Answer of 1

Array	1	6	2	4	3	5
Index	0	1	2	3	4	5

Call #1:

quicksort(array, 0, 5)

Array	1	6	2	4	3	5
Index	0	1	2	3	4	5
	l, pivot					r

Pivot is picket the left-most one.

Now, do partition:

Swap, pivot with right position. i=0 and j=4.

Array	5	6	2	4	3	1
Index	0	1	2	3	4	5
	L, i				j	Pivot, r

While arr[i] < pivot, i++. We get below result as arr[0] > pivot i.e. 5 > 1.

Array	5	6	2	4	3	1
Index	0	1	2	3	4	5
	L, i				j	Pivot, r

While arr[j] > pivot, j--. We get j = -1.

Array	5	6	2	4	3	1
Index	0	1	2	3	4	5
	L, i					Pivot, r

Since, j crossed i. We stop and swap pivot with i. We get below results.

Array	1	6	2	4	3	5
Index	0	1	2	3	4	5
	L, i					r

Now we do self-calls:

quicksort(arr, 0, -1) -> This will stop as 0 > -1.
quicksort(arr, 1, 5)

Self-call #1:

quicksort(arr, 1, 5)

Array	1	6	2	4	3	5
Index	0	1	2	3	4	5
		L, pivot				r

Partition:

Swap pivot element to right element. We have i=1 and j = 4.

Array	1	5	2	4	3	6
Index	0	1	2	3	4	5
		L,i			j	r, pivot

While arr[i] < pivot, i++. We'll get i= 5 as everything is less than pivot.

Array	1	5	2	4	3	6
Index	0	1	2	3	4	5
		L			j	i, r, pivot

I crossed j so we don't loop over j. Now, swap pivot and I and return i=5.

Array	1	5	2	4	3	6
Index	0	1	2	3	4	5
		L				i, r

We got new pivot location i=5 returned. Now, do self-calls on the left and right partitions.

quicksort(arr, 1, 4)
quicksort(arr, 6, 5) -> we don't do this as 6 > 5.

Self-call #2:

quicksort(arr, 1, 4)

Pivot is always selected to be left.

Array	1	5	2	4	3	6
Index	0	1	2	3	4	5
		L, pivot			r	

Partition:

Swap pivot element to right element. We have i=1 and j = 3.

Array	1	3	2	4	5	6
Index	0	1	2	3	4	5
		L, i		j	R, pivot	

While arr[i] < pivot, i++. We'll get i= 5 as everything is less than pivot.

Array	1	3	2	4	5	6
Index	0	1	2	3	4	5
		L		j	I, R, pivot	

I crossed j so we don't loop over j. Now, swap pivot and I and return i=5.

Array	1	3	2	4	5	6
Index	0	1	2	3	4	5
		L			i, R	

We got new pivot location i=4 returned. Now, do self-calls on the left and right partitions.

quicksort(arr, 1, 3)
quicksort(arr, 5, 4) -> we don't do this as 5 > 4.

Self-call #3:

quicksort(arr, 1, 3)

Pivot is the left-most element.

Array	1	3	2	4	5	6
Index	0	1	2	3	4	5
		L, pivot		R		

Partition:

Swap pivot with right position.

Array	1	4	2	3	5	6
Index	0	1	2	3	4	5
		L, i	j	R, pivot		

While arr[i] < pivot, i++. We’ll get i= 1 as 4 > 3.

Array	1	4	2	3	5	6
Index	0	1	2	3	4	5
		L, i	j	R, pivot		

While arr[j] > pivot, j--. We’ll get j= 2 as 2 < 3.

Array	1	4	2	3	5	6
Index	0	1	2	3	4	5
		L, i	j	R, pivot		

As I and j are stuck, we swap the values and continue again.

Array	1	2	4	3	5	6
Index	0	1	2	3	4	5
		L, i	j	R, pivot		

While arr[i] < pivot, i++. We’ll get i= 2.

Array	1	2	4	3	5	6
Index	0	1	2	3	4	5
		L	J, i	R, pivot		

I crossed j so we don’t loop over j. Now, swap pivot and I and return i=2.

Array	1	2	3	4	5	6
Index	0	1	2	3	4	5
		L	i	R		

We got new pivot location i=2 returned. Now, do self-calls on the left and right partitions.

quicksort(arr, 1, 1) we stop as low == high
quicksort(arr, 3, 3) we stop as low == high

We get final result.

Array	1	2	3	4	5	6

Answer of 2

Array: = [5, 1, 4, 3, 6, 2, 7, 1, 3]

Size, n = 9

For simplification, see the sorted array only to see what L, E and R would be.

Since, n =9, 3n/4 = 3 * 9 / 4 ≈ 6.

Array	5	1	4	3	6	2	7	1	3

Sorted Array	1	1	2	3	3	4	5	6	7

<u>When pivot is 1.</u>

L = []
E = [1, 1]
R = [2,3,3,4,5,6,7]

L is of size 0 and R is of size 7.

<u>When pivot = 2</u>

L = [1, 1]
E = [2]
R = [3,3,4,5,6,7]

L is of size 2 and R is of size 6.

When pivot = 3

L = [1, 1, 2]
E = [3, 3]
R = [4,5,6,7]

L is of size 3 and R is of size 4.

When pivot = 4

L = [1, 1, 2, 3, 3]
E = [4]
R = [5,6,7]

L is of size 5 and R is of size 3.

When pivot = 5

L = [1, 1, 2, 3, 3, 4]
E = [5]
R = [6,7]

L is of size 6 and R is of size 2.

When pivot = 6

L = [1, 1, 2, 3, 3, 4, 5]
E = [6]
R = [7]

L is of size 7 and R is of size 1.

When pivot = 7

L = [1, 1, 2, 3, 3, 4, 5, 6]
E = [7]
R = []

L is of size 8 and R is of size 0.

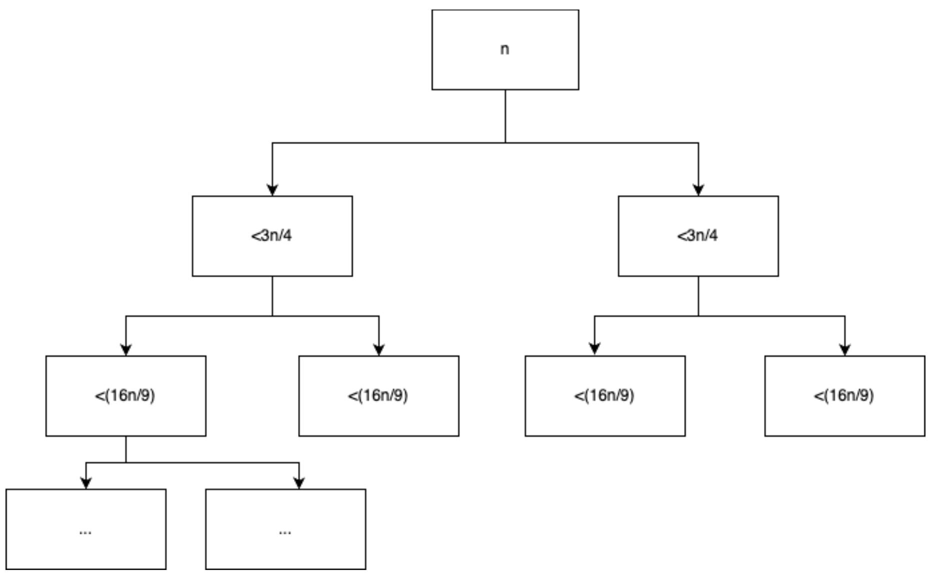
a. From above, we can see that pivots [3,3, 4] are the only good pivots.

The pivots [1, 1, 2, 5, 6, 7] are bad pivots as either L or R is greater than 6.

b. No, if the array have duplicates, then there's no guarantee that at least half of them would be good pivots.

Answer of 3

The best case ideally would be to split the array in n/2 for both Left and Right partition. However, pivot itself always makes sure that neither Left and Right can be n/2.



Running Time = no. of levels * amount of work at each level

At each level, the array is divided into two partitions of < 3n/4. So, the height of the tree is the same as the number of levels.

$n,\ \frac{3}{4}n, \left(\frac{3}{4}\right)^2 n, \left(\frac{3}{4}\right)^3 n, \ldots 1, 0$

$1 + \log_{4/3} n$

Which will be O(logn).

At each level of the tree, the total processing time is O(n).

Hence Total Running Time = O(nlogn)

This is the best running time for quick sort O(nlogn).

Answer of 4

```
class Solution {
    public int findKthLargest(int[] nums, int k) {
        int position = nums.length - k;
        int start = 0;
        int end = nums.length - 1;

        while (start<end){
            int cursor = quickSelect(nums, start, end);

            if(cursor == position){
                break;
            } else if(position < cursor){
                end = cursor - 1;
            } else {
                start = cursor + 1;
            }
        }

        return nums[position];
    }

    int quickSelect(int[] arr, int start, int end) {
        int pivot = arr[end];

        int position = start;

        for(int i = start; i < end; i++){
            if(arr[i] < pivot){
                if (position != i ){
                    swap(arr, i, position);
                }

                position++;
            }
        }

        arr[end] = arr[position];
        arr[position] = pivot;

        return position;
    }

    void swap(int[] arr, int index1, int index2){
        int temp = arr[index1];
        arr[index1] = arr[index2];
        arr[index2] = temp;
```

```
        }

}
```