1 Definitions

Suppose that the nodes $A$, $B$, $C$ in a binary search tree are arranged as follows.

```
    A
   / \
  B   C
```

Which of the following describes the relationship between $A$, $B$, $C$?
- $A \leq B \leq C$
- $A \leq B, C$
- $A \geq B, C$
- $B \leq A \leq C$

Now suppose that nodes $A$, $B$, $C$ are arranged as follows in the binary search tree.

```
    A
   / \    
  B   C
```

What is the relationship between $A$, $B$, $C$?
- $B \leq A \leq C$
- $B \leq C \leq A$
- $C \leq B \leq A$
- $C \leq A \leq B$

If two different binary search trees contain the same set of values, which of the following is common between them?
- Their pre-order traversals.
- Their in-order traversals.
- Their post-order traversals.
- Their root nodes.

Which of the following describes the height of a binary search tree on $n$ nodes?
- $O(\log n)$
- $\Omega(\log n)$
- $\Theta(\log n)$
- All of the above.

If the length of a path from the root of a red-black tree to one of the leaf NIL nodes is 100, what could be the length of another path from the root to some other NIL node?
- 45
- 180
- 30
- All of the above.

Suppose that $r$ is the root of a red-black tree on $n$ nodes. Assume all nodes have distinct values. If we sort the values stored in the tree to get $x_1 < x_2 < \cdots < x_n$, and find the index $i$ where $r = x_i$, what can be said about $i$?
- $i \geq \Omega(\sqrt{n})$
- $i \geq \Omega(n)$
- $i \leq \Theta(n)$
- $i \leq 0.1n$

What is the worst-case runtime of operations INSERT/DELETE/SEARCH on a red-black tree storing $n$ nodes?
- $O(n)$
- $O(n \log n)$
- $O(\log n)$

2 Red-Black Trees

Is the following a valid red-black tree? We are not drawing the implicit NIL nodes.

```
    A
   / \    
  B   C
```

- Yes
- No

Is the following a valid red-black tree?

```
    A
   / \    
  B   C
```

- Yes
- No

Is the following a valid red-black tree?

```
    A
   / \    
  C   B
```

- Yes
- No

Which of the following describes the height of a red-black tree on $n$ nodes?
- $O(\log n)$
- $O(\log \log n)$
- $O(n)$
- All of the above.

If the length of a path from the root of a red-black tree to one of the leaf NIL nodes is 100, what could be the length of another path from the root to some other NIL node?
- 45
- 180
- 30
- All of the above.

Suppose that $r$ is the root of a red-black tree on $n$ nodes. Assume all nodes have distinct values. If we sort the values stored in the tree to get $x_1 < x_2 < \cdots < x_n$, and find the index $i$ where $r = x_i$, what can be said about $i$?
- $i \geq 0.5n$
- $i \geq 0.5n \log n$
- $i \geq 0.5n \log \log n$
- $i \geq 0.5n \log \log \log n$

What is the worst-case runtime of operations INSERT/DELETE/SEARCH on a red-black tree storing $n$ nodes?
- $O(n)$
- $O(n \log n)$
- $O(\log n)$
- $O(\log n \log \log n)$