Problem 47. (8 points):

A bitmap image is composed of pixels. Each pixel in the image is represented as four values: three for the primary colors(red, green and blue - RGB) and one for the transparency information defined as an alpha channel.

In this problem, you will compare the performance of direct mapped and 4-way associative caches for a square bitmap image initialization. Both caches have a size of 128 bytes. The direct mapped cache has 8-byte blocks while the 4-way associative cache has 4-byte blocks.

You are given the following definitions

```
typedef struct{
    unsigned char r;
    unsigned char g;
    unsigned char b;
    unsigned char a;
}pixel_t;

pixel_t  pixel[16][16];
register int i, j;
```

Also assume that

- `sizeof(unsigned char) = 1`
- `pixel` begins at memory address `0`
- Both caches are initially empty
- The array is stored in row-major order
- Variables `i`,`j` are stored in registers and any access to these variables does not cause a cache miss

A. What fraction of the writes in the following code will result in a miss in the direct mapped cache?

```
for (i = 0; i < 16; i ++){
    for (j = 0; j < 16; j ++){
        pixel[i][j].r = 0;
        pixel[i][j].g = 0;
        pixel[i][j].b = 0;
        pixel[i][j].a = 0;
    }
}
```

Miss rate for writes to pixel:_______________%

B. Using code in part A, what fraction of the writes will result in a miss in the 4-way associative cache?

Miss rate for writes to pixel: _______________ %

C. What fraction of the writes in the following code will result in a miss in the direct mapped cache?

```
for (i = 0; i < 16; i ++){
    for (j = 0; j < 16; j ++){
        pixel[j][i].r = 0;
        pixel[j][i].g = 0;
        pixel[j][i].b = 0;
        pixel[j][i].a = 0;
    }
}
```

Miss rate for writes to pixel:_______________%

D. Using code in part C, what fraction of the writes will result in a miss in the 4-way associative cache?

Miss rate for writes to pixel:_______________%