

Quick Sort

Elements: 157, 110, 147, 122, 111, 149, 151, 141, 123, 112, 117, 133

(i) pivot element as first element in array.

$$\text{pivot} = 157$$

$j \rightarrow$ at last element.

$i \rightarrow$ first element

(i) move i from left to right, if $i < j$ swap stop at element greater than pivot

(ii) move j from right to left, stop at element less than pivot.

if $i < j$ swap $A[i], A[j]$,

if $i \geq j$ stop

Step 1 157, 110, 147, 122, 111, 149, 151, 141, 123, 112, 117, 133
 \uparrow_i \downarrow_j swap

\Rightarrow 133, 110, 147, 122, 111, 149, 151, 141, 123, 112, 117, 157.
 \uparrow_i \downarrow_j pivot

Step 2 133, 110, 147, 122, 111, 149, 151, 141, 123, 112, 117, 157.
 \uparrow_i \downarrow_j swap

\Rightarrow 133, 110, 117, 122, 111, 149, 151, 141, 123, 112, 147, 157.
 \uparrow_i \downarrow_j pivot

Step 3 133, 110, 117, 122, 111, 149, 151, 141, 123, 112, 147, 157.
 \uparrow_i \downarrow_j swap

133, 110, 117, 122, 111, 112, 151, 141, 123, 149, 147, 157.
 \uparrow_i \downarrow_j

Step 4-

133, 110, 117, 122, 111, 112, 151, 141, 123, 149, 147, 157.
 \uparrow_i \downarrow_j swap

\Rightarrow 133, 110, 117, 122, 111, 112, 123, 141, 151, 149, 147, 157.
 \uparrow_i \uparrow_j

Step 5-

133, 110, 117, 122, 111, 112, 123, 141, 151, 149, 147, 157.
 \uparrow_i \uparrow_j $j \leq i$ swap pivot $a[i:j]$

\Rightarrow 123, 110, 117, 122, 111, 112, 133, 141, 151, 149, 147, 157

Now recursively sort left part & right part. as 133 is middle now.

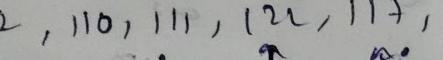
Step 6: Pivot \downarrow 123, 110, 117, 122, 111, 112, 123, $\boxed{138}$, $\left[\begin{matrix} 141, 131, 149, 147 \end{matrix} \right]$ 137; swap \uparrow Pivot \uparrow \leq Noswap.

$$112, 110, 117, 122, 111, \boxed{123}, \boxed{133}, \boxed{141}, [151, 149, 147] \boxed{167}$$

$$\text{Step 2:} \quad \begin{array}{c} \text{pivot} \\ \downarrow \\ [12, 110, 117; 122, 111] \end{array} | 123, 133, 141, \begin{array}{c} \text{pivot} \\ \downarrow \\ [151, 149, 147] \end{array} | 152$$

~~π_1~~ $\rightarrow \pi_1, \pi_2, \pi_3$ swap.

\Rightarrow pivot \downarrow swap \rightarrow $112, 110, 111, 122, 117, \boxed{123}, 133, 141, 147, 149, 157, 150$

Step 8 → pivot
 \downarrow
 112, 110, 111, 122, 117, $\boxed{123 \quad | \quad 132}$ 141 $\boxed{142, \quad | \quad 149, \quad | \quad 154, \quad | \quad 157}$


114, 110, 112, 122, 174, 123, 133, 141, 147, 149, 151, 157

Step 9:- pivot pivot
 111, 110, 112, 122, 117, 123, 133, 141, 142, 149, 151, 152-
swap swap

swap	swap	110	111	112	117	122	123	133	141	147	149	151	157
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\Rightarrow Sorted (9 steps).

(ii) Last element as pivot element:-

pivot = 133

Step 1:-

157, 110, 147, 122, 111, 149, 151, 141, 123, 112, 117, 133
↑
i → pivot
swap.
↓
j < pivot

→ 157 123

Step 2:- → 117, 110, 147, 122, 111, 149, 151, 141, 123, 112, 157, 133
↑
i
swap.

Step 3:-

112, 110, 112, 122, 111, 149, 151, 141, 123, 147, 157, 133
↑
i
swap.

Step 4:- 117, 110, 112, 122, 111, 123, 151, 141, 149, 147, 157, 133.

↑
i
j
swap.
↓
pivot

Step 5:- [17, 110, 112, 122, 111, 123] [133, 141, 149, 147, 157, 151]
↑
i
pivot
swap.

Step 6:- 117, 110, 112, 122, 111, [123, 133] 141, 149, 147, 157, 151
↑
i
j
swap.
↓
pivot
swap.

Step 7:- 110, 117, 112, 122, 111, [123, 133, 141, 147, 149, 151, 157]
↑
pivot
swap.
↓
sorted.

Step 8:-

110, [111], 112, 122, 117, 123, 133, 141, 147, 149, 151, 157.
↑
pivot
swap.
↓
sorted.

Step 9:-

[110, 111], 112, [117], 122, [123, 133, 141, 147, 149, 151, 157].
↑
pivot
pivot

Step 10:- 110, 111, 112, 117, 122, 123, 133, 141, 147, 149, 151, 157.
↓
sorted.

10 steps

(iii) Random element.

Pivot = 141

Step 1:- 157, 140, 142, 122, 111, 149, 151, 141, 143, 112, 117, 133
↑
Pivot swap.

Step 2:- 133, 110, 147, 122, 111, 149, 151, 141, 143, 112, 117, 157.
↑
Pivot swap.

Step 3:- 133, 110, 117, 122, 111, 149, 151, 141, 143, 112, 147, 157.
↑
Pivot swap.

Step 4:- 133, 110, 117, 122, 111, 112, 151, 141, 143, 149, 147, 157.
↑
Pivot swap.

Step 5:- 133, 110, 117, 122, 111, 112, 141, 151, 143, 149, 147, 157.
↑
Pivot swap.

Step 6:- 112, 110, 117, 122, 111, 133, 141, 147, 143, 149, 157.

Step 7:- 133 140 117 122 111 112 151, 143, 149, 147, 157

Step 8:- 110 111 112 117 133 122 143 147 149 151 157

Step 9:- 140, 111, 112, 117, 122, 133, 143, 147, 149, 15, 157

110 111 112 117 122 133 141 143 147 149 151 157

9 steps.