For the sequence of instructions shown below, show how they would progress through the pipeline.

Part 1:

- Assume that **forwarding HAS been implemented**
- We will predict that any branch instruction is **NOT TAKEN**
- Branches or Jumps are resolved after the EX stage.
- Assume that register $8 *does not equal* $1 for the 1st Beq instruction
- Assume that register $17 *does equal* $26 for the 2nd Beq instruction

Instruction	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SUB $1, $2, $3	F	D	E	M	W												
Add $8, $9, $10		F	D	E	M	W											
Beq $1, $8, X			F	D	E	M	W										
Lw $7, 0($20)				F	D	E	M	W									
Add $11, $7, $12					F	D	D	E	M	W							
Sw $11, 0($24)						F	F	D	E	M	W						
X: Addi $17, $17, 1								F	D	E	M	W					
Beq $17, $26, Y									F	D	E	M	W				
Sub $5, $6, $7										~~F~~	~~D~~						
Or $8, $5, $5											~~F~~						
Y: Addi $17, $17, 1												F	D	E	M	W	
Sw $17, 0($10)													F	D	E	M	W
SUB $1, $2, $3														F	D	E	…
Add $8, $9, $10															F	D	…

Technically, nothing done, but can think of instruction as progressing through pipeline

Part 2:

- (i) Assume that this sequence of code is executed 100 times. How many cycles does the pipelined implementation take?
- (ii) How many cycles would this code take in a multi-cycle implementation?

- From Part 1, you can see that it takes 17 clock cycles to execute 12 instructions.
- However, we can start the next "iteration" in clock cycle 14. Therefore, it *really* only takes 13 cycles for each iteration and 17 CCs for the last one.
- Therefore, iterations 1 through 99 take 13 CCs each
  - (13 x 99 = 1287 CCs)
- Iteration 100 takes 17 CCs
- Therefore 1287 CCs + 17 CCs = 1304 CCs

- For the multi-cycle implementation, we have:
  - 9 instructions that take 4 CCs
  - 2 instructions that take 3 CCs
  - 1 instruction that takes 5 CCs
- Therefore, each "iteration" takes: (9x4) + (2x3) + (1x5) = 36 + 6 + 5 = 47 CCs
- If there are 100 iterations, then 4700 CCs are required

Pipelining gives us a speed up of 4700 / 1304 = 3.6 for this implemention

- Little to no extra HW is needed!