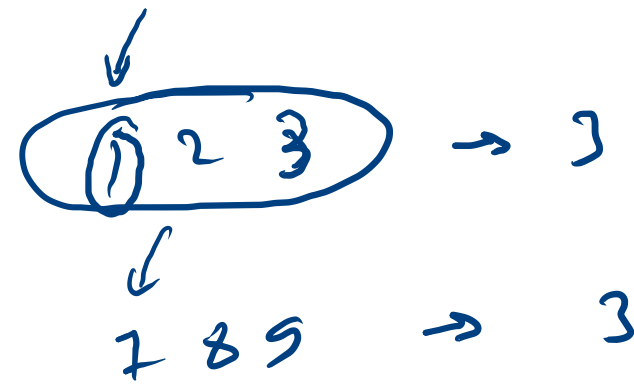
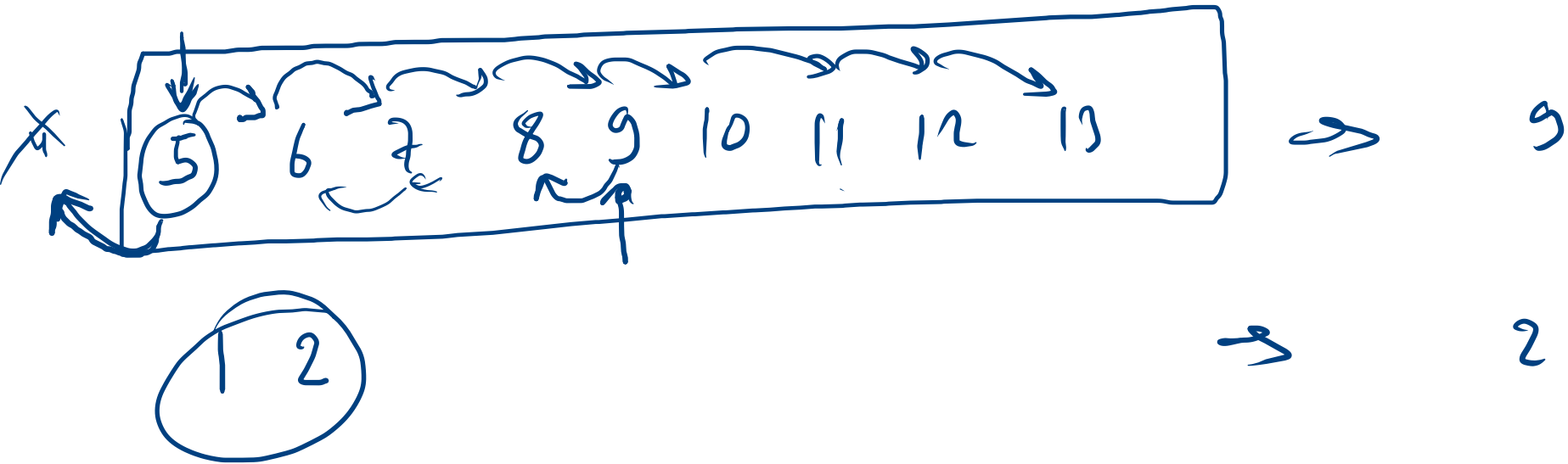
1
 1
 5
 2
 2

for map a1

e in a2

containsKey(e) &&
get(e) > 0
print(e)
put(get(e) - 1)

12 5 1 2 10 2 13 7 11 8 9 11 8 9 5 6 11



1
2
3

12 5 1 2 10 2 13 7 11 8 9 11 8 9 5 6 11
 ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓

searching $O(1)$

12 → +
 5 → +
 1 9
 2 6
 10
 13
 7
 11
 8

keySet

2, 2, 5, 6, 8, 1

(val-1) α

start
 5 6 7 8 9 10 11 12 13
 size 1 2 3 4 5 6 7 8 9 ←

1 2
 size 1 2 ←

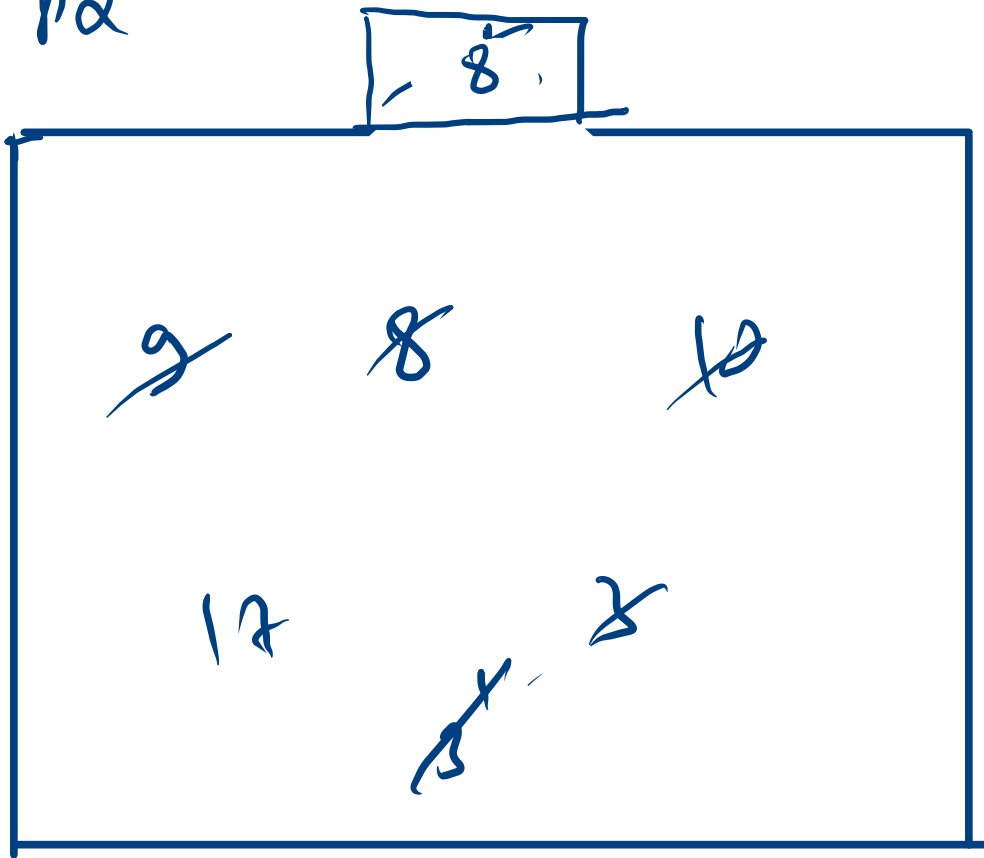
add \rightarrow log n
 remove \rightarrow log n
 peek \rightarrow O(1)

~~10~~ | ~~90~~ | ~~70~~ | ~~40~~ | ~~50~~ | 10 | 70 | 80 | 30

add
 9
 8
 10
 12

3
 3'

pq

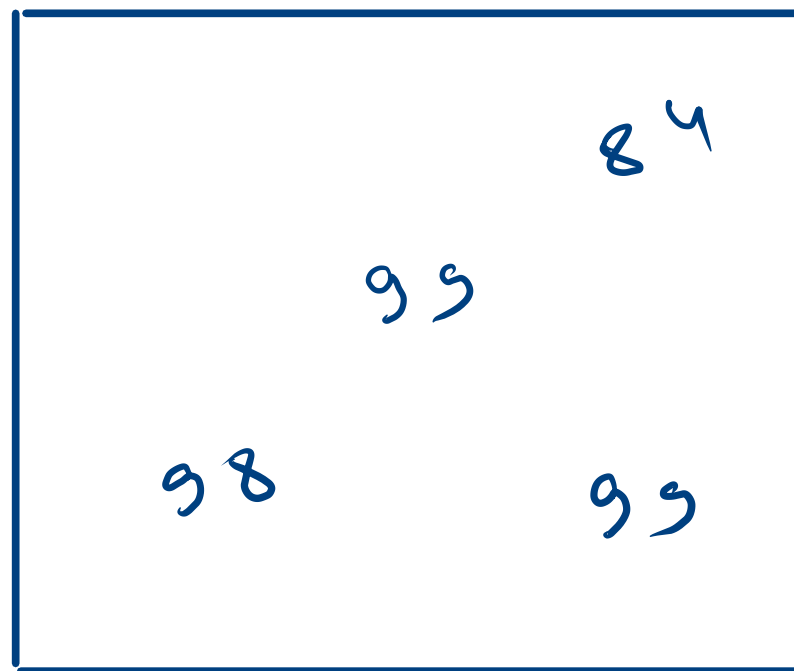


rem

3'
 3
 8
 9
 10

$\overline{12}$ $\overline{62}$ $\overline{22}$ $\overline{15}$ $\overline{37}$ $\overline{99}$ $\overline{11}$ 37 $\overline{98}$
67 31 84 59

$k = 4$



add	$\log(k)$
rem	$\log(k)$

smaller
remove

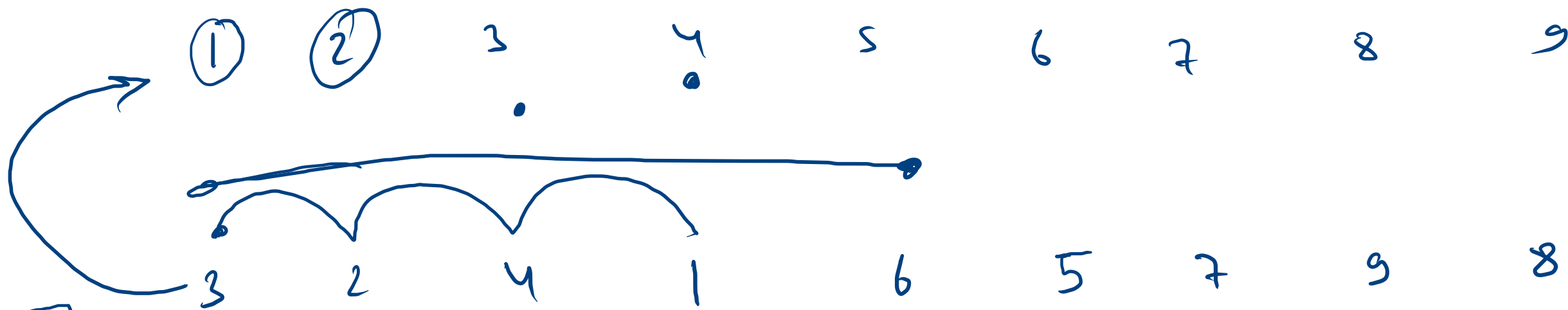
$in(k+1)$
 $pr.remove$

$k \leq n$

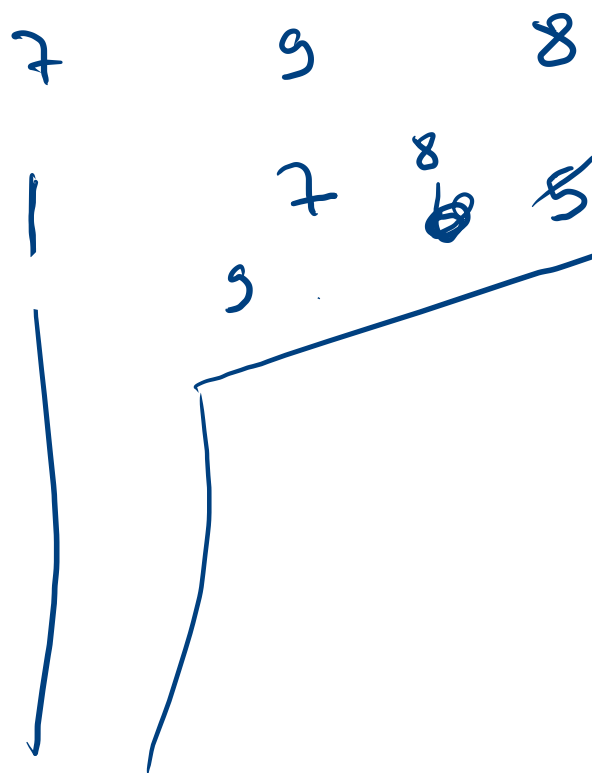
$\log k < \log(n)$

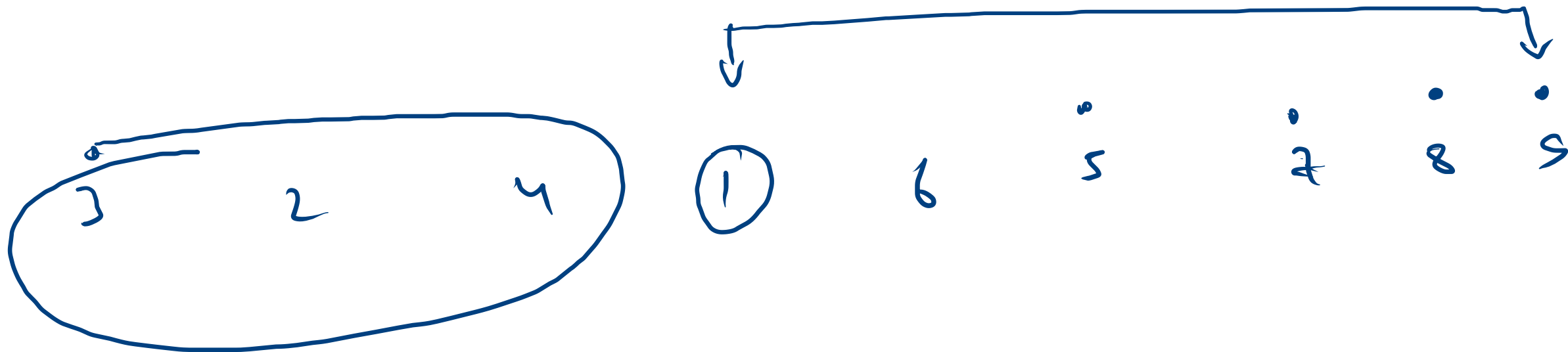
$n \log(n)$

$k=3$



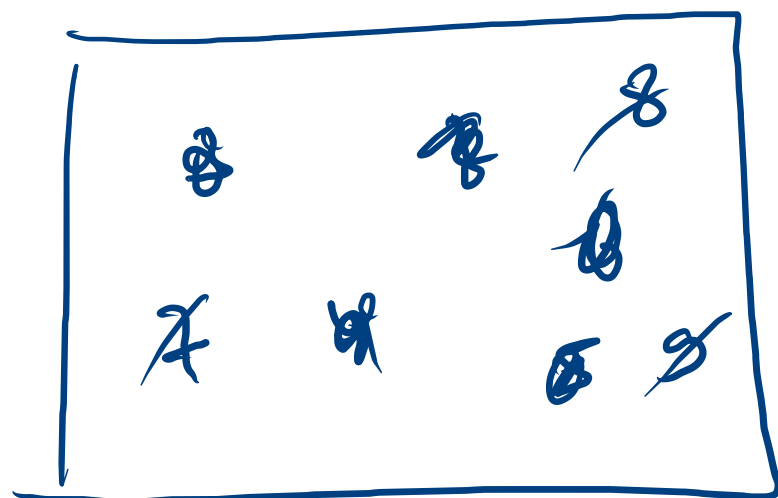
1 2 3 4 5 6





$k = 3$

all
print (remove)



1
2
3
4

5
6
7
8

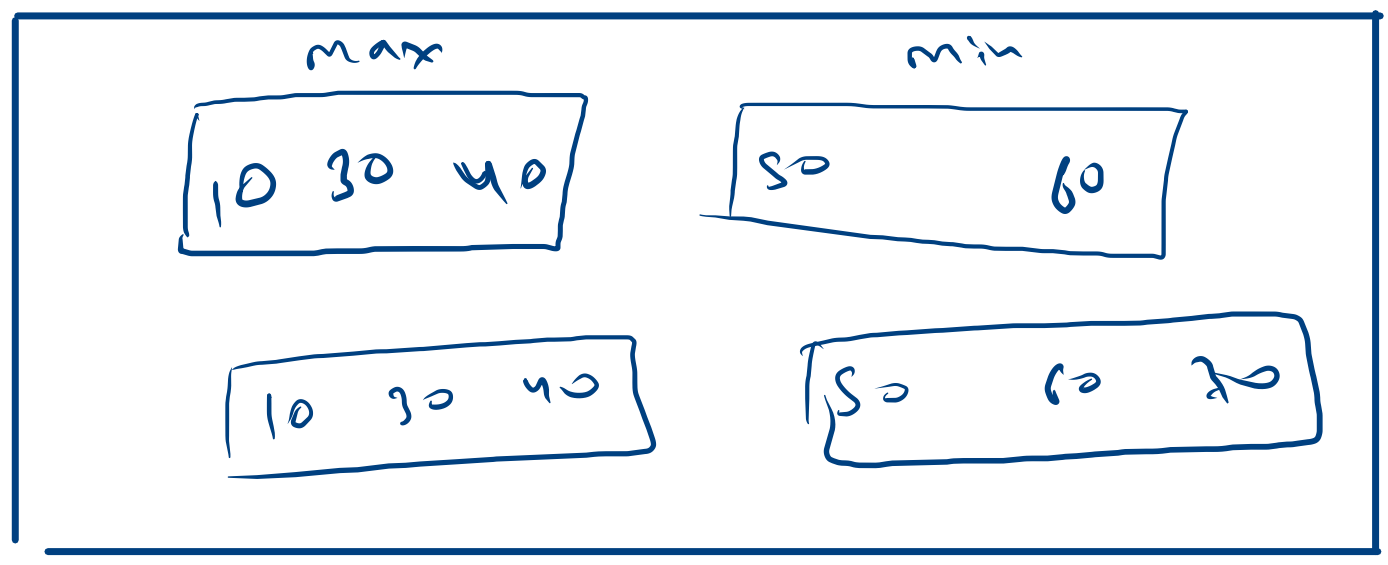
add 30
add 10
add 20

a 30
a 20

remove → 20
peek → 10

a 40
a 80
a 60
peek 40
remove 40

peek 30
remove 30
remove → 50

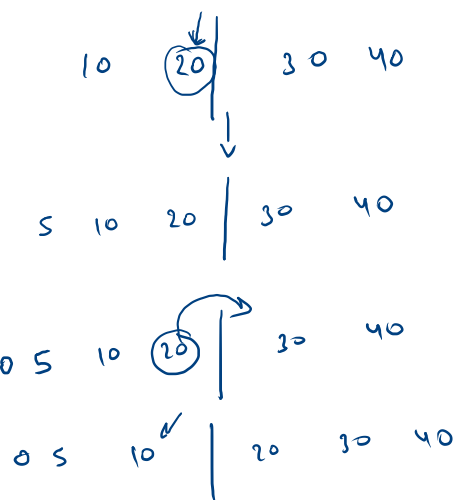


5
③

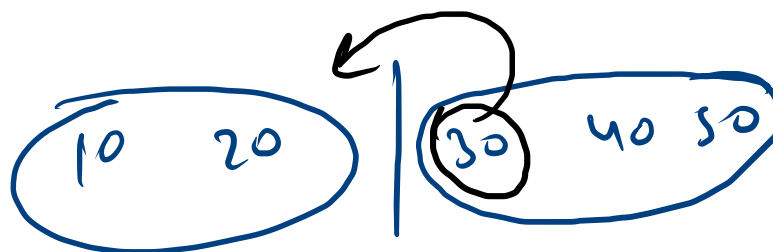
1 2 3 4 even

Left

right min



10 20 | 30 40



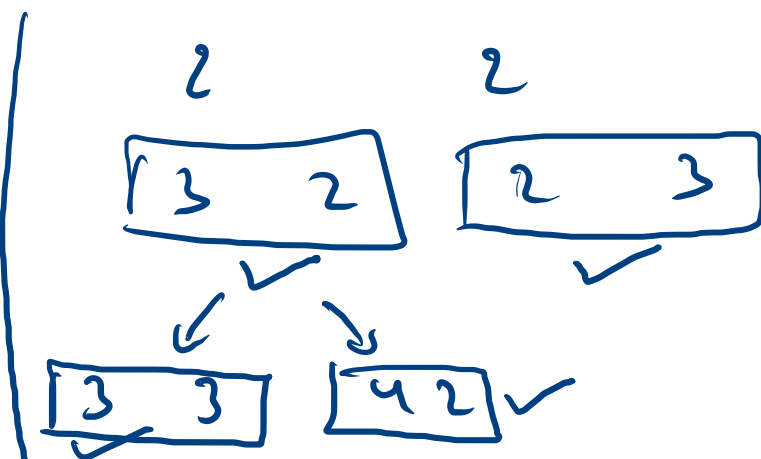
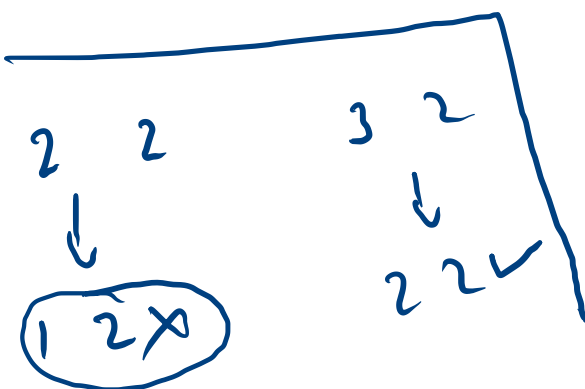
5 add

0 add

50 add

10 20 30 | 40 50

add



left.size == right.size+2

left.remove
right.add

★
left.size+1==right.size

right.remove
left.add

4 → 2 2
5 → 3 2