

## Quick Sort (20 pts)

### Problem Description

Given an array  $\mathbf{a}$  with  $N$  numbers  $\mathbf{a}[1], \mathbf{a}[2], \dots, \mathbf{a}[N]$  (possibly repeated), run the following quick sort algorithm `QUICKSORT( $\mathbf{a}, 1, N$ )` on the array, as introduced in Week 7 of the class, for a budget of  $B$  swaps or until the array is sorted. Then, print out the content of the array.

Note that there are many different variant versions of the quick sort algorithm. You are asked to implement the version below *exactly* to produce the correct answer for this problem.

`QUICKSORT( $A, \ell, r$ )`

```
1  if  $\ell < r$ 
2       $m = \text{PARTITION}(A, \ell, r)$ 
3      QUICKSORT( $A, \ell, m - 1$ )
4      QUICKSORT( $A, m + 1, r$ )
```

`PARTITION( $A, \ell, r$ )`

```
1   $pivot = A[\ell]$ 
2   $i = \ell + 1$ 
3   $j = r$ 
4  while  $i < j$ 
5      while  $i \leq r \ \& \ A[i] \leq pivot$ 
6           $i = i + 1$ 
7      while  $j \geq \ell \ \& \ A[j] > pivot$ 
8           $j = j - 1$ 
9      if  $i \geq j$ 
10         break
11     SWAP( $A[i], A[j]$ )
12 if  $\ell < j \ \& \ A[\ell] > A[j]$ 
13     SWAP( $A[\ell], A[j]$ )
14 return  $j$ 
```

### Input

The first line includes two integers  $N$  and  $B$ , representing the size of the array and the budget on the number of swaps. The second line includes  $N$  integers, representing the elements of the array  $\mathbf{a}[1], \mathbf{a}[2], \dots, \mathbf{a}[N]$ . All numbers are separated by a space.

## Output

- If the array can be sorted within  $B$  swaps, output a line of

The array is [the content of the array] after [X] swaps.

where [the content of the array] lists the final  $\mathbf{a}[1], \mathbf{a}[2], \dots, \mathbf{a}[N]$  after sorting, and [X] is the actual number of swaps taken, which would be a unique number using the version of the quick sort algorithm above.

- If the array is not sorted after  $B$  swaps, output a line of

The array is [the content of the array] after [B] swaps.

where [the content of the array] lists the intermediate  $\mathbf{a}[1], \mathbf{a}[2], \dots, \mathbf{a}[N]$  after the  $B$  swaps, and [B] is just the number  $B$ .

## Constraint

- $1 \leq N \leq 2^{10}$
- $1 \leq B \leq 2^{10}$
- $-2^{30} \leq \mathbf{a}[n] \leq 2^{30}$  for  $n \in \{1, 2, \dots, N\}$

## Sample Testcases

### Sample Input 1

3 2  
1 3 2

### Sample Input 2

4 2  
2 3 4 1

### Sample Input 3

4 2  
2 2 4 1

### Sample Output 1

The array is 1 2 3 after 1 swaps.

### Sample Output 2

The array is 1 2 4 3 after 2 swaps.

### Sample Output 3

The array is 1 2 2 4 after 2 swaps.

## Hint

- By design, you can pass this homework by simulating the quick sort algorithm properly. There is no need for other arithmetic calculations or cuts.