Guerrilla Section 5: Caches

You are given a MIPS machine with a single level of 2KiB direct-mapped cache with 512B cache blocks. It has 1MiB of physical address space.

The function `foo` is ran on the system with a cold cache and as the only process:

```c
#define ARRAY_LEN 4096
#define STEP_SIZE 64

// A starts at 0x10000
// B starts at 0x20000

foo( int* A, int* B ) {
    int total = 0;
    for ( int i = 0; i < ARRAY_LEN; i += STEP_SIZE ) {
        total += A[ i ];
        total -= B[ i ];
    }
}
```

1. Calculate the number of Tag, Index, and Offset bits for this cache.
   - Tag: 9
   - Index: 2
   - Offset: 9

2. Calculate the hit percentage for this cache after running `foo`.
   - 0%

3. The cache is now cleared and the code is run again. This time, A and B are pointing to the same array, which starts at 0x10000. Calculate the new hit percentage.
   - 75%

4. Assume A and B starts once again at 0x10000 and 0x20000. What is the new hit percentage if we ran `foo` on a fully associative cache, with all other parameters staying the same?
   - 50%

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**Problem 2:**

**Question 1:**

a. You are given a 16 KiB direct-mapped cache with 128 B blocks and a write-back policy. Assume a 64-bit address space and byte-addressed memory.

   Tag: 50  Index: 7  Offset: 7

b. We have a 32-bit byte-addressed machine with an 8-way set-associative cache that uses 32 B blocks and has a total capacity of 8 KiB.

   Tag: 22  Index: 5  Offset: 5
Problem 3:

a. Calculate the AMAT for a system with the following properties:
   - L1 cache hits in 1 cycle with local hit rate 20%
   - L2 cache hits in 10 cycles with local hit rate 80%
   - L3 cache hits in 100 cycles with local hit rate 90%
   - Main memory always hits in 1000 cycles
   
   \[ \text{AMAT} = 1 + (1 - 0.2)(10 + (1 - 0.8)(100 + (1 - 0.9)(1000))) = 41 \]

b. How slow can you go? Your system consists of the following:
   - L1 cache hits in 2 cycles with a miss rate of 20%
   - L2 cache hits in 10 cycles
   - Main memory always hits in 300 cycles

   You want your AMAT to be \( \leq 22 \) cycles. What does your local L2 miss rate need to be? What is the equivalent global miss rate?

   \[ \text{AMAT} = \text{L1 Hit time} + \text{L1 Miss rate} \times (\text{L2 Hit time} + \text{L2 Miss rate} \times \text{L2 Miss penalty}) \]
   \[ 22 \geq 2 + 0.2 \times (10 + X \times 300) \]
   \[ X = \frac{22 - 2}{0.2 \times 10} = 3, \text{or 30\% local miss rate} \]
   \[ \text{Global miss rate} = 30\% \times 20\% = 6\% \]

Q4:

1. \( \text{0xC5C8} \) -- binary decimal: 1111.001, mantissa 111001000, exponent is 3 + 31 = 34
2. \( 2^{10} - 1 \) -- max is 1.111111111 and exponent of \( 2^{9} \) -> 1111111111
   which is \( 2^{10} - 1 \)
3. \( 2^{15} - 2^{9} - 1 \) -- We're basically looking for the number of positive norms and denorms. We have 6+9 bits of exponent and significand to set in any arrangement except those arrangements which represent zero, infinity, or NaN. So we have \( 2^{15} - 2^{9} \) (number of arrangements where exponent is \( 2^{10} - 1 \) and significand is anything) - 1 (zero).