COMP4300 Spring 2022
Homework 2
Due 29 April 2022, 11:59pm

1. Suppose you are designing a cache for a machine with 32-bit addresses. The cache is 1MB in size. Cache blocks are 1024 bytes.
   a. How many blocks can be held in the cache
   b. How many bits of the address are devoted to the offset?
   c. If the cache is direct-mapped, how many bits are devoted to the tag and index?
   d. If the cache is 8-way set associative, how many bits are devoted to the tag and index? How many sets are there?
   e. If the cache is fully associative, how many bits are devoted to the tag and index?

a) $1\ MB = 2^{20}\ \frac{bytes}{cache}$; $1024 = 2^{10}\ \frac{bytes}{block}$

$2^{20}\ \frac{\cancel{bytes}}{cache} \Big/ 2^{10}\ \frac{\cancel{bytes}}{block} = \boxed{2^{10}\ \frac{blocks}{cache} = 1024}$

b) 1024 byte blocks

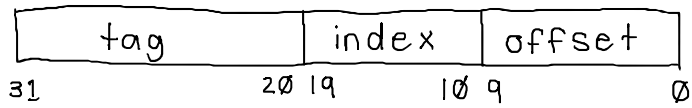
$\Downarrow$

$2^{10} \longrightarrow$ 10-bit offset

c) 1024 blocks / cache

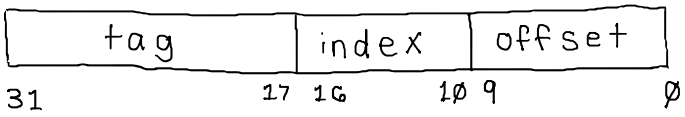
$\Downarrow$

$2^{10} \longrightarrow$ 10-bit index, 12-bit tag

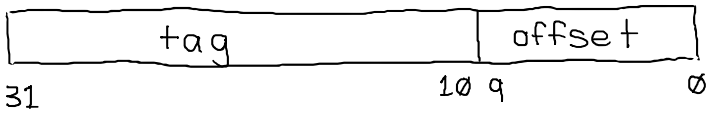


d) 8 blocks / set

1024 / 8 = 128 sets $\longrightarrow 2^7$ sets $\longrightarrow$ 7-bit index, 15-bit tag



e) No index
22-bit tag



2. Suppose you have a machine with separate I- and D- caches. The miss rate on the I-cache is 2%, and on the D-cache 3%. On an I-cache hit, the value can be read in the same cycle the data is requested. On a D-cache hit, one additional cycle is required to read the value. The miss penalty is 100 cycles for either cache. 35% of the instructions on this RISC machine are LW or SW instructions, the only instructions that access data memory. A cycle is 2ns. What is the average memory access time?

avg mem access time split I/D cache =

(% mem access for instruction)(avg mem access time for instruction load)

+ (% mem access for data load/store)(avg mem access time for data)

I-cache

avg mem access time =

hit time + miss rate (miss penalty)

= 1 + 0.02(100) = 3

D-cache

avg mem access time =

hit time + miss rate (miss penalty)

= 2 + 0.03(100) = 5

Split I/D cache

avg mem access time =

$\left(\frac{1}{1.35}\right)(3) + \left(\frac{0.35}{1.35}\right)(5) = 3.52$ cycles

$3.52 \text{ cycles} \times \frac{2 \text{ ns}}{\text{cycle}} = \boxed{7.04 \text{ ns}}$