# CS161 – Fall 2016
## Homework Assignment 1

## Due: Sunday, October 16th @ 11:59

1. [15%] Consider two possible improvements that can be used to enhance a machine. You can either make multiply instructions run four times faster than before, or make memory access instructions run two times faster than before. You repeatedly run a program that takes 100 seconds to execute. Of this time, 25% is used for multiplication, 40% for memory access instructions, and 35% for other tasks.

    a. What will the speedup be if you improve only multiplication? [5%]
    b. What will the speedup be if you improve only memory access? [5%]
    c. What will the speedup be if both improvements are made? [5%]

2. [20%] Assume that multiply instructions take 4 cycles to execute and account for 20% of the instructions in a typical program and that the other 80% of the instructions require an average of 2 cycles for each instruction.

    a. What is the percentage of time that the CPU spends doing multiplication? [5%]
    b. Estimate the CPI value for a typical program executing on this machine [5%].
    c. Assume that it is possible to reduce the number of cycles required for multiplication from 4 to 2, but this will require a 20% increase in the cycle time. Nothing else will be affected. Should we proceed with this modification? Explain why or why not [10%].

3. [10%] Suppose that we have two implementations of the same instruction set architecture (ISA). Computer A has a clock cycle time of 250 ps and a CPI of 2.2 for some program, and computer B has a clock cycle time of 500 ps and a CPI of 1.2 for the same program. Which computer is faster for this program, and by how much? Explain your answer.

4. [10%] Consider three different processors P1, P2 and P3 executing the same instruction set. P1 has a 3GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4GHz clock rate and a CPI of 2.2.

    a. Which processor has the highest performance expressed in instructions per second? [5%].
    b. If the processors each execute a program in 10 seconds, what is the number of cycles and the number of instructions needed to complete this program? [5%].

5.  [10%] For the MIPS assembly instructions below, what is the corresponding C statement?
    Assume that the variables f, g, h, i, and j are assigned to registers $s0, $s1, $s2, $s3, and $s4,
    respectively. Assume that the base address of the arrays A and B are in registers $s6 and $s7,
    respectively.

    ```
    sll $t0, $s0, 2      # $t0 = f * 4
    add $t0, $s6, $t0   # $t0 = &A[f]
    sll $t1, $s1, 2      # $t1 = g * 4
    add $t1, $s7, $t1   # $t1 = &B[g]
    lw $s0, 0($t0)       # f = A[f]
    addi $t2, $t0, 4
    lw $t0, 0($t2)
    add $t0, $t0, $s0
    sw $t0, 0($t1)
    ```

6.  [10%] Translate the following C code to MIPS. Assume that the variables f, g, h, i, and j are
    assigned to registers $s0, $s1, $s2, $s3, and $s4, respectively. Assume that the base address of
    the arrays A and B are in registers $s6 and $s7, respectively. Assume that the elements of the
    arrays A and B are 4-byte words:

    ```
    B[8] = A[i] + A[j];
    ```

7.  [10%] Assume $t0 holds the value 0x00101000. What is the value of $t2 after the following
    instructions?

    ```
    slt $t2, $0, $t0
    bne $t2, $0, ELSE
    j DONE
    ELSE: addi $t2, $t2, 2
    DONE:
    ```

8.  [15%] Design a variable-length opcode assignment scheme that supports the following
    instruction formats in a 36-bit instruction:

    - **Type 1**: instructions with two 15-bit addresses and one 3-bit register number
    - **Type 2**: instructions with one 15-bit address and one 3-bit register number
    - **Type 3**: instructions with no registers or addresses

    Break down the instructions into separate fields and identify how many instructions of each
    type can be supported by your design.  In your design, maximize the number of type 1
    instructions that can be supported and explain why it is important. *Note that this question has
    nothing to do with MIPS ISA that we consider in class, it is about a hypothetical variable-
    length instruction set.*

    **Type1:**
    Format:

How many instructions?_____

Explain why:_____

**Type2:**

Format:

How many instructions?_____

Explain why:_____

**Type3:**

Format:

How many instructions?_____

Explain why:_____