Fill in your name and NetID.  
Please do not start the quiz until I tell you to do so.

Directions: Answer the following questions to the best of your ability. When appropriate, we encourage you to show your work, to help us understand your thought process. Quizzes count toward your grade; please take them seriously.

1. In a B-tree, what is the relationship between the number of keys and number of children in a node?

   Solution: The number of children is always exactly one more than the number of keys. 
   Important Detail, but not required for full credit: The above rule obviously only applies to internal nodes. Leaves don’t have any children.

2. In a B-tree, what is special about the distance between the root and each leaf?

   Solution: Every leaf is the same distance from the root.

   How is this special property preserved?

   Solution: We never add new nodes above or below others; instead, we always split nodes horizontally. Thus, the only way to change the distance from root to leaf is to split the root.
   Important Detail, but not required for full credit: The above overlooks deletion, but the same principle applies: we only reduce the height by joining the root node together.

(over)
3. I’ve drawn a single-node 2-3-4 tree below. Draw the tree as it would be after you inserted the value 13. You may use the top-down or bottom-up strategies.

Solution: You are not required to state whether you used the top-down or bottom up strategy. In the top-down strategy, you would split the node before you inserted 13, so only one final configuration is possible:

However, if you used the bottom-up strategy, two configurations are possible, because you can choose to pull up either 15 or 16 from the overloaded node. Thus, your answer might be the one above, or this other one:

4. Here is a small red-black tree. Insert the key A into the tree as it stands; then re-draw the tree after the red-red problem has been fixed. (Use the bottom-up strategy.)

Use an R or the word “red” to mark any red nodes.

Solution:
Here is the tree after insertion:

```
  L
   \  
    F red
     \  
      A red
```

And here it is after the red-red problem has been fixed:

```
  F
   /  
  A red L red
```