Functions with Pass-by-Reference

Lab 8: Insertion Sort

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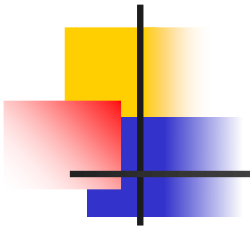


Purposes of the Lab

- **Understanding the followings:**
  - **Pass by value & pass by reference**
  - **Reference type**

Reference Type

```
1  // Fig. 5.19: fig05_19.cpp
2  // Initializing and using a reference.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     int x = 3;
9     int &y = x; // y refers to (is an alias for) x
10
11    cout << "x = " << x << endl << "y = " << y << endl;
12    y = 7; // actually modifies x
13    cout << "x = " << x << endl << "y = " << y << endl;
14 } // end main
```

```
x = 3
y = 3
x = 7
y = 7
```

Fig. 5.19 | Initializing and using a reference.

```
1  // Fig. 5.20: fig05_20.cpp
2  // References must be initialized.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     int x = 3;
9     int &y; // Error: y must be initialized
10
11    cout << "x = " << x << endl << "y = " << y << endl;
12    y = 7;
13    cout << "x = " << x << endl << "y = " << y << endl;
14 } // end main
```

Fig. 5.20 | Uninitialized reference causes a compilation error. (Part 1 of 2.)

Pass-by-Value vs. Reference

```
1  // Fig. 5.18: fig05_18.cpp
2  // Comparing pass-by-value and pass-by-reference with references.
3  #include <iostream>
4  using namespace std;
5
6  int squareByValue( int ); // function prototype (value pass)
7  void squareByReference( int & ); // function prototype (reference pass)
8
9  int main()
10 {
11    int x = 2; // value to square using squareByValue
12    int z = 4; // value to square using squareByReference
13
14    // demonstrate squareByValue
15    cout << "x = " << x << " before squareByValue\n";
16    cout << "Value returned by squareByValue: "
17       << squareByValue( x ) << endl;
18    cout << "x = " << x << " after squareByValue\n" << endl;
19
20    // demonstrate squareByReference
21    cout << "z = " << z << " before squareByReference" << endl;
22    squareByReference( z );
23    cout << "z = " << z << " after squareByReference" << endl;
24 } // end main
```

Fig. 5.18 | Passing arguments by value and by reference. (Part 1 of 2.)

```
25
26  // squareByValue multiplies number by itself, stores the
27  // result in number and returns the new value of number
28  int squareByValue( int number )
29  {
30     return number *= number; // caller's argument not modified
31  } // end function squareByValue
32
33  // squareByReference multiplies numberRef by itself and stores the result
34  // in the variable to which numberRef refers in function main
35  void squareByReference( int &numberRef )
36  {
37     numberRef *= numberRef; // caller's argument modified
38  } // end function squareByReference
```

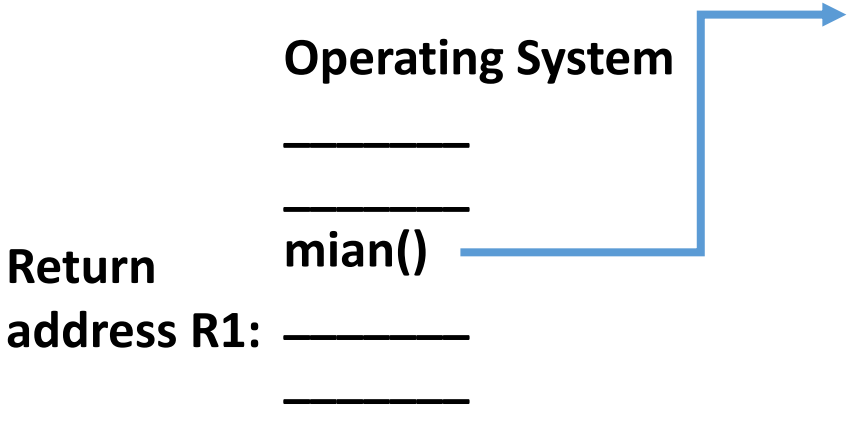
```
x = 2 before squareByValue
Value returned by squareByValue: 4
x = 2 after squareByValue

z = 4 before squareByReference
z = 16 after squareByReference
```

Fig. 5.18 | Passing arguments by value and by reference. (Part 2 of 2.)

Activation Records

- When a function is called, an activation record (AR) is pushed into a *stack*. After executing the function, the activation record is popped (removed) from the stack. Stack is a piece of Last-in-first-out memory. Data can only be stored or retrieved from the top of the stack.




```
Int main(){
Int x=10;
Int number = 20;
squareByValue(x);  // call_1
squareByValue(number); // call_2
squareByReference(x); // call_3
squareByReference(number); // call_4
Return 0;
}
Int squareByValue (int number){
return number*number;
}

void squareByReference(int &numberRef){
numberRef = numberRef * numberRef;
}
```

AR of main()

Return address R1	
x	10
number	20

More on Pass-by-Value vs. Reference (1)

```
Int main(){
Int x = 10 , number = 20;
squareByValue(x);  // call_1
Ret addr R2: squareByValue(number); // call_2
Ret addr R3: squareByReference(x); // call_3
Ret addr R4: squareByReference(number); // call_4
Ret addr R5: return 0; }
```

```
Int squareByValue (int number){
return number*number; }

void squareByReference(int &numberRef){
numberRef = numberRef * numberRef; }
```

Making call_1

AR of call_1

Return address R2
number 10

AR of main()

Return address R1
x 10
number 20

After executing call_1

AR of main()

Return address R1
x 10
number 20

Making call_2

AR of call_2

Return address R3
number 20

AR of main()

Return address R1
x 10
number 20

After executing call_2

AR of main()

Return address R1
x 10
number 20

Also see
https://courses.washington.edu/css342/zander/css332/passby.html
for another example.

More on Pass-by-Value vs. Reference (2)

```
                Int main(){
                Int x = 10 , number = 20;
                squareByValue(x);  // call_1
Ret addr R2:    squareByValue(number); // call_2
Ret addr R3:    squareByReference(x); // call_3
Ret addr R4:    squareByReference(number); // call_4
Ret addr R5:    return 0; }

                Int squareByValue (int number){
                return number*number; }

                void squareByReference(int &numberRef){
                numberRef = numberRef * numberRef; }
```

Making call_3

AR of call_3

AR of main()

Return address R4
Address of *x* in main() for *numberRef*
Return address R1
x 10
number 20

After executing call_4

AR of main()

Return address R1
x 100
number 400

Making call_4

AR of call_4

AR of main()

Return address R5
Address of *number* in main() for *numberRef*
Return address R1
x 100
number 20

After executing call_3

AR of main()

Return address R1
x 100
number 20

Passing an Array to Function

- An array can only be passed to a function by reference.
- Two ways – both need to pass the starting address of an array and the number of elements in the array to a function.
  - Using array name. Array name itself can be used as the starting address of an array.

    int anArray[100] = {0}; // an integer array whose elements are initialized to 0
    int aFunc(int [ ], int); // a function prototype that has an array parameter

    Making calls:
    aFunc(anArray, 100);

  - Using the address of the first element in the array.

    Making calls:
    aFunc(&anArray[0], 100); // **&** is an operator that takes the address of a variable

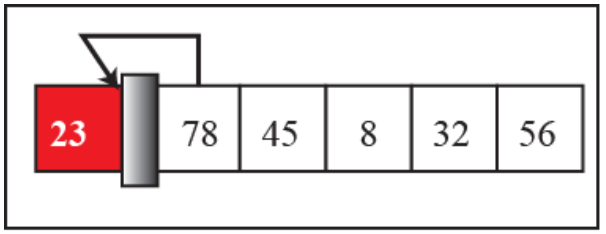
Lab 8: Insertion Sort

- **Write a program to sort integers in ascending order.**
  - **You should write a function with the following prototype:**
    int insertionSort(int [ ], int, int&, int&);
    The first parameter **int[ ]** is to hold a list of unsorted integers in the beginning and then the sorted integers on the return.
    The second parameter **int** is to hold the number of integers.
    The third parameter **int&** is to hold the location of the third smallest integer that last occurs in the original array. Assume the first unsorted integer has a location of 0.
    The fourth parameter int& is to hold the number of moves of elements made by insertion sort to complete sorting. You should minimize the number of moves.
    The return value of this function should be the third smallest integer. If there is no third smallest integer, return the second smallest integer. If there is no second smallest integer, return the smallest integer. You can use **retInt = insertionSort(…)** to receive the return value of a function call. Here, **retInt** is an integer variable.
  - **Your main function should look like as follows:**

```
int main() {
        for each test case:
        read a list of integers,
        sort the integers by calling insertionSort(…),
        Print out the third smallest integer, its location, and the number of moves on a line.
        Print out the sorted integers on a line
        }
```

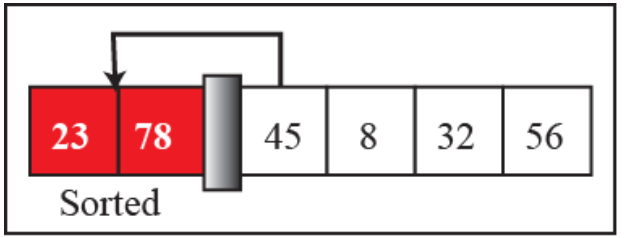
Example of Sorting in Ascending Order

- The number of moves is 15.



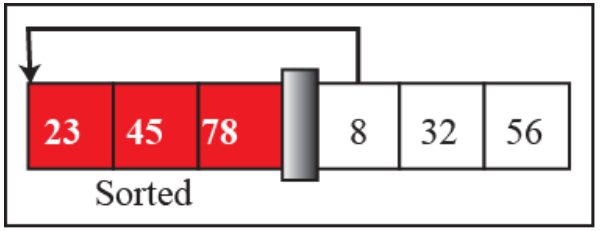
Original list

0 move



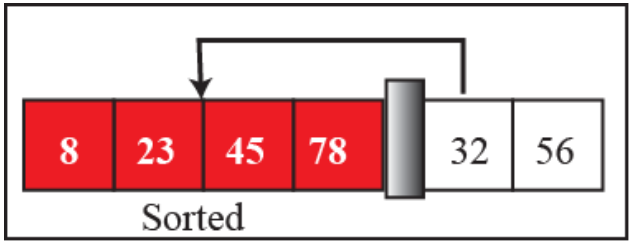
After pass 1

3 moves



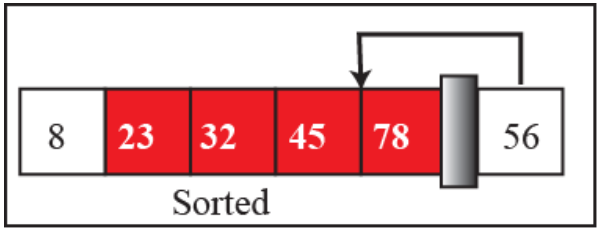
After pass 2

5 moves



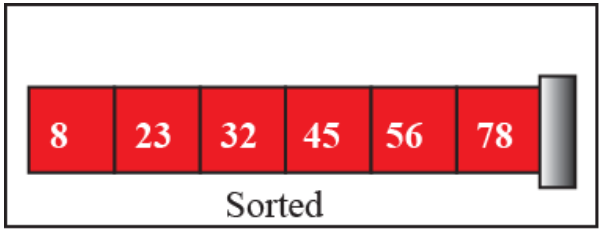
After pass 3

4 moves



After pass 4

3 moves



After pass 5

The third smallest integer is 32. The location of its last occurrence is 4. We need l5 moves to sort the integers.

Input

The first line gives the number of test cases. The input of a test case takes a line which has a list of integers separated by space characters. The first number in such a line is the number of integers need be sorted in this test case. There are at least one and at most 100 integers to be sorted.

Output

- **The output of each test case takes two lines. Each line should start with a # as follows.**

the third smallest integer, its location of the last occurrence, the number of moves
the sorted integers

Grading

- If only the sorted results are correct, get 70 points.
- All outputs are correct, get 100 points.
- TA must ensure the function int insertionSort(int [ ], int, int&, int&) should be written.

Example of Input & Output

Input	Output
10 5 1 2 3 5 4 3 1 1 2 15 1 3 4 7 9 11 13 15 14 12 10 8 6 4 2 1 2 6 1 1 1 2 2 2 6 1 1 2 1 2 2 10 1 2 3 4 5 6 7 8 9 10 10 10 9 8 7 6 5 4 3 2 1 6 1 1 3 2 2 3 20 87 88 12 55 23 44 65 44 78 66 -1 -1 -1 40 103 88 103 87 87 20	# 3 2 3 # 1 2 3 4 5 # 2 2 0 # 1 1 2 # 3 1 62 # 1 2 3 4 4 6 7 8 9 10 11 12 13 14 15 # 2 0 0 # 2 # 2 5 0 # 1 1 1 2 2 2 # 2 5 3 # 1 1 1 2 2 2 # 3 2 0 # 1 2 3 4 5 6 7 8 9 10 # 3 7 63 # 1 2 3 4 5 6 7 8 9 10 # 3 5 6 # 1 1 2 2 3 3 # 20 19 115 # -1 -1 -1 12 20 23 40 44 44 55 65 66 78 87 87 87 88 88 103 103