



Figure 1: Diagram for Solution of Question 1

Question 1 (10 points): The Average Memory Access Time (AMAT) for a program P executing in a given processor is 2.0 clock cycles per access. 25% of the instructions are loads or stores. The access time for both L1 data and L1 instruction caches is 1 clock cycle and these two accesses occur in parallel in the case of an instruction that accesses memory. The miss rate for the L1 instruction cache is 1%, the miss rate for the L1 data cache is 5%. The miss penalty for both L1 caches is the same. What is the average penalty, expressed in number of cycles for an access that misses in either L1 data or L1 instruction cache?

Let N be the number of instructions executed.

$$\begin{aligned}
 \text{AMAT} &= \frac{\text{cycles for memory access}}{\text{number of memory accesses}} \\
 \text{cycles for memory access} &= (1.0 + 0.01 \times \text{penalty} + 0.25 \times (1.0 + 0.05 \times \text{penalty})) \times N \\
 &= (1.25 + 0.0225 \times \text{penalty}) \times N \\
 \text{number of memory accesses} &= 1.25 \times N \\
 2.0 &= \frac{(1.25 + 0.0225 \times \text{penalty}) \times N}{1.25 \times N} \\
 \text{penalty} &= \frac{2.0 \times 1.25 - 1.25}{0.0225} \\
 &= \frac{2.5 - 1.25}{0.0225} = \frac{1.25}{0.0225} = 55.6 \text{ cycles}
 \end{aligned}$$

Another way to do the solution is to assume that the program has 10000 instructions as shown in Figure 1. Then we have:

$$\begin{aligned}
 \text{AMAT} &= \frac{12500 + 225 \times \text{penalty}}{12500} = 2.0 \\
 \text{penalty} &= \frac{25000 - 12500}{225} = \frac{12500}{225} = 55.6 \text{ cycles}
 \end{aligned}$$

The wording of the question also allow for the interpretation that the L1D and the L1I accesses happen in parallel. Still the total number of accesses is $1.25 \times$ the number of instructions. AMAT is a ratio between the number of cycles required to access memory and the number of accesses. Therefore, this interpretation leads to:

$$\begin{aligned}\text{AMAT} &= \frac{10000 + 225 \times \text{penalty}}{12500} = 2.0 \\ \text{penalty} &= \frac{25000 - 10000}{225} = \frac{15000}{225} = 66.7 \text{ cycles}\end{aligned}$$