CS 429 Homework 10

Name: _____ Section #: _____

Instructions: Work these problems on your own paper. As usual, you may collaborate with your classmates and ask for assistance from the TA. But don't copy anyone else's answer. Each problem is worth the same number of points (more or less).

1. Do problem 4.47 on p. 474 of Bryant and O'Hallaron. For part B, you don't have to test your Y86 version.

2. Consider the following Y86 code fragment:

```
irmovq   $3, %rax
irmovq   $4, %rbx
addq     %rax, %rbx
```

   (a) Explain carefully the data dependency problem for the naive pipelined implementation (without data forwarding) of the Y86 we've been discussing. Be sure to say at which stages of the naive pipeline, the values of `%rax` and `%rbx` are needed by the `addq` statement and at which they become available.

   (b) Insert the minimum number of nop's into the code to resolve the problem.

   (c) Explain the introduction of stalls and bubbles into the pipeline to resolve the problem without explicit nop's.

   (d) Explain how adding data forwarding to the pipeline solves the problem. Be explicit about what values are forwarded and from what stages of the pipeline, and to which stage.

3. Do problem 4.51 on p. 476 of Bryant and O'Hallaron.

4. **Extra credit:** Complete the leet code easy problem Univalued Binary Tree located at leetcode.com/problems/univalued-binary-tree in C. Include the function in your submission for this homework. Hint: Check your answer on leet code before submitting.