Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Computer Organization (CS 345)**

**Final Exam**

Part 1: Short Answer (30 points)

a) Bits and bytes (2 points each).

1. How many bits are in a byte?

1. How many bytes are used in a 64-bit floating point register?
2. How many bytes are in an ASCII character?

b) Boolean algebra (2 points each): reduce each of the following Boolean expressions to a value or a sum of products equation. Assume A, B, C, and D are Boolean variables. ~ = NOT, \* = AND, and + = OR. 1 = true and 0 = false.

1. (A+1) + B\*1
2. B\*1 \* (B + 0)
3. (A + B \* C) \* D
4. D + (A \* B \* C \* 1)

c) Assembly programming (4 points each)

1. Write assembly code to store 23, 14, and -3 in temporary integer registers $t0, $t2, and $t4.
2. Write an assembly instruction to multiply the value stored in $t2 by 4. Additionally, use the shift left logical (sll) instruction to multiply the value stored in $t2 by 4. Recall that shifting to the left by one bit multiplies by 2.

1. Write a for-loop that decrements $t4 by one, five times.
2. Write a function that takes two parameters and returns the product of the two numbers.

Part 2: Long Answer (70 points, 10 points each)

1. List the basic component that is common to all flip-flops, the storage capacity of this component, and the CPU memory component for which flip-flops are often used. Then, explain the difference between edge-triggered and level-triggered flip-flops and why both are useful.
2. Draw a state machine that transitions between the three basic CPU states. The final state actually consists of a group of states – one for each of six possible opcodes – ALU, load, store, move, branch, and jump.
3. Draw a multiplexor that takes seven data inputs. How many bits do you need to use for the selector? Why? What is provided as output from the multiplexor? Why?
4. Given the following instruction, provide the 32-bit binary representation of the instruction (this is one 32-bit binary number), and provide the hexadecimal representation of the instruction. The opcode for sub is 0 hex, the function code for sub is 22 hex, $t1 is represented as 9d, $t2 is represented as 10d, and $t3 is represented as 11d. Hint: the attached sheet shows how many bits are in each portion of the instruction.  
     
   sub $t1, $t2, $t3
5. Create Boolean sum of products equations for the following truth table. You should have two equations in your solution, one for each output.  
     
   A B C Output1 Output2

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0 0 0 0 0  
0 0 1 0 1

0 1 0 1 0

0 1 1 0 1

1 0 0 1 0

1 0 1 0 0

1 1 0 0 0

1 1 1 0 1

1. Draw complete logic gates for the equations from the previous problem. How long does it take to get a correct output? Assume propagation delays are 2ns for a NOT gate, 5ns for an OR gate, and 10 ns for an AND gate.
2. Draw a component-based model for a 5-bit adder that adds two 5-bit values stored in registers and stores the result in a register. Be sure to indicate all possible inputs and outputs for each component.