# 15-213: Introduction to Computer Systems Written Assignment 6

This written homework covers Code Optimization, Linking and Dynamic Memory Allocation.

## Directions

Complete the question(s) on the following pages with single paragraph answers. These questions are not meant to be particularly long! Once you are done, submit this assignment on Canvas.

Below is an example question and answer.

Q: Please describe benefits of two's-complement signed integers versus other approaches.

A: Other representations of signed integers (ones-complement and sign-and-magnitude) have two representations of zero (+0 and -0), which makes testing for a zero result more difficult. Also, addition and subtraction of two's complement signed numbers are done exactly the same as addition and subtraction of unsigned numbers (with wraparound on overflow), which means a CPU can use the same hardware and machine instructions for both.

## Grading

Each assignment will be graded in two parts:

1. Does this work indicate any effort? (e.g. it's not copied from a homework for another class or from the book)
2. Three peers will provide short, constructive feedback.

## Due Date

This assignment is due on March 15 by 11:59PM Pittsburgh time (currently UTC-4). Remember to convert this time to the timezone you currently reside in.

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## Question 1

Compilers are not just tools that can turn source code into executables, they can also make optimizations for the programmer to improve performance. Name one technique (among the many) that compilers use to make optimizations, and identify one guarantee that compilers must deliver when attempting to implement those optimizations.

One optimization technique used by compilers is reordering of instructions to leverage machine-level parallelism. As long as the reordering does not impact the correctness of the code, the compiler creates an executable that requires fewer CPU cycles to run to completion, improving performance.

No matter the optimizations implemented, compilers must be careful to preserve the correctness of the source code as written. Function calls extracted out of loop guards, for instance, can have hidden side effects that no longer "accumulate" when the O(n) function calls are optimized to only O(1) calls, resulting in a difference between the optimized and unoptimized compiled code.

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# Question 2

Each of the following subproblems contains two modules. For each problem, identify the multiply-defined symbols for both modules, explain how the linker would resolve the references to these multiply-defined symbols. Use the 3 Linker's Symbol Rules to justify your answer.

| | Module 1 | Module 2 |
|---|---|---|
| a | int main()<br>{<br>}  | int main = 0;<br>int x;<br>int y; |
| b | int x = 1;<br>int main; | void x;<br>void main()<br>{<br>    int x = 1;<br>} |
| c | double y = 1.0;<br>void main()<br>{<br>    int p = 0;<br>} | int x;<br>int y;<br>int main; |
| d | int x;<br>double y;<br>double z = 1.0; | int y;<br>double x;<br>int z; |
| e | int main;<br>int x;<br>double p;<br>long y()<br>{<br>    double x = 0;<br>} | double main;<br>long y;<br>void x()<br>{<br>    int p = 0;<br>} |

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| |
|---|
| a. The multiply-defined symbol is main.<br>This is a link-time error because of symbol main (Rule 1). |
| b. The multiply-defined symbols are x and main.<br>x will refer to x in module 1, main will refer to main in module 2 (Rule 2). |
| c. The multiply-defined symbols are y and main.<br>y will refer to y in module 1, main will refer to main in module 1 (Rule 2). |
| d. The multiply-defined symbols are x, y, z.<br>The linker will arbitrarily choose one of the definitions for x and y (Rule 3), z will refer to z in module 1 (Rule 1). |
| e. The multiply-defined symbols are main, x, y.<br>This is a link-time error because of symbol y (Rule 1). |

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