Sri Lanka Institute of Information Technology

B.Sc. Honours Degree in Information Technology

Specialized in Information Technology

Final Examination
Year 2, Semester 2 (2024)

IT2070 – Data Structures and Algorithms

Duration: 2 Hours

November 2024

Instructions to Candidates:

- This paper has 4 questions.
- Answer all questions in the booklet given.
- The total marks for the paper is 100.
- This paper contains 7 pages, including the cover page.
- Electronic devices capable of storing and retrieving text, including calculators and mobile phones are not allowed.
- 10 minutes reading time is allowed.

Question 1 **(25 Marks)**

a) What is the key principle by which a stack operates and what are the two main operations associated with it? (1 Mark)

b) How does the stack data structure support real-world applications such as browser history or undo operations in text editors? (2 Marks)

c) Can queues perform the tasks mentioned in (b) more efficiently? Justify your answer. (2 Marks)

d) Consider the following circular queue given in Figure 1. Draw the queue frames and indicate the values for rear, front, and count after performing below operations. (6 Marks)

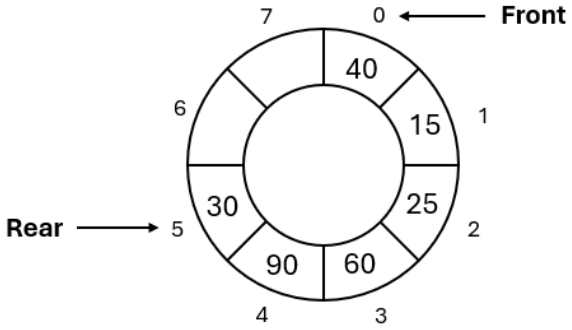

Figure 1. Circular Queue

i) Insert(50)
ii) Insert (70)
iii) Insert (100)
iv) Remove()
v) Remove()
vi) Insert(35)

e) **"A circular queue is considered full when (rear + 1) % size == front"**. Do you agree/disagree with this statement? Justify your answer. (3 Marks)

f) Assume following StackX class given in Figure 2 is implemented. You need to introduce a new method to StackX class to reverse individual words of a given string. Write a Java code segment for ***String reverseString(String input)*** method to take a string input from the user. Use only a stack data structure and obtain the following output. (8 Marks)

Input: "Hello how are you" ***Output:*** "olleH woh era uoy"

StackX
- char[] wordStack - int maxSize - int top
+void push(char c) +char pop( ) +char peek( ) +boolean isEmpty( ) +boolean isFull( )

Figure 2. StackX Class

g) Write the main program to call reverseString(String input) and display the reversed string. ***Hint: You can predefine the size of the stack.*** (3 Marks)

Question 2 **(25 Marks)**

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a) Differentiate between singly linked lists and doubly linked lists. Give one application for both types. (2 Marks)

b) Consider the linked list given in Figure 3 and execute following code segments sequentially on the linked list. For each code segment display the output.

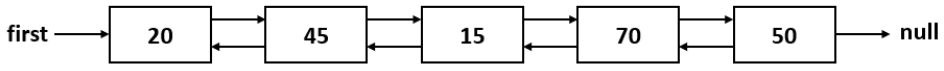

Figure 3. Doubly Linked List

i. (2 Marks)

```
Link temp = first;
while (temp != null)
{
   System.out.print(temp.data + ", ");
   temp = temp.next;
}
```

ii.
```
Link temp = first;
while (temp.next != null)
        temp = temp.next;
while (temp != null)
{
        System.out.print(temp.data + ", ");
        temp = temp.prev;
}
```
(2 Marks)

c) Consider the linked list given in Figure 3. Write down the relevant code segments for the following instances. Assume all operations are sequentially executed on the same linked list.

i. Insert value 30 after the existing node value 70 (4 Marks)

ii. Remove the first link from link list. (2 Mark)

d) Assume a complete binary tree consists of 27 nodes. Calculate the height of the tree. (2 Marks)

e) Consider the values given below. Arrange them into a binary search tree. (2 Marks)

180, 300, 270, 110, 80, 160, 410, 140, 290, 360, 170, 30, 505

f) Consider the tree you have derived in 2)e). Display the elements in the tree in given traversing order.

i. In-order (1 Mark)

ii. Pre-order (2 Marks)

iii. Post-order (2 Marks)

g) Draw the tree structure after performing following operations on the tree you have derived in 2)e).

i. Delete (30) (1 Mark)

ii. Delete (270) (1 Mark)

iii. Delete (180) (2 Marks)

Question 3 **(25 Marks)**

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a) Compare and contrast Exact Analysis and Asymptotic Notations. (2 Marks)

b) Express T(n) of following pseudocodes using RAM model.

i) (4 Marks)

```
i = 0
for ( j = 0 to 4 )
        while ( i <= 2 )
                i = i + 1
        print j
```

ii) (3 Marks)

```
j = 10
while ( j >= 0 )
        print j
        j = j - 2
```

c) Any recursive problem can have only one base/initial condition. Do you agree with this statement? Briefly explain your answer using an example. (2 Marks)

d) Obtain the recurrence equation for Quick Sort best case. (4 Marks)

```
QUICKSORT (A,p,r)
1 if p < r
2    q = PARTITION(A, p, r)
3    QUICKSORT (A, p, q-1)
4    QUICKSORT (A, q+1, r)
```

e) Solve the recurrence equation received in (d) using Master Theorem. (3 Marks)

$$T(n) = \begin{cases} \Theta\left(n^{\log_b a}\right) & f(n) = O\left(n^{\log_b a - \varepsilon}\right) \rightarrow f(n) < n^{\log_b a} \\ \Theta\left(n^{\log_b a} \lg n\right) & f(n) = \Theta\left(n^{\log_b a}\right) \rightarrow f(n) = n^{\log_b a} \\ \Theta\left(f(n)\right) & f(n) = \Omega\left(n^{\log_b a + \varepsilon}\right) \rightarrow f(n) > n^{\log_b a} \\ & \text{if } af(n/b) \le cf(n) \text{ for c} < 1 \text{ and large } n \end{cases}$$

f) Comment on the performance of (e) comparing with Merge Sort algorithm. (2 Marks)

g) Illustrate the operations of New Insertion sort algorithm for the array A with given set of elements. (For illustration process assign the values only once and then use a diagrammatic approach to reach the answer.) (5 marks)

	1	2	3	4
A	**7**	**1**	**5**	**3**

```
NEW-INSERTION-SORT (A)
1 for j = 2 to A.length
2       i = 1
3       while A[j] > A[i]
4               i = i + 1
5       key = A[j]
6       for k = 0 to j – i – 1
7               A[j-k] = A[j-k-1]
8       A[i] = key
```

Question 4 **(25 Marks)**

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a) State whether the following statements are TRUE or FALSE. (5 Marks)

i) All heaps are full binary trees.
ii) Heapify() is a recursive algorithm.
iii) Time complexity of build_heap() is O(n).
iv) Time complexities of heapsort() and mergesort() are equal.
v) Priority queue is an application of heaps.

b) Using a suitable example derive the equation for the number of shifts occurred in Naïve String-matching algorithm, where ***n*** is the number of characters in Text and ***m*** is the number of characters in Pattern. (3 Marks)

c) Compute the number of shifts occurred in the following Text and the Pattern using the equation obtained in (b). (2 Marks)

T = abcdefg
P = add

d) Briefly describe the performance of the scenario mentioned in (b) along with its complexity using Big (O) notation. (3 Marks)

e) Following is the pseudocode for heapify() algorithm.

```
MAX_HEAPIFY (A,i)
1.      l  = LEFT(i);
2.      r  = RIGHT(i);
3.      if l ≤ A.heap_size and A[ l ] > A[ i ]
4.              largest = l;
5.      else largest = i;
6.      if r ≤ A.heap_size and A[r] > A[largest]
7.              largest = r;
8.      if largest ≠ i
9.              exchange A[i] with A[largest]
10.             MAX_HEAPIFY (A,largest)
```

i) What is the purpose of having if() condition in line number 3? (2 Marks)

ii) What is the purpose of having if() condition in line number 6? (2 Marks)

f) Draw the state transition diagram for Pattern P = ***bbb*** along with the input alphabet = {a,b}. (8 Marks)

End of the paper