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Experiment No.	**1 B**

AIM:	Experiment on finding the running time of an algorithm. Comparing selection and insertion sort algorithms.
Program 1	
PROBLEM STATEMENT :	**Details** – The understanding of running time of algorithms is explored by implementing two basic sorting algorithms namely Insertion and Selection sorts. These algorithms work as follows. **Insertion sort**– It works similar to the sorting of playing cards in hands. It is assumed that the first card is already sorted in the card game, and then we select an unsorted card. If the selected unsorted card is greater than the first card, it will be placed at the right side; otherwise, it will be placed at the left side. Similarly, all unsorted cards are taken and put in their exact place. **Selection sort– I**t first finds the smallest value among the unsorted elements of the array is selected in every pass and inserted to its appropriate position into the array. In this algorithm, the array is divided into two parts, first is sorted part, and another one is the unsorted part. Initially, the sorted part of the array is empty, and unsorted part is the given array. Sorted part is placed at the left, while the unsorted part is placed at the right. In selection sort, the first smallest element is selected from the unsorted array and placed at the first position. After that second smallest element is selected and placed in the second position. The process continues until the array is entirely sorted. --- **Problem Definition & Assumptions** – For this experiment, you need to implement two sorting algorithms namely Insertion and Selection sort methods. Compare these algorithms based on time and space complexity. Time required to sorting algorithms can be performed using high_resolution_clock::now() under namespace std::chrono. You have togenerate1,00,000 integer numbers using C/C++ Rand function and save them in a text file. Both the sorting algorithms uses these 1,00,000 integer numbers as input as follows. Each sorting algorithm sorts a block of 100 integers numbers with array indexes numbers A[0..99], A[0..199], A[0..299],..., A[0..99999]. You need to use high_resolution_clock::now() function to find the time required for 100, 200, 300.... 100000 integer numbers. Finally, compare two algorithms namely Insertion and Selection by plotting the time required to sort 100000 integers using LibreOffice Calc/MS Excel. The x-axis of 2-D plot represents the block no. of 1000 blocks. The y-axis of 2-D plot representsthe tunning time to sort 1000 blocks of 100,200,300,...,100000 integer numbers. Note – You have to use C/C++ file processing functions for reading and writing randomly generated 100000 integer numbers.
ALGORITHM:	Insertion and selection sort are the 2 most fundamental sorting algorithms. Selection sort is a non-scalable, non-practical algorithm whereas insertion sort is practical for small inputs. Insertion sort is a stable sorting algorithm whereas Selection sort is unstable. **Selection Sort:** **Invariant:** All the elements to the left of the iterator are sorted and no element on the right is smaller than any of the elements on the left.

Algorithm:

Algorithm 4 Selection Sort

```
1: for i = 1 to n − 1 do
2:     min = i
3:     for j = i + 1 to n do
4:         // Find the index of the i^th smallest element
5:         if A[j] < A[min] then
6:             min = j
7:         end if
8:     end for
9:     Swap A[min] and A[i]
10: end for
```

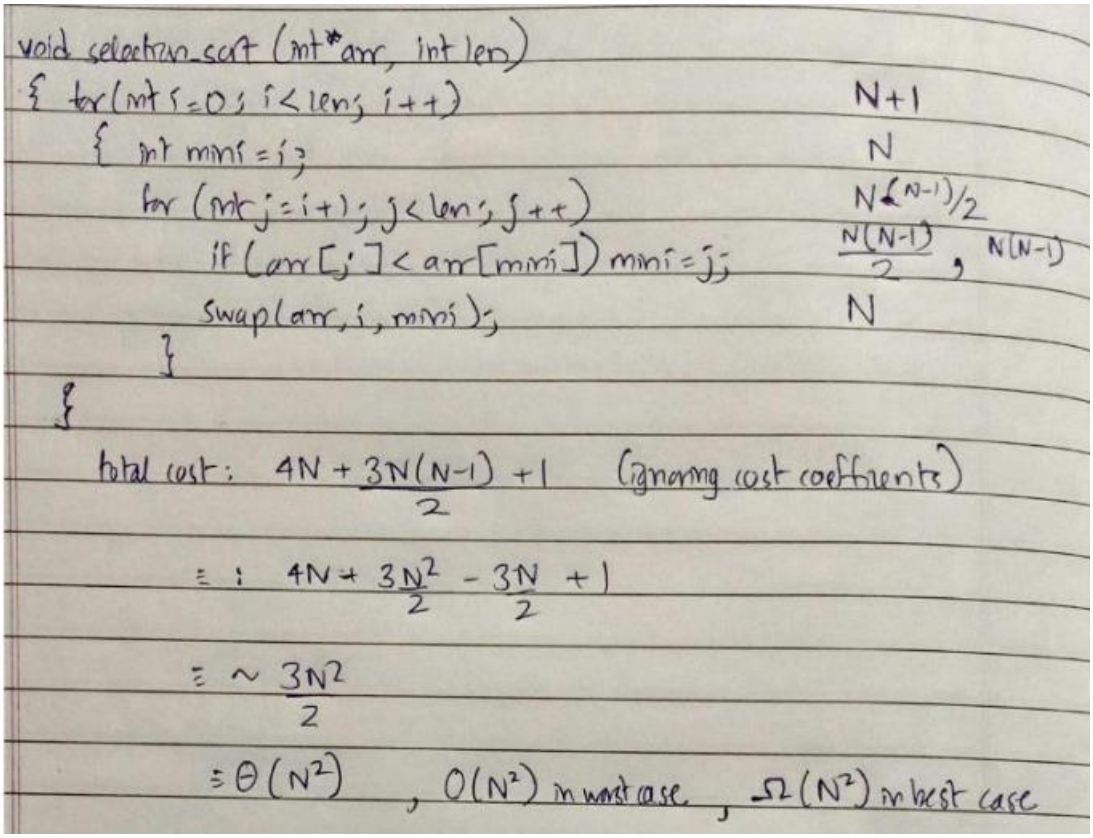
Trace:

i	min	0	1	2	3	4	5	6	7	8	9	10
		S	O	R	T	E	X	A	M	P	L	E
0	6	S	O	R	T	E	X	A	M	P	L	E
1	4	A	O	R	T	E	X	S	M	P	L	E
2	10	A	E	R	T	O	X	S	M	P	L	E
3	9	A	E	E	T	O	X	S	M	P	L	R
4	7	A	E	E	L	O	X	S	M	P	T	R
5	7	A	E	E	L	M	X	S	O	P	T	R
6	8	A	E	E	L	M	O	S	X	P	T	R
7	10	A	E	E	L	M	O	P	X	S	T	R
8	8	A	E	E	L	M	O	P	R	S	T	X
9	9	A	E	E	L	M	O	P	R	S	T	X
10	10	A	E	E	L	M	O	P	R	S	T	X
		A	E	E	L	M	O	P	R	S	T	X

Code:

```
void selection_sort(int* arr,int len)
{
    for (int i = 0; i < len; i++)
    {
        int mini = i;
        for (int j = i + 1; j < len; j++)if (arr[j] < arr[mini])mini = j;
        swap(arr, i, mini);
    }
}
```

Analysis:



Insertion Sort:

Invariant: Elements to the left of the iterator are sorted, whereas elements to right are not seen yet. At every turn, each chosen element is put in its proper place on the left side of the iterator.

Algorithm:

INSERTION-SORT(A)

```
1  for j ← 2 to length[A]
2      do key ← A[j]
3         ▷ Insert A[j] into the sorted sequence A[1 .. j − 1].
4         i ← j − 1
5         while i > 0 and A[i] > key
6             do A[i + 1] ← A[i]
7                i ← i − 1
8         A[i + 1] ← key
```

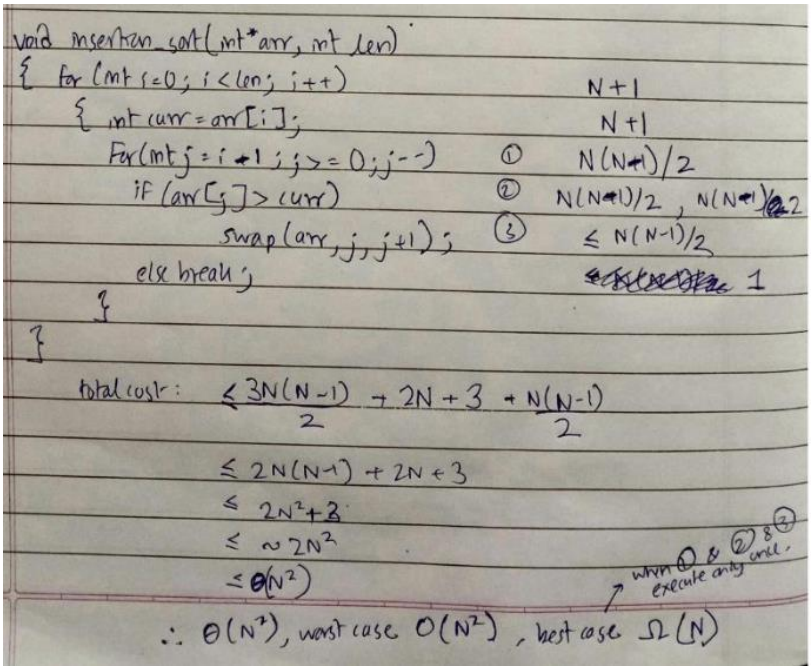
Trace:

i	j	0	1	2	3	4	5	6	7	8	9	10
		S	O	R	T	E	X	A	M	P	L	E
1	0	O	S	R	T	E	X	A	M	P	L	E
2	1	O	R	S	T	E	X	A	M	P	L	E
3	3	O	R	S	T	E	X	A	M	P	L	E
4	0	E	O	R	S	T	X	A	M	P	L	E
5	5	E	O	R	S	T	X	A	M	P	L	E
6	0	A	E	O	R	S	T	X	M	P	L	E
7	2	A	E	M	O	R	S	T	X	P	L	E
8	4	A	E	M	O	P	R	S	T	X	L	E
9	2	A	E	L	M	O	P	R	S	T	X	E
10	2	A	E	E	L	M	O	P	R	S	T	X
		A	E	E	L	M	O	P	R	S	T	X

Code:

```
void insertion_sort(int *arr, int len)
{
    for (int i = 0; i < len; i++)
    {
        int curr = arr[i];
        for (int j = i-1; j >= 0; j--)if (arr[j] > curr)swap(arr, j, j+1);
else break;
    }
}
```

Analysis:



PROGRAM:

```c
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>
#include <limits.h>
#include <time.h>

void swap(int *arr, int i, int j)
{
    int temp = arr[i];
    arr[i] = arr[j];
    arr[j] = temp;
}

void selection_sort(int* arr,int len)
{
    for (int i = 0; i < len; i++)
    {
        int mini = i;
        for (int j = i + 1; j < len; j++)if (arr[j] < arr[mini])mini = j;
        swap(arr, i, mini);
    }
}

void insertion_sort(int *arr, int len)
{
    for (int i = 0; i < len; i++)
    {
        int curr = arr[i];
        for (int j = i-1; j >= 0; j--)if (arr[j] > curr)swap(arr, j, j+1);
else break;
    }
}

int main(){

    //accessing the required file
    FILE *fptr;
    fptr=fopen("input.txt","w");
    if(fptr!=NULL)printf("file accessed.\n");
    else {printf("error in accessing file.\n");return -1;}

    //setting capacity and range to fill the file
    int capacity=100000;
    int range=100;
```

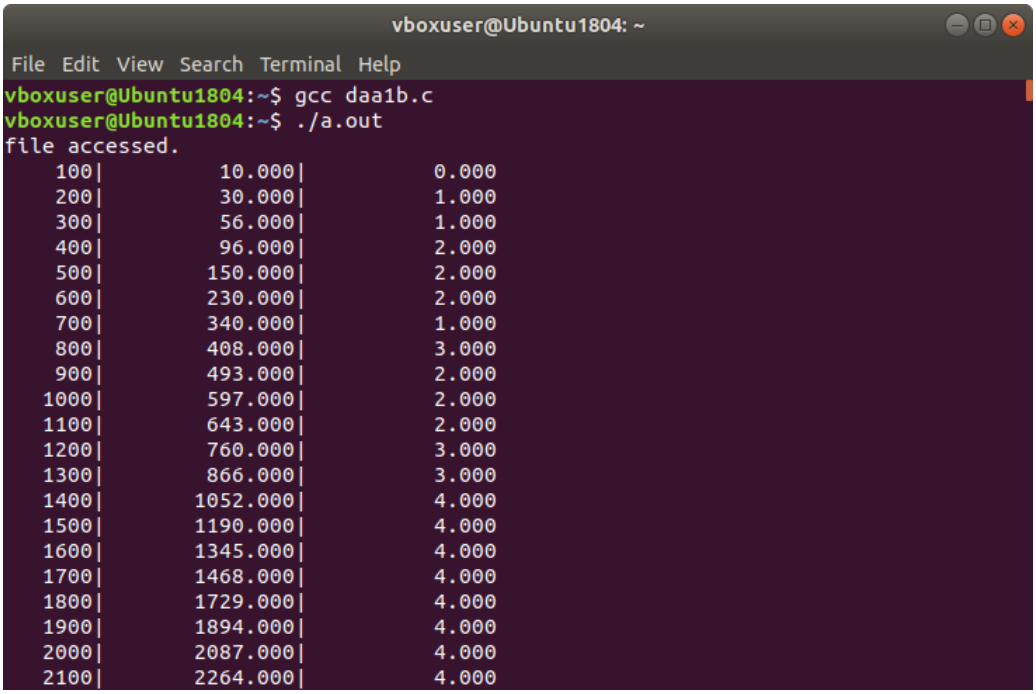
```
    for(int i=0;i<capacity;i++){
        putw(rand()%(range+1),fptr);
    }

    //initializing reciever array and clock variables
    int arr[capacity];
        int arr2[capacity];
    clock_t start_t;
    clock_t end_t;


    for(int i=100;i<=capacity;i+=100){

        //filling for selection sort
        for(int j=0;j<i;j++){
            arr[j]=getw(fptr);
        }
        start_t=clock();
        selection_sort(arr,i);//selection sort
        end_t=clock();
        printf("%7d|%10.3f|",i,(double)(end_t-start_t));

        /*rewind(fptr); //or can use fseek(fptr, 0, SEEK_SET); to reset
pointer to start of file
        as we want same numbers for insertion sort too*/
        fseek(fptr, 0, SEEK_SET);

        //filling for insertion sort
        for(int k=0;k<i;k++){
            arr2[k]=getw(fptr);
        }
        start_t=clock();
        insertion_sort(arr2,i);//insertion sort
        end_t=clock();
        printf("%10.3f\n",(double)(end_t-start_t) );
    }

    //closing file
    fclose(fptr);
}
```

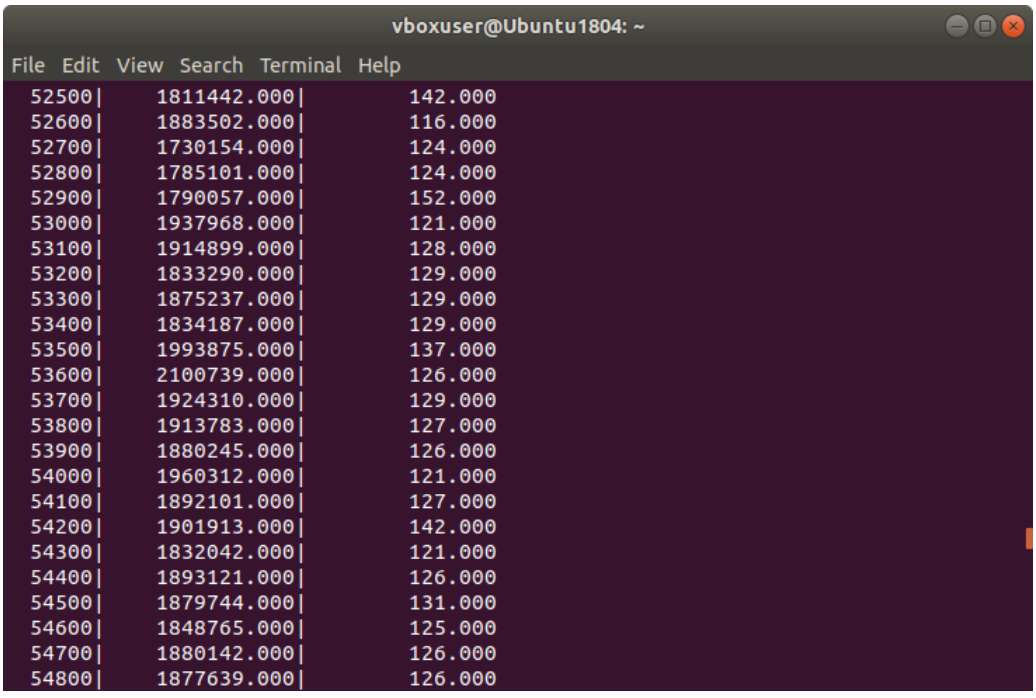
Hence a text file is created with 1 lakh random integers ranging from 1-100 and the experiment is carried upon this file.

RESULT:

Outputs:

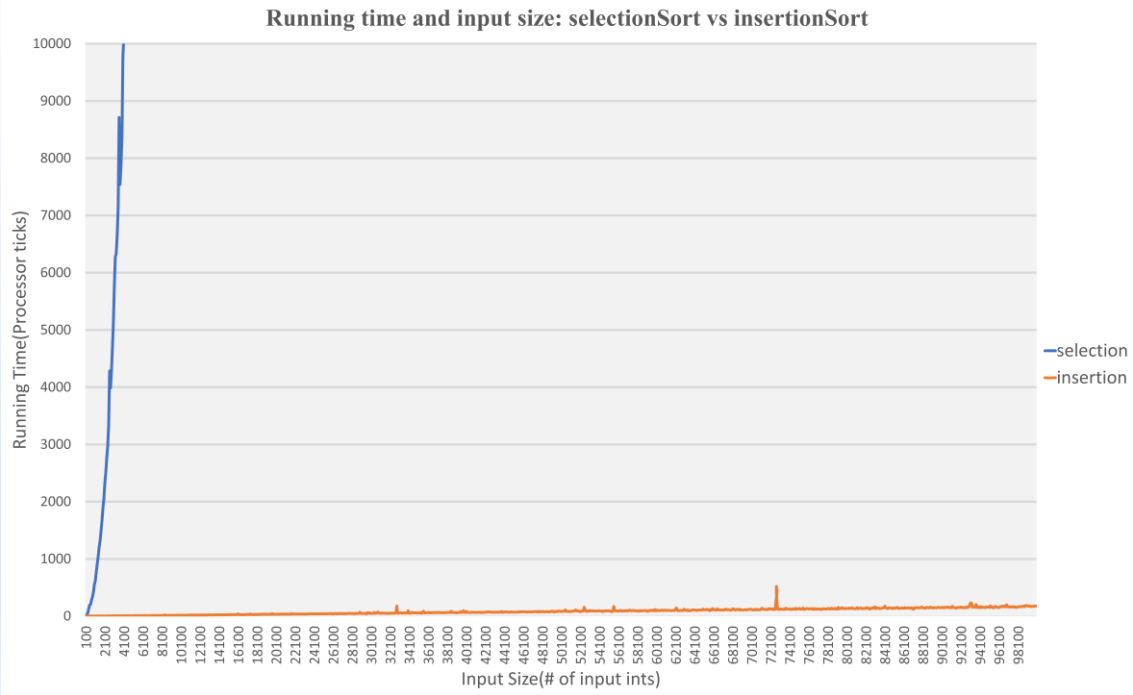
Column 1 is input size, column 2 is selection sort running time, and column 3 is insertion sort running time. All running times are in terms of CPU ticks. All inputs are integers ranging from 1 to 100. Input size was varied from 100 to 100000.





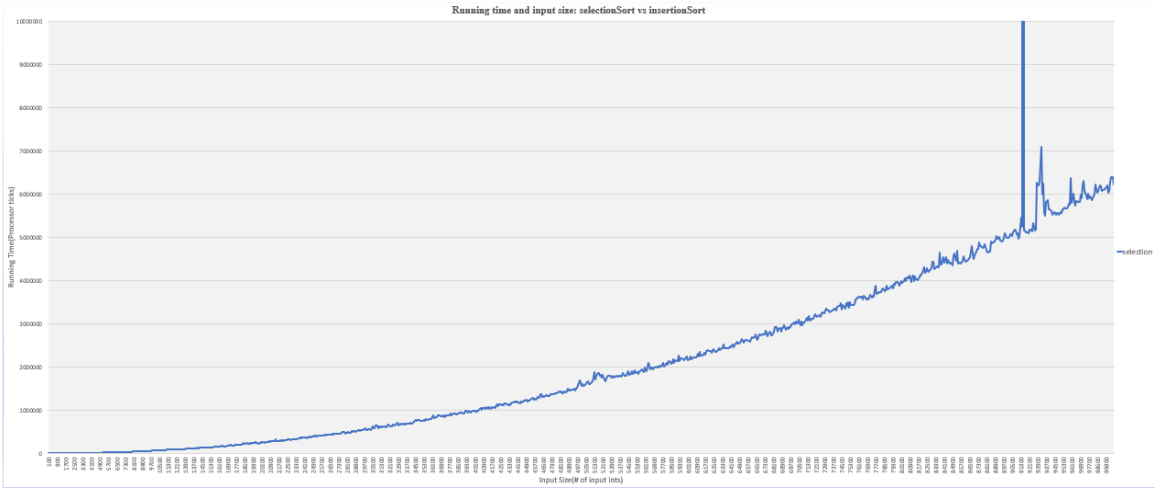
Plots:

The above output was exported to Excel via a text file and the line graph was plotted.

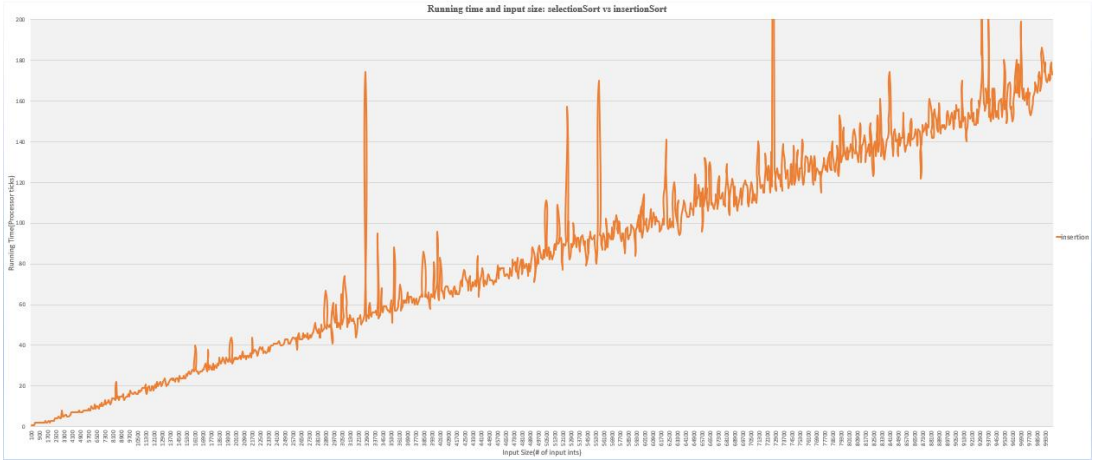


Separate plots:

Selection Sort:



Insertion Sort:



Conclusions:

1. It is clearly seen that insertion sort is much better than selection sort for any input size given.
2. Selection sort is undergoing a steep quadratic increase in running time with respect to input size and becoming unscalable. This is in line with its theoretical classification of $\theta(N^2)$.
3. Insertion sort is almost linear with a very less rate of increase. This is surprising as it is supposed to be $\sim(N^2)$ on average and $\theta(N)$ only in the best case. But this might be because some parts of the randomly generated inputs are partially sorted, and hence the only sorting required is for the out-of-order pairs(inversions) in which case it is linearly dependent on the number of inversions.
4. Both algorithms store inputs in arrays and are in-place sorts. We have declared a constant 1 lakh size int array for both algorithms. Other than that, selection sort takes 7 int declarations and 2 pointers. Insertion sort takes 6 int declarations and 2 pointers. All these considerations are irrespective of input size. Hence both algorithms have constant space complexity θ (1).