Homework 5
Due 10/13 at 11 am

1. For classical 5-stage MIPS pipeline calculate branch penalty for taken and not-taken branches in case of:
   a. (10 points)
      Delayed branches if a delay-slot instruction is chosen “from before”
   b. (10 points)
      Delayed branches if a delay-slot instruction is chosen “from target”
   c. (10 points)
      Delayed branches if a delay-slot instruction is chosen “from fall-through”
   d. (10 points)
      What is the difference between delayed branches and nullifying branches?

2. Assume that we have the following stages in the pipeline: IF, ID, ALU1, MEM, ALU2, WB. Stages IF, ID and WB have the same functionality as in MIPS pipeline. Stage ALU1 performs effective address calculation for instructions that access memory, MEM stage accesses memory, and ALU2 stage performs ALU operations. Find the effective addition to CPI assuming the following frequencies of branches:
   Jumps 10%
   Not-taken branches 20%
   Taken branches 70%
   a. (10 points)
      For flush-pipeline technique
   b. (10 points)
      For predict-taken technique
   c. (10 points)
      For predict-not-taken technique
   d. (10 points)
      Which technique is the best and why?

3. In the following MIPS code with FP instructions:
   L.D F4, 0(R2)
   MUL.D F4, F4, F2
   ADD.D F2, F6, F8
   DIV.D F10, F8, F4
   ADD.D F10, F2, F12
   a. (10 points)
      Identify all RAW, WAW and WAR hazards. Assuming that ADD.D and SUB.D take 4 cycles to execute, MUL.D takes 7 cycles and DIV.D takes 25 cycles, and that there is no forwarding, how long does it take to execute this code? How many stalls are necessary due to hazards?
   b. (10 points)
      Apply forwarding to resolve RAW hazards. Use arrows to indicate where forwarding is done and list remaining stalls. How long does it take now to execute the code?
c. **(10 points)**
   Apply renaming to resolve WAW and WAR hazards and list remaining stalls. How long does it take now to execute the code?