King Saud University	College of Computer and Information Sciences Department of Computer Science
Data Structures CSC 212	**Final Exam - Fall 2019**
Date: 21/12/2019	Duration: 3 hours

Guidelines: No calculators or any other electronic devices are allowed in this exam.

Student ID:	Name:
Section:	Instructor:

1.1	1.2	2	3	4	5	6	7	8	Total

Question 1 .... 14 points

(a) (6 points) Choose the run time from A to D for each of the following cases:

A. $O(1)$. **B**. $O(\log n)$. **C**. $O(n)$. **D**. $O(n \log n)$. **E**. $O(n^2)$.

1. The worst case of `DoubleLinkedList.remove`. ___
2. The worst case of `LinkedPQ.enqueue`. ___
3. The worst case of `BST.insert`. ___
4. The best case of `DoubleLinkedList.remove`. ___
5. The best case of `Heap.insert`. ___
6. The worst case of `ArrayList.findNext`. ___
7. The best case of `LinkedPQ.enqueue`. ___
8. The worst case of `AVL.find`. ___
9. The worst case of `ArrayStack.pop`. ___
10. The worst case of `Heap.insert`. ___
11. The worst case of `Heap sort`. ___
12. The best case of `Heap.remove`. ___

(b) (8 points) Choose the most appropriate data structure for each of the following tasks.

A. LinkedList.	**B**. ArrayList.	**C**. DoubleLinkedList.	**D**. LinkedQueue.
E. LinkedPQueue.	**F**. LinkedStack.	**G**. BT.	**H**. BST.
I. AVL.	**J**. BPlusTree.	**K**. HeapPQueue.	**L**. Graph.

1. An algorithm reads an unknown number of integers from a file, then depending on an input from the user computes one of the following: sum, product, min, max or average of the numbers. ___
2. An algorithm reads the list of flights operated by an airline company in the form $(City_i, City_j)$, meaning there is a flight between the two cities. The algorithm must check whether its is possible to fly from a given city to another using only the flights of this company. ___
3. An algorithm spell-checks the user input by comparing the input text to a set of pre-stored words. ___
4. A hospital wants to manage the waiting list in the emergency service. Cases with the same level of severity are treated according to the order of arrival. ___

Question 2 .... 12 points

(a) (6 points) Fill each entry of the table below by T (for true) or F (for false).

	Time (worst case): $O(n \log n)$	Comparison-based	In-place	Stable
Merge sort				
Quick sort				
Radix sort				

(b) (6 points) Consider the following array where keys are integer and data is of type string: $A = \{(3, B), (5, D), (3, A), (2, E), (7, E), (5, B), (1, F)\}$. We want to sort this array in increasing order. Choose the result produced by the given algorithm from the following options:

(A) $\{(1, F), (2, E), (3, B), (3, A), (5, D), (5, B), (7, E)\}$

(B) $\{(1, F), (2, E), (3, A), (3, B), (5, B), (5, D), (7, E)\}$

(C) $\{(1, F), (2, E), (3, A), (3, B), (5, D), (5, B), (7, E)\}$

(D) $\{(1, F), (2, E), (3, B), (3, A), (5, B), (5, D), (7, E)\}$

(E) None of the above.

1. Heap sort (in sift-down, swap left if children are equal): (A) (B) (C) (D) (E)
2. Bubble sort: (A) (B) (C) (D) (E)

Question 3 .... 12 points

(a) Write the method **private boolean** `f(BTNode<T> t, T e, int k)`, member of `BT`, which return true if `e` appears in `t` at a depth that is equal or greater than `k` (assume that `t` is at depth 0).

```
1 private boolean f(BTNode<T> t, T e, int k) {
2   if (...)
3     ...;
4   if (...)
5     ...;
6   return ...;
7 }
```

- Line 2:
  - (A) `if (e.equals(t.data))`
  - (B) `if (t==null)`
  - (C) `if (t.left==null && t.right==null)`
  - (D) `if (k > 0)`
  - (E) None
- Line 3:
  - (A) `return true;`
  - (B) `return k;`
  - (C) `return false;`
  - (D) `return k == e.data;`
  - (E) None
- Line 4:
  - (A) `if (k>0 || e.equald(t.data))`
  - (B) `if (k<=0 && e.equald(t.data))`
  - (C) `if (k>0 && e.equald(t.data))`
  - (D) `if (k<0 && e.equald(t.data))`
  - (E) None

- Line 5:
  - (A) `return k>0;`
  - (B) `return false;`
  - (C) `return e.equald(t.data);`
  - (D) `return true;`
  - (E) None

- Line 6:
  - (A) `return f(t.left,e,k-1)&&f(t.right,e,k-1);`
  - (B) `return f(t.left,e,k)&&f(t.right,e,k);`
  - (C) `return f(t.left,e,k)||f(t.right,e,k);`
  - (D) `return f(t.left,e,k-1)||f(t.right,e,k-1);`
  - (E) None

(b) Repeat the same questions as above, but this time as a user.

```
1  public static <T> boolean f(BT<T> bt, T e, int k) {
2    if (...)
3      return ...;
4    ...;
5    return ...;
6  }
7  private static <T> int rf(BT<T> bt, T e, int k) {
8    if (...)
9      return ...;
10   if (...) {
11     if (...)
12       return ...;
13     ...;
14   }
15   if (...) {
16     if (...)
17       return ...;
18     ...;
19   }
20   return ...;
21 }
```

- Line 2:
  - (A) `if (bt.empty())`
  - (B) `if (k == 0)`
  - (C) `if (bt.full())`
  - (D) `if (!bt.full())`
  - (E) None

- Line 3:
  - (A) `return false;`
  - (B) `return true;`
  - (C) `return e.equals(bt.retrieve());`
  - (D) `return k == 0;`
  - (E) None

- Line 4:
  - (A) `bt.find(relative.LeftChild);`
  - (B) `bt.find(relative.Parent);`
  - (C) `bt.find(relative.RightChild);`
  - (D) `bt.find(relative.Parent);`
  - (E) None

- Line 5:
  - (A) `return rf(bt,e,k);`
  - (B) `return rf(bt.left,e,k)||rf(bt.right,e,k);`
  - (C) `return rf(bt,e,k-1);`
  - (D) `return rf(bt,e,k+1);`
  - (E) None

- Line 8:
  - (A) `if (k<=0)`
  - (B) `if (k<0 && e.equals(bt.retrieve()))`
  - (C) `if (k<=0 && e.equals(bt.retrieve()))`
  - (D) `if (k==0 || e.equals(bt.retrieve()))`
  - (E) None

- Line 9:
  - (A) `return true;`

(B) `return k < 0;`

(C) `return e.equals(bt.retrieve());`

(D) `return false;`

(E) None

- Line 10:

(A) `if (bt.find(Relative.Parent)){`

(B) `if (bt.find(Relative.Root)){`

(C) `if (bt.find(Relative.LeftChild)){`

(D) `if (bt.find(Relative.LeftChild)!=nulll){`

(E) None

- Line 11:

(A) `if (rf(bt,e,k-1))`

(B) `if (rf(bt,e,k))`

(C) `if (rf(bt,e,k+1))`

(D) `if (rf(bt,e,2*k))`

(E) None

- Line 12:

(A) `return k>0;`

(B) `return true;`

(C) `return k<=0;`

(D) `return false;`

(E) None

- Line 13:

(A) `bt.find(Relative.Root);`

(B) `bt.find(Relative.Parent);`

(C) `bt.find(Relative.LeftChild);`

(D) `bt.find(Relative.RightChild);`

(E) None

- Line 15:

(A) `if (bt.find(Relative.RightChild)){`

(B) `if (bt.find(Relative.Root)){`

(C) `if (bt.find(Relative.RightChild)!=nulll){`

(D) `if (bt.find(Relative.Parent)){`

(E) None

- Line 16:

(A) `if (rf(bt,e,2*k+1))`

(B) `if (rf(bt,e,k+1))`

(C) `if (rf(bt,e,k-1))`

(D) `if (rf(bt,e,k))`

(E) None

- Line 17:

(A) `return k<=0;`

(B) `return false;`

(C) `return true;`

(D) `return k>0;`

(E) None

- Line 18:

(A) `bt.find(Relative.RightChild);`

(B) `bt.find(Relative.LeftChild);`

(C) `bt.find(Relative.Parent);`

(D) `bt.find(Relative.Root);`

(E) None

- Line 20:

(A) `return k<=0;`

(B) `return false;`

(C) `return k>=0;`

(D) `return k==0;`

(E) None

Question 4 .... 14 points

(a) (4 points) Choose the most appropriate answer.

1. In a min heap:

(A) All keys at level k are smaller than all keys in level $k+1$. (B) The largest key is always at the last level. (C) The key of the left child of any node is smaller than the key of its right child. (D) All of the above. (E) None of the above.

2. The worst case run time for bottom-up heap construction is:

   (A) $O(1)$. (B) $O(\log n)$. (C) $O(n)$. (D) $O(n \log n)$ (E) $O(n^2)$.

(b) (10 points) Consider the following heap represented as an array: 20, 18, 12, 10, 11, 5, 2, 6, 4, 3. Choose the correct answer for every operation (all operations are done on the above heap).

1. Heap after inserting 19:
   (A) 20, 19, 12, 10, 18, 5, 2, 6, 4, 3, 11 (B) 20, 19, 12, 11, 18, 5, 2, 6 ,4, 11, 3 (C) 20, 18, 12, 10, 11, 5, 2, 6, 4, 3, 19 (D) 20, 18, 12, 10, 19, 5, 2, 6, 4, 3,11 (E) None
2. Heap after inserting 1 **then** 23: (A) 20,18, 23, 10, 11, 12, 2, 6, 4, 3, 1, 5 (B) 20, 18, 12, 10, 11, 5, 2, 6, 4, 3, 1, 23 (C) 23, 18, 20, 10, 11, 12, 2, 6, 4, 3, 1, 5 (D) 23, 20, 18, 10, 11, 12, 2, 6, 4, 3, 1, 5 (E) None
3. Heap after deleting one key: (A) 20, 18, 12, 10, 11, 5, 2, 6, 4 (B) 3, 18, 12, 10, 11, 5, 2, 6, 4 (C) 12, 18, 5, 10, 11, 3, 2, 6, 4 (D) 18, 11, 12, 10, 3, 5, 2, 6, 4 (E) None
4. Heap after deleting two keys: (A) 4, 18, 12, 10, 11, 5, 2, 6 (B) 18, 11, 12, 10, 4, 5, 2, 6 (C) 12, 4, 5, 10, 11, 3, 2, 6 (D) 12, 11, 4, 10, 3, 5, 2, 6 (E) None

Question 5 .... 14 points

(a) (4 points)

Remark 1. *In what follows the depth of tree is the number of levels in the tree from the root to a leaf (counting number of nodes not edges). Hence, tree with 1 node has depth 0.*

Choose the most appropriate answer:

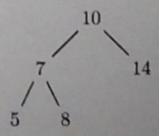
1. The maximum depth of an AVL tree with 8 nodes is:

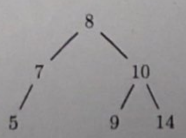
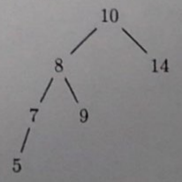
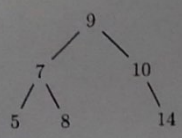
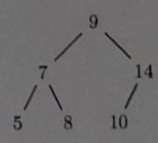
   (A) 1. (B) 2. (C) 3. (D) 4. (E) 5.

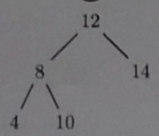
2. The minimum number of rotations caused by an insert in an AVL tree with n nodes and height h is (a single rotation is counted 1; a double rotation is counted 2):

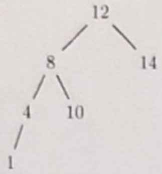
   (A) 0. (B) 1. (C) 2. (D) h (E) n.

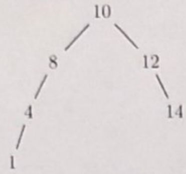
(b) (10 points) Choose the correct result in each of the following cases (follow the the convention of replacing with the smallest key in the right sub-tree when necessary):

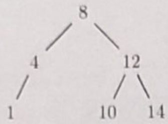
1. After inserting the key 9 in the AVL  , the tree becomes:

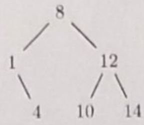
   (A)  (B)  (C)  (D)  (E) None

2. After inserting the key 1 in the AVL  , the tree becomes:

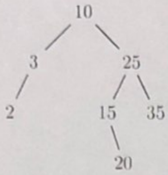
(A) 

(B) 

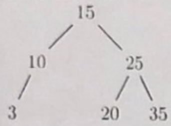
(C) 

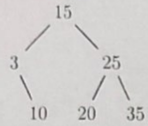
(D) 

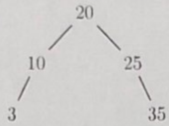
(E) None

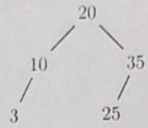
3. After deleting the key 2 from the AVL 

, the tree becomes:

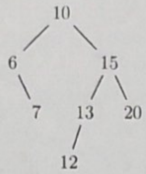
(A) 

(B) 

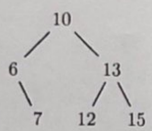
(C) 

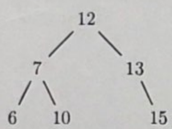
(D) 

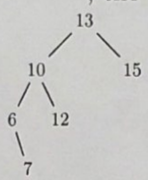
(E) None

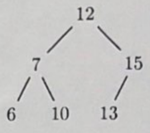
4. After deleting the key 20 from the AVL 

, the tree becomes:

(A) 

(B) 

(C) 

(D) 

(E) None

Question 6 .... 14 points

(a) (4 points) Choose the most appropriate answer:

1. The insert operation in a hash table using external chaining has a best case run time:

   (A) $O(1)$ (B) $O(\log n)$ (C) $O(n)$ (D) $O(n \log n)$ (E) None

2. How many keys can a hash table that uses folding on a single digit store if the key contains 3 digits?

   (A) 4 (B) 8 (C) 26 (D) 27 (E) 28

(b) (10 points) Use the hash function $H(key) = key\%5$ to store the sequence of keys 25, 13, 14, 23, 16 in a hash table of size 5. Use the following collision resolution strategies:

1. Linear rehashing (c=1):

Key	25	13	14	23	16
Position					
Number of probes					

2. External chaining:

Key	25	13	14	23	16
Index of the list					

3. Coalesced chaining with cellar size 2 and address region size 5 (put -1 if there is no next element):

Key	25	13	14	23	16
Position					
Index of next element					

Question 7 .... 14 points

(a) (4 points)

Remark 2. *In what follows, a tree with 1 node has depth 1 and height 1. Recall also that a B+ tree has two parameters, m: the maximum number of children and l: the maximum number of elements in a leaf node.*

Choose the most appropriate answer:

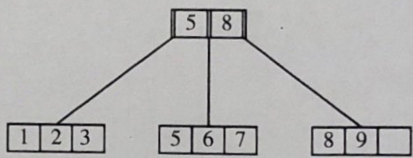
1. The minimum number of children of a root node in a B+ tree is:

   (A) 0 (B) 1 (C) 2 (D) $\lceil \frac{m}{2} \rceil$ (E) None

2. The maximum number of data elements in a B+ tree with $m = l$ and height h is :

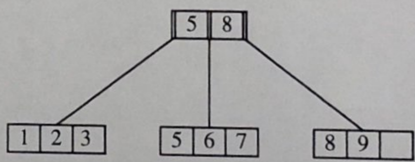
   (A) m^h (B) 2^h (C) h^m (D) $h + m$ (E) None

(b) (10 points) Choose the correct result in each of the following cases (when possible, always borrow and transfer to the left):

1. After inserting the key 4 in the B+ tree 

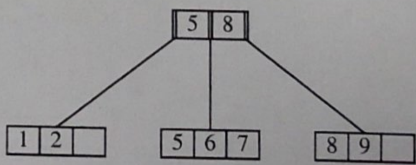
, the **root** becomes:

   (A) 4 7 (B) 5 8 (C) 4 (D) 5 (E) None

2. After inserting the key 10 in the B+ tree 

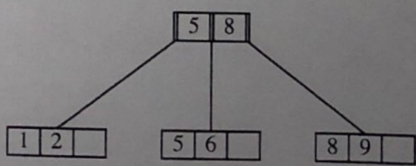
, the **root** becomes:

   (A) 5 10 (B) 5 8 (C) 6 (D) 6 10 (E) None

3. After deleting the key 2 from the B+ tree 

, the **root** becomes:

   (A) 8 (B) 5 8 (C) 6 (D) 6 7 (E) None

4. After deleting the key 5 from the B+ tree 

, the **root** becomes:

   (A) 8 (B) 5 8 (C) 6 (D) 2 (E) None

Question 8 .... 6 points

(a) (2 points) Choose the most appropriate answer:

1. Adjacency matrix takes $O(n^2)$ memory space, when is it appropriate to use it instead of adjacency list:

   (A) The graph is sparse. (B) The graph is dense. (C) The graph is unweighted (D) The number of edges is less than the number of nodes. (E) None.

2. You apply DFS from a given node and you find out that all nodes were visited. This means:

   (A) The graph is directed. (B) Some nodes have no edges. (C) The graph is connected. (D) The graph contains cycles. (E) None.

(b) (4 points) Given the following graph adjacency matrix, answer the questions below.

	A	B	C	D	E	F
A		3	3			5
B	3		1	5		
C	3	1				
D		5				2
E						
F	5			2		

1. Which of the following sequences are simple paths in this graph? Answer by T (true) or F (false).

   (a) $(C, B, D, E,)$ ___

   (b) (C, B, A) ___

   (c) (C, A, F, D, B) ___

   (d) (B, A, F, D, B, C) ___

2. Answer by T (true) or F (false).

   (a) The graph is connected. ___

   (b) The number of edges in the graph is 6. ___

   (c) (A, B, D, F, A) is a cycle. ___

   (d) The shortest path from F to B is (F, A, B). ___

3. The BFS traversal of this graph starting from A is (insert neighbors in the data structure in increasing alphabetic order):

   (A) A, D, B, C, F. (B) A, B, C, D, F. (C) A, B, C, F, D. (D) A, F, B, C, D. (E) A, C, B, F, D.

4. The DFS traversal of this graph starting from A is (insert neighbors in the data structure in increasing alphabetic order):

   (A) A, F, D, C, B. (B) A, F, C, D, B. (C) A, B, C, F, D. (D) A, F, B, C, D. (E) A, C, B, F, D.