INSERTION SORT

1. Definition

Insertion Sort is a simple comparison-based sorting algorithm that builds the final sorted array **one element at a time**, by inserting each new element into its correct position among the previously sorted elements.

2. Key Idea

1. Consider first element as sorted.
2. Pick the next element (called *key*).
3. Compare it with elements in the sorted part (left side).
4. Shift larger elements one position to the right.
5. Insert the key in its correct position.
6. Repeat for all elements.

Insertion Sort works similarly to sorting playing cards in your hand.

3. Example

Array:
`[5, 4, 3, 2, 1]`

Pass 1: key = 4

Shift 5 → place 4
Array → `[4, 5, 3, 2, 1]`

Pass 2: key = 3

Shift 5, 4 → place 3
Array → `[3, 4, 5, 2, 1]`

Pass 3: key = 2

Shift 5, 4, 3 → place 2
Array → `[2, 3, 4, 5, 1]`

Pass 4: key = 1

Shift 5, 4, 3, 2 → place 1
Array → `[1, 2, 3, 4, 5]`

Sorted!

4. Algorithm (Pseudocode)

```
InsertionSort(arr, n)
    for i = 1 to n-1
        key = arr[i]
        j = i - 1

        while j >= 0 and arr[j] > key
            arr[j+1] = arr[j]      // shift right
            j = j - 1

        arr[j+1] = key             // insert key
```

5. Properties

Property	Value
Algorithm Type	Comparison-based
Technique	Insertion
In-place	Yes
Stable	✔ Yes
Adaptive	✔ Yes (best-case O(n))

Component	Worst Case
Passes	n – 1
Comparisons	n(n – 1)/2
Shifts	n(n – 1)/2
Time Complexity	$O(n^2)$
Space Complexity	O(1)
Stable?	Yes
Adaptive?	Yes

6. Advantages

- Simple and intuitive
- Efficient for small datasets
- Good for nearly-sorted arrays
- Stable
- Adaptive
- Online algorithm (can sort data as it arrives)

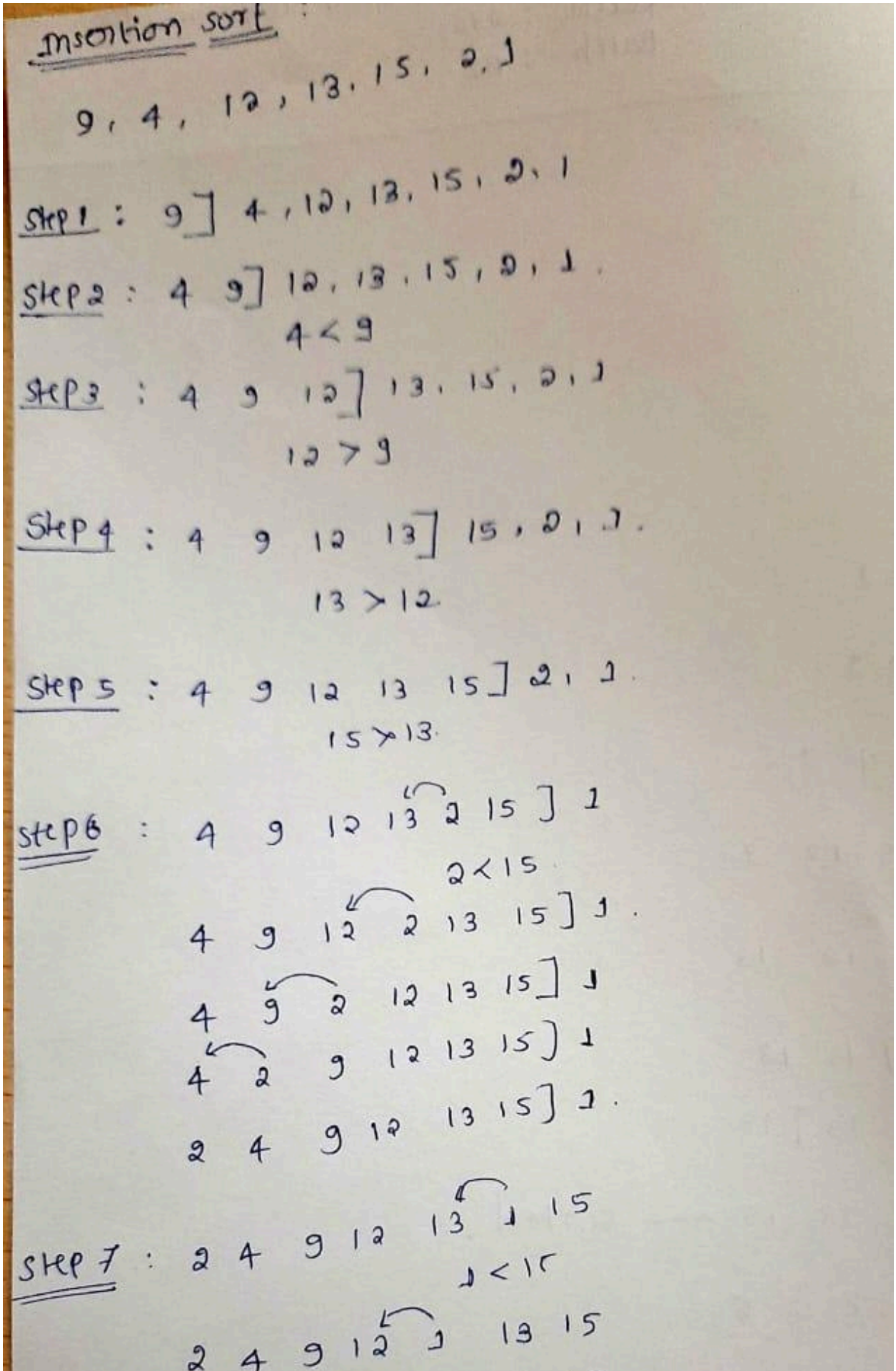
7. Disadvantages

- Slow for large datasets
- Worst case $O(n^2)$
- Many shifts compared to selection sort

8. Real-Life Analogy

Sorting cards in your hand:
You pick a card and insert it at the right place among already sorted cards.

9. EFFICIENCY ANALYSIS IS THE SAME AS BUBBLE SORT


Insertion sort
9, 4, 12, 13, 15, 2, 1
Step 1 : 9] 4, 12, 13, 15, 2, 1
Step 2 : 4 9] 12, 13, 15, 2, 1.
4 < 9
Step 3 : 4 9 12] 13, 15, 2, 1
12 > 9
Step 4 : 4 9 12 13] 15, 2, 1.
13 > 12
Step 5 : 4 9 12 13 15] 2, 1.
15 > 13
Step 6 : 4 9 12 13 2 15] 1
2 < 15
4 9 12 2 13 15] 1.
4 9 2 12 13 15] 1
4 2 9 12 13 15] 1
2 4 9 12 13 15] 1.
Step 7 : 2 4 9 12 13 1 15
1 < 15
2 4 9 12 1 13 15