2. (6 points)

   CPI is a measure of clock cycles per instruction that is used to compare Instruction Set Architectures. Find the average CPI in the following situations. The pipeline start-up time is **not** included in the CPI.

   (a) (3 points) Suppose this instruction mix is executed on the pipeline datapath where **Branch is determined in the ID stage** and the datapath implements data forwarding, load-use stalling, branch data stalling and branch flushing when necessary. Assume *half of all* branch instructions are mispredicted and 10% *of all* branch instructions generate a branch data hazard requiring one stall; and a quarter of all load-words are followed by a use and generate a load-use hazard. State the average CPI for each instruction and the total average weighted CPI in the table below. Show your work and the formula you used.

Instruction	Instruction Mix	Average CPI
Load words	14%	1.25cc
Store words	10%	1cc
R-format	60%	1cc
Branch	10%	1.65cc
Jump	6%	1cc
Total Weighted Average CPI		1.1cc

Load Words Execution Time = 1(3/4) + 2(1/4) = 1.25cc

Store Words Execution Time = 1cc

R-Format Execution Time = 1cc

Branch Execution Time = 1(0.45) + 2(0.05) + 2(0.45) + 4(0.05) = 1.65cc

Jump = 1cc

Total weighted: 1.25(0.14) + 1(0.10) + 1(0.6) + 1.65(0.1) + 1(0.06) = 1.1cc

(b) (3 points) Suppose this instruction mix is executed on the pipeline datapath where **Branch is determined in the ID stage** and the datapath implements data forwarding, load-use stalling, branch data stalling and branch flushing when necessary. Assume only *10% of all* branch instructions are mispredicted and 10% *of all* branch instructions generate a branch data hazard requiring one stall; and a quarter of all load-words are followed by a use and generate a load-use hazard. State the average CPI for each instruction and the total average weighted CPI in the table below. Show your work and the formula you used.

Instruction	Instruction Mix	Average CPI
Load words	14%	1.25cc
Store words	10%	1cc
R-format	60%	1cc
Branch	10%	1.21cc
Jump	6%	1cc
Total Weighted Average CPI		1.056cc

Load Words Execution Time = 1(3/4) + 2(1/4) = 1.25cc

Store Words Execution Time = 1cc

R-Format Execution Time = 1cc

Branch Execution Time = 1(0.81) + 2(0.09) + 2(0.09) + 4(0.01) = 1.21cc

Jump = 1cc

Total weighted: 1.25(0.14) + 1(0.10) + 1(0.6) + 1.21(0.1) + 1(0.06) = 1.056cc