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[Question 1]

Consider three different classes of instructions: Class A, Class B, and Class C. The following table gives the number of cycles required to execute a single instruction from each class of instructions.

Instruction Type	Number of Cycles
Class A	4
Class B	3
Class C	2

The first code sequence has 10 instructions: 4 of A, 1 of B, and 5 of C. The second sequence has 11 instructions: 4 of A, 1 of B, 4 of C.

NOTE TO GRADERS:

This questions says that the second sequence has 11 instructions when in reality it only has 9 instructions, keep this in mind when grading this question. The below solutions *should* be correct though, assuming the second sequence has 9 instructions.

   a. Which sequence will be faster (find the number of cycles)? By how much? Show your work.

   1st: (4*4)+(1*3)+(5*2) = 16 + 3 + 10 = 29 cycles

   2nd: (4*4)+(1*3)+(4*2) = 16 + 3 + 8 = 27 cycles

   29 - 27 = 2 cycles

   The second sequence is faster by 2 cycles.

   b. What is the CPI for each sequence? Show your work.

   1st: 29 cycles / 10 instructions = 2.9 CPI

   2nd: 27 cycles / 9 instructions = 3 CPI

[Question 2]

In the following instruction sequence for a MIPS 5-stage pipelined datapath, list the data hazards:
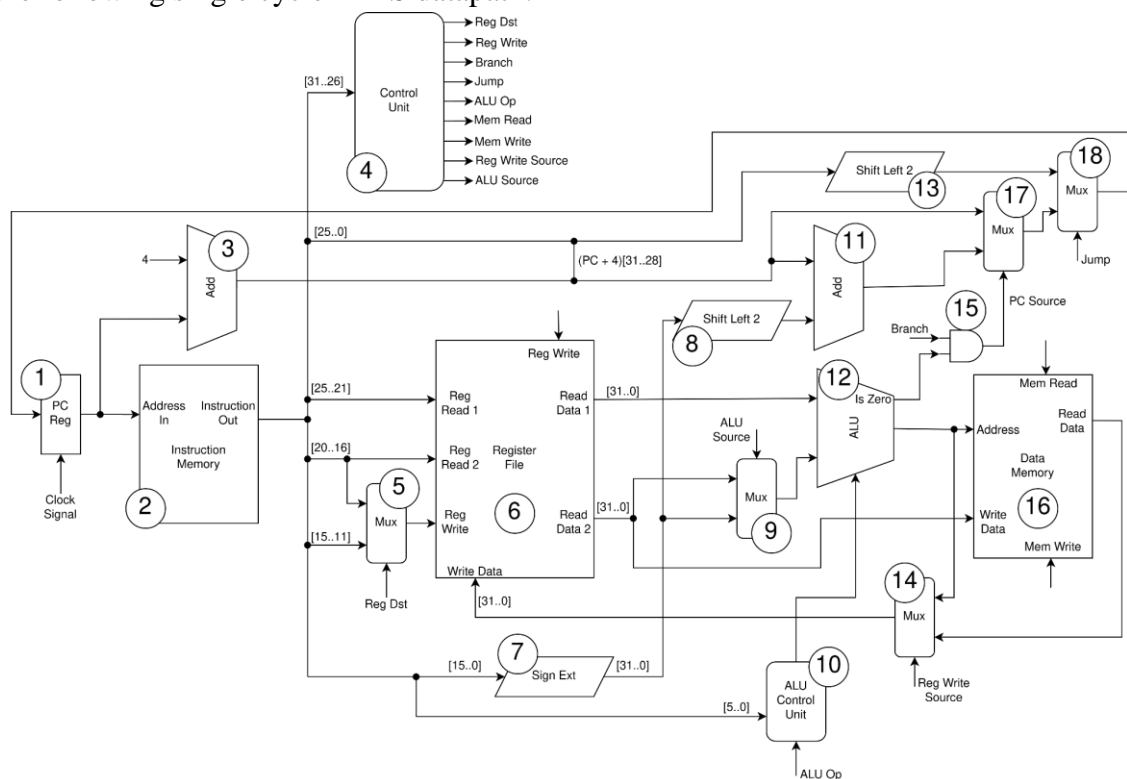
```
sub $s3, $s2, $s1
sw $s3, 8($s4)
addi $s5, $s3, 1
lw $s6, 32($s5)
```

[Question 3]

Given the following single cycle MIPS datapath:

a. For each of the following instructions, list the stages that are necessary for the execution of the given instruction: (IF, ID, EX, MEM, WB)

    i. sub $t3, $t4, $t5

    IF, ID, EX, WB

    ii. sw $s7, 12($s4)

    IF, ID, EX, MEM

b. For each of the following instructions, list the component numbers (as shown in the diagram above) that are required for the given instruction:

    i. sub $t3, $t4, $t5

    Needed: 1, 2, 5, 6, 9, 12, 14

    Optional (Control Path, PC update): 3, 4, 10, 17, 18

    Wrong: 7, 8, 11, 13, 15, 16

    ii. sw $s7, 12($s4)

    Needed: 1, 2, 6, 7, 9, 12, 16

    Optional (Control Path, PC update): 3, 4, 10, 17, 18

    Wrong: 5, 8, 11, 13, 14, 15

[Question 4]
Given the instructions below:
```
sw $s1, 4($s2)
lw $s3, 8($s4)
addi $s5, $s3, 16
sub $s7, $t1, $t2
```
Considering data forwarding, compute the number of cycles needed and explain where data forwarding would be needed to avoid data hazard(s). <u>Show your work.</u>

Instruction	1	2	3	4	5	6	7	8	9	10
sw $s1, 4($s2)	F	D	E	M	W					
lw $s3, 8($s4)		F	D	E	M	W				
NOP		-	-	-	-	-	-			
addi $s5, $s3, 16				F	D	E	M	W		
sub $s7, $t1, $t2					F	D	E	M	W	

[Question 5]
   a. Consider a byte-addressable memory system with the following contents:

Memory Location	Value
0xc534	0x34
0xc535	0x2f
0xc536	0x26
0xc537	0x27
0xc538	0x47
0xc539	0x83
0xc53a	0xa4
0xc53b	0x33

If the following instruction is executed:
```
lw $t0, 8($t1)
```
$t1 contains the address 0xc530. What will $t0 contain? Use Big-Endian.
0x4783a433
   b. Assume that $s0 contains the value 0x34343434 and $s1 contains the address 0x3ccc3333. Assume that the memory data, starting from address 0x3ccc3333 is: 77 66 55 44. What will be the value of $s0 after the following code is executed:
```
lbu $s0, 0($s1)
```
0x00000077