

**Problem 1:** State and define the hazards presented by instruction level parallelism. For each one, indicate how it can be resolved.

*1. Data Hazards*

- *RAW (Data dependence) cannot use a value before it is computed. Resolve by forwarding or stalling*
- *WAW (Output dependence) cannot write a value if a logically preceding instruction might overwrite it. Resolve by pipeline design (in-order op-fetch + in-order WB), stalling on potential write to pending register, or renaming*
- *WAR (anti-dependence) cannot write a value before logically preceding instruction reading the previous value have done so. Resolve by pipeline design (in-order issue with in-order operand fetch), stalling or renaming.*

*2. Structural Hazards*

*Attempt to use the same hardware resource for two different purposes at once. Resolve by adding hardware resources (as design time) or stalling*

*3. Control Hazards*

*Cannot determine the control flow until the condition of the branch is resolved. Resolve by stalling. Mitigated by predicting and discarding miss-predicts.*

**Problem 2.** Your current version of ZippyCAD runs through a benchmark design in 43 minutes on your ZIPS10 computer. ZIPS has a new model that they are offering to sell to you. ZIPS30 is a scalar machine like ZIPS10, but 3 times faster. Or you can get the ZIPS1010 vector upgrade that performs vectorized code at 10 times the performance of ZIPS10. You know that ZippyCAD spends a lot of time in its numerical library, so you are intrigued. *How much of ZippyCAD would need to vectorize for the ZIPS1010 to beat the ZIPS30?*

$$SU_{vector} = \frac{T_{scalar}}{T_{vector}} = \frac{1}{(1-f) + f/x} = \frac{1}{1-f + f/10} \geq 3$$

$$f \geq 20/27 \approx 74\%$$