Name:_____

Problem 1: (33 Points Total) Decompilation

Here is a mystery function. It expects 4 arguments. The first two are pointers, the third is an integer and the final argument is another pointer. Remember that MIPS passes its arguments in registers $a0-$a4.

```
hmmm:       add $t0, $0, $0
family:     beq $t0, $a2, guy
            add $t1, $0, $0
            add $t2, $0, $0
robot:      addi $t3, $0, 3
            beq $t2, $t3, chicken
            sll $t3, $t2, 2
            add $t3, $t3, $a3
            lw $t3, 0($t3)
            sub $t4, $t0, $t2
            sll $t4, $t4, 2
            add $t4, $t4, $a0
            lw $t4, 0($t4)
            mul $t6, $t3, $t4
            add $t1, $t1, $t6
            addi $t2, $t2, 1
            j robot
chicken:    sll $t5, $t0, 2
            add $t5, $t5, $a1
            sw $t1, 0($t5)
            add $t0, $t0, 1
            j family
guy:        jr $ra
```

a) (20 points) Translate the *hmmm* function into C code. The more "C-like" that you make your code, the more credit you will get, e.g. use for/while loops instead gotos, use array references instead of '*', and so on. Try to be as clear as possible. We will not deduct points for syntax errors *unless* they are significant enough to alter the meaning of your code.

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b) (10 points) Knowing that $a2 is 10, the frequency is 1 GHz and given the following cycle times for each of the instructions, how many seconds will it take to execute the above program?

Instructions	# cycles
beq, j, jr	3
add, addi, sll, sub, sw	4
lw, mul	5

c) (3 points) Describe, in English, what this function computes.

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Problem 2: (32 Points Total) Instruction Set Architecture

MIPS has three instruction types, R, I, and J-type. You should know that the R-type the opcode is always 000000_2. Also for your reference, here are the exact formats for the three MIPS instruction types.

R-type

Opcode (6 bits)	Rs (5 bits)	Rt (5 bits)	Rd (5 bits)	Shift amount (5 bits)	Function (6 bits)

I-type

Opcode (6 bits)	Rs (5 bits)	Rt (5 bits)	Immediate (16 bits)

J-type

Opcode (6 bits)	Target address (26 bits)

a) (4 points) If we have *N* J-type MIPS instructions, what is the maximum number of MIPS I-type instructions that we can have?

Imagine a modified MIPS instruction set with a register file consisting of 64 general purpose registers rather than the usual 32. Assume that we still want to use a uniform instruction length of four bytes (32 bits) and that the total number of instructions must remain unchanged. Also assume that you can expand and contract fields in an instruction but that you cannot omit them.

b) (7 points) How would the format of R-type (arithmetic and logical instructions) change? Label all the fields with their name and bit length. What is the consequence of this change?

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c) (7 points) How does this change the I-type instructions? What is the consequence of this change?

d) (7 points) How does this change the J-type instructions? What is the consequence of this change?

e) (7 points) Imagine we are translating machine code to use the larger register set? Give an example of an instruction that used to fit into the old format but is impossible to translate directly into a single instruction in the new format. Write a short sequence of instructions that could replace it.

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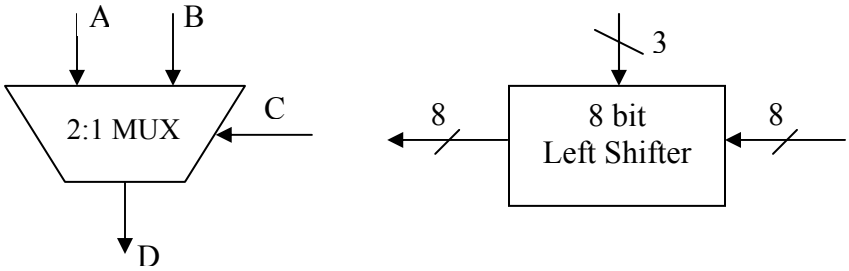
Problem 3: (35 Points Total) Arithmetic

a) (20 points) Design an 8-bit left shifter using only 2 to 1 MUXs:



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b) (10 points) The 2:1 MUX has the following delay properties: A -> D = 5ns; B -> D = 6ns; and C -> D = 3ns. What is the critical path of your 8-bit left shifter?

c) (5 points) We plan to use the 8-bit shifter that you just designed in the following datapath. The registers have the following properties: $t_{clk\text{-}to\text{-}q}$ = 3ns, t_{setup} = 2ns, and t_{hold}=1ns. What is the maximum clock frequency we can run this circuit at?