5. (12 points)

The code sequence below executes correctly on the single cycle computer; we want to execute it on a pipelined datapath where **branching is determined in the ID stage**. You must consider where stall might occur between the conditional branch instruction and an instruction immediately before the branch, or where an instruction is flushed from the pipeline. A one clock cycle delay is needed if the instruction immediately before the branch is an *R-format* instruction or an `ADDI/SUBI` instruction and a data dependency exists. A two clock cycle delay is needed if the instruction immediately before the branch is a *load word* instruction and a load-use hazard exists. The datapath will insert the necessary stalls to execute these instructions correctly. The datapath implements *data forwarding*, general *load-use stalling*, and *branch flushing*.

(a) (6 points) Indicate the instructions that are potentially flushed or that have a stall between itself and a prior instruction by using (*) beside that instruction. Rearrange the code to remove stalls if they exist. (You do not need to (and cannot) remove stalls due to branch flushing.)

*	Original	Rearranged Code
	100 ADDI X1,XZR,#50	100 ADDI X1, XZR,#50
	104 ADD X5,XZR,XZR	104 ADD X5, XZR, XZR
	108 LDUR X3,[X7,#400]	108 LDUR X3,[X7, #400]
*	112 STUR X3,[X7,#300]	112 LDUR X2,[X4,#200]
	116 LDUR X2,[X4,#200]	116 ADD X5, X5, X3
*	120 STUR X2, [X4,#400]	120 SUBI X1, X1, #1
	124 ADDI X7,X7,#8	124 STUR X3,[X7 #300]
	128 ADDI X4,X4,#8	128 STUR X2, [X4, #400]
	132 ADD X5,X5,X3	132 ADDI X7, X7, #8
	136 SUBI X1,X1,#1	136 ADDI X4, X4, #8
*	140 CBNZ X1,#-8	140 CBNZ X1, #-8
*	144 ADD X4,X5,X5	144 ADD X4, X5, X5
	148 ADD X7,X7,X7	148 ADD X7, X7, X7

(b) (1 point) In the original sequence of code, what is the total number of instructions that are *flushed*?

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(c) (5 points) State the total numbers of clock cycles, not including pipeline start-up time, that are required to run the i) original sequence of code, and ii) the rearranged code. iii) What is the speedup (old execution time / new execution time)?

i) Outside Loop + 50(Loop) + Flush
= 4cc + 50(14cc) + 49
= 753cc

i) Outside Loop + 50 (loop) + Flush
= 4 + 50(9cc) + 49
= 503

iii) 753 / 503 = 1.479x increase