CS M151B Winter 2015 Homework 5 Solutions

1. PH 4.13.1.
   Without forwarding, if the output of instruction A is used as input by instruction B, then there must be at least two instructions between A and B, so that B's ID stage occurs in the cycle at or later than A's WB stage.
   The three cases in which this occurs are the add and the first lw, the first lw and the or, and the or and the sw. For the first and third cases we need two nops each. For the second case, we only need one nop because the second lw doesn't rely on anything earlier.
   There are 10 instructions, so there are 10 + (5–1) = 14 cycles.

2. PH 4.14.1.
   There's an ambiguity as to whether "branches execute in the EX stage" means that the PC is updated in the EX stage or only that the decision is made in the EX stage (and then updates the PC in the MEM stage). The diagram below assumes the second interpretation. If the PC is updated in the EX stage instead, the second lw's IF stage would start in cycle 6. The trade-off is a smaller misprediction penalty for a potentially longer critical path.

   Forwarding occurs between the lw and beq, but we need to stall one cycle because we need to wait for lw's MEM stage to finish before beq's EX stage starts. Since the first time we mispredict in choosing taken, sw and its following instructions will be started in the pipeline and then flushed by beq's EX stage.

Instruction	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**
lw r2, 0(r1)	IF	ID	EX	M	WB										
beq r2, r0, L2		IF	*ID*	ID	EX	M	WB								
sw r1, 0(r2)			*IF*	IF	ID	EX	–	–							
next after sw					IF	ID	–	–	–						
2nd after sw						IF	–	–	–	–					
lw r3, 0(r2)							IF	ID	EX	M	WB				
beq r3, r0, L1								IF	*ID*	ID	EX	M	WB		
beq r2, r0, L2									*IF*	IF	ID	EX	M	WB	
sw r1, 0(r2)											IF	ID	EX	M	WB

3. 4.16.
   1. Always taken: 60%. Always not taken: 40%.
   2. We will predict correctly on the sequence as: N Y N N. That is, the first, third, and fourth will be incorrect predictions and the second will be correct. The accuracy is 25%.
   3. We will predict correctly on the sequence as:
      N Y N N N N N N Y N Y N Y Y N …
      N1 *T1* *T1*
      where the second row shows which of the four states N2, N1, T1, T2 we are in at the end of the loop. Since after the second iteration we will begin and end at T1, the steady-state

CS M151B Homework 5 Solutions (Problem 3)

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3. We will predict correctly on the sequence as:

N Y N N N	N N N Y N	Y N Y Y N …
N1	T1	T1

where the second row shows which of the four states N2, N1, T1, T2 we are in at the end of the loop. Since after the second iteration we will always begin and end at T1, the steady-state will be Y N Y Y N, which has an accuracy of 60%. The first and second iteration have accuracies of 20%. Thus, given x iterations, our total accuracy will be (.20*2 + .60*(x-2)) / x. As x goes to infinity, the ".60*x-2" term dominates the ".20*2" term, so our accuracy will approach 60%.

Note that this problem assumes usage of the predictor in the book, which allows for flipping between the weakly predict taken and the weakly predict not taken states with just one misprediction.