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Given a cache hierarchy with 8 words with a cache access time of 5 ns and a memory access time of 50ns, and the following set of memory accesses representing the tag and index: 22, 28, 31, 22, 16, 13, 31, 8, 5, 13, 8, and 5.

- If the cache is a direct-mapped cache, show the sequence for accessing the cache and calculate the total access time. Draw the final cache table
- If the cache is a 2-way set associative cache, show the sequence for accessing the cache and calculate the total access time.
- Determine which cache has the better performance and by how much.

22 = 10110 28 = 11100 31 = 11111 16 = 10000 13 = 01101 8 = 01000
 5 = 00101

Direct

$$3 \times 5ns + 9 \times (5+50) = \boxed{510ns}$$

Index	V	Tag	Memory
000	N	10 → 01	m(16 → 8)
001	N		
010	N		
011	N		
100	N	11	m(28)
101	N	01 → 00 → 01 → 00	m(13 → 5 → 13 → 5)
110	N	10	m(22)
111	N	11	m(31)

22 (miss), 28 (miss), 31 (miss), 22 (Hit), 16 (miss), 13 (miss), 31 (Hit), 8 (miss), 5 (miss), 13 (miss), 8 (Hit), 5 (miss)

Index	V	Tag	Memory	V	Tag	Memory
00	Y	111 → 100 → 010	m(28 → 16 → 8)	Y	111 → 100	m(28 → 16)
01	Y	011 → 001 → 011 → 001	m(13 → 5 → 13 → 5)	Y	011 → 001 → 011	m(13 → 5 → 13)
10	Y	101	m(22)	N		
11	Y	111	m(31)	N		

22 (miss), 28 (miss), 31 (miss), 22 (Hit), 16 (miss), 13 (miss), 31 (Hit), 8 (miss), 5 (miss), 13 (Hit), 8 (Hit), 5 (Hit)

$$5 \times 5 + 7 \times 55 = \boxed{410ns} \Rightarrow \boxed{\frac{510}{410}}$$

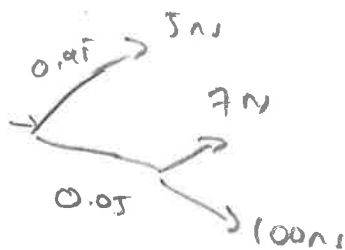
Average Memory Access Time

Given a Level-1 cache with a hit rate of 95%, a cache access time of 5 ns, and a memory access time of 100ns, find the average memory access time

$$0.95 \times 5 \text{ ns} + (5 + 100) \times 0.05 \leftarrow$$

10 ns

The processor in the Example is given a L2 cache with a hit rate of 85%, and a cache access time of 7ns. Find the average memory access time



$$\begin{aligned} &0.95 \times 5 \text{ ns} + 0.05 \left((5 \text{ ns} + 7 \text{ ns}) \times 0.85 + 0.15 (5 + 7 + 100) \right) \leftarrow \\ &4.75 + 0.85 (10.2 \text{ ns} + 16.8 \text{ ns}) \\ &4.75 + 1.35 \\ &= 6.1 \text{ ns} \end{aligned}$$

The processor in the Example is given a L3 cache with a hit rate of 80%, and a cache access time of 10ns. Find the average memory access time

$$0.95 \times 5 + 0.05 (12 \times 0.85 + 0.15 (0.8 (5 + 7 + 10) + 0.2 (5 + 7 + 10 + 100)))$$