DIT181 Data Structures and Algorithms: Assignment 3

Maximum points you can get from Assignment 3 is **130 points** (100 points + 30 points BONUS). Distribution of points within questions has been given in parentheses below.

- **Criteria to pass "Assignments" sub-course (3.5 HEC)**: From each assignment (i.e. Assignment #1, Assignment #2 and Assignment#3) you have to get minimum 50 points (out of 100 points for Assignments #1and #2, and out of 130 points for Assignment #3).

Information about Deliverables: You will submit a pdf file for the answers to questions that do not require programming. For the answers consisting of implementation in Java, you will submit the .java files that you worked on and completed. Please ensure that you follow these submission instructions while submitting your Assignment#3 on Canvas.

Please, make sure that your code is compilable and runnable.

- Work on the skeleton codes provided.
- Do not rename or alter anything in the predefined public classes/constructors/methods in the skeleton codes. Please do not change anything that we already implemented in the skeleton files. Such attempt will break the unit tests.
- Do not change the name of the skeleton files you are working on.
- Don't bundle any of your code in packages. Please, just submit java files for questions that require coding.
    - For **Question 2**, you will work on `RPN.java` skeleton file and submit the final version of `RPN.java`.
    - For **Questions 3-6**, you will work on `SinglyLinkedList.java` skeleton file and submit the final version of `SinglyLinkedList.java`.
    - For **Questions 7-9**, you will work on `Tree.java` skeleton file and submit the final version of `Tree.java`.
    - If you also decide to solve **Question 10** (BONUS QUESTION), you will work on `HashTable.java` skeleton file and submit the final version of `HashTable.java`

- For answers that do not require programming, make sure that you submit a *PDF file* for your written/scanned work. This is due to that pdf generally more accepted format for reading, furthermore preserves the formatting.
    - [THIS IS A RECOMMENDATION] We would highly recommend using Latex for scientific formatting. An easy way to get going: www.overleaf.com (Links to an external site.)Links to an external site. , if you like online editing.
- When you submit, place all relevant files (only .pdf and .java files) in a folder and name the folder "assignmentX_groupY" where the X is the assignment number and Y group number. Compress (i.e., zip, but NOT rar) the folder, to obtain "assignmentX_groupY.zip" file. Submit "assignmentX_groupY.zip" file on Canvas. Make sure not to include any hidden files (especially from macOs, see the following link: https://superuser.com/questions/757593/what-is-ds-store-file-in-windows)

Submission Deadline: 11.03.2018 at 08:00 am in the morning SHARP!!

Stacks and Queues

Question 1 Show how to implement a queue using 2 stacks (no Java code is needed, just a sketch and pseudo code) **(11 points)**. What are the complexities of `enqueue()` **(2 points)** and `dequeue()` operations **(2 points)**?

Note: A stack is a data structure with `push()`, `pop()`, and `isEmpty()` operations; a queue is a data structure with `enqueue()`, `dequeue()` and `isEmpty()` operations.

Question 2 (20 points) This question will require that you work on `RPN.java` skeleton file. Implement a simple Reverse Polish Notation (RPN) calculator. Reverse Polish Notation (RPN) is a way of representing arithmetic expression, which does not require parentheses. See these resources for more explanations:

- https://www.youtube.com/watch?v=UU5UhVQhYkY
- http://mathworld.wolfram.com/ReversePolishNotation.html
- https://en.wikipedia.org/wiki/Reverse_Polish_notation
- http://hp15c.com

Your job is to implement an RPN calculator that will read from the input terminal (i.e., standard input) and print the results on the standard output. Example session with the calculator may look as follows:

```
$ java RPN
> 2
2
> 5
2 5
> +
7
> quit
Quitting
```

The text that follows the > character has been typed by the user, whereas the other lines have been output by the calculator. After processing a line of input, the calculator should print the current contents of its evaluation stack, or quit if the word `quit` appeared. You should start with the `RPN.java` skeleton file, which currently contains code that reads input and prints messages on the standard output. The calculator should support the operators `+`, `-`, `*` and `/` on integers. [You should use the standard `Stack` collection from Java]

Linked Lists

Questions from this part will require that you work on the `SinglyLinkedList.java` skeleton file.

Question 3

Implement the method `get(int n)`, which should return the element of index n (indexing starts with 0). If the index is out of bounds, the exception `IllegalArgumentException` should be thrown **(8 points)**. What is the complexity of this method? **(2 points)**

Question 4

Implement the method `insertAt(Item x, int n),` which should insert an element at index n into the list. If the index is out of bounds, the exception `IllegalArgumentException` should be thrown **(8 points)**. What is the complexity of this method? **(2 points)**

Question 5

Implement the method `removeAt(int n)`, which should remove an element at index n from the list. If the index is out of bounds, the exception `IllegalArgumentException` should be thrown **(8 points)**. What is the complexity of this method? **(2 points)**

Question 6

Implement the method `reverse()`, which should reverse the list **(8 points)**. What is the complexity of this method? **(2 points)**

Trees

In this part of the assignment you will work on the `Tree.java` skeleton file. The `Tree` class defined in the file represents a generic binary tree with labels in all nodes. You may assume that the depth of the tree is at most $O(\log_2 n)$.

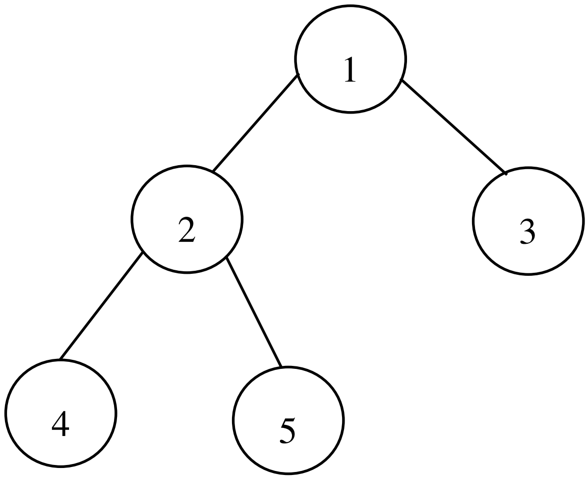
Question 7

Implement the method `nthBFS(int)`, which returns the nth element in Breadth First Search (BFS) order ("Breadth First Search" is also known as "Level Order Search") **(6 points)**.

Question 8

Implement the method `printDFS()`, which should print the labels of the tree's nodes in **pre-order** depth-first-search (DFS). The labels should be separated by new-lines, and may be printed using `toString()` method. **(7 points)**.
For example, for the graph below, the method should print the following lines:

```
1
2
4
5
3
```



What is the complexity of this method? **(2 points)**

Question 9
Implement the method `insertBST(Item i)`. The method assumes that the tree is a binary search tree (BST) and inserts item *i* into it. When the item is inserted the method should modify the rest of the tree so that the tree is still a BST. **(7 points)**. If the item already exists in the tree, another copy should be inserted. **(3 points)**.

Hash Tables

Question 10 (BONUS QUESTION: 30 points).
During Hands-on Programming Session #8, you worked on the implementation of linear probing. In this part of your assignment, you will also implement quadratic probing hash table, and perform simulations to compare the observed performance of hashing (i.e., linear vs. quadratic) with the theoretical results. You were asked to fill in the first half of the table for linear probing during the Hands-on Programming Session #8. In this question, you are asked to complete the table. You will have to hand in both the table, in a pdf file, and the code produced for linear and quadratic probing hash tables for this question.

You will base your solution on the `HashTable.java` skeleton file, which you also used during Hands-on Programming Session #8. Implement a probing hash table and insert 10,000 randomly generated integers into the table and count the average number of probes used. This average number of probes used is the average cost of a successful search. Repeat this test 10 times and calculate minimum, maximum and average values of average cost. Run the test for both linear and quadratic probing and do it for final load factors $\lambda = 0.1, 0.3, 0.5, 0.7, 0.9$. Always choose the capacity of the table so that no rehashing is needed. For instance, for final load factor $\lambda = 0.5$, in order to insert 10,000 integers into the hash table, the size of the table should be approximately 20,000 (i.e., $10000/\lambda = 10000/0.5 = 20000$). You must make some adjustments to make table size a prime number. For instance, 20,011 is the prime number that is slightly larger than 20,000. You can refer to the following link for the list of prime numbers:
http://compoasso.free.fr/primelistweb/page/prime/liste_online_en.php

At the end of your simulations, please fill in the following table.

Load Factor (λ)	Average Cost for a Successful Search					
	Linear Probing			Quadratic Probing		
	minimum	Maximum	average	minimum	Maximum	Average
0.1						
0.3						
0.5						
0.7						
0.9						