7. In this question we will examine the cache performance of a computing system when running a specific program. A profile of the program has determined that the memory locations accessed by the program is in the following order:

```
0x1000 4000
0x1000 4020
0x1000 4004
0x1000 4028
0x1000 4024
0x1000 4020
0x1000 400C
0x1000 402C
0x1000 4040
0x1000 4000
0x1000 400C
0x1000 402C
0x1000 4020
0x1000 4024
0x1000 4004
0x1000 4000
```

Assume a memory system with the following specifications:

- Memory word: 4 bytes (memory is byte-addressable).
- Cache type: direct mapped cache
- Cache size: 8 words.
- Cache block size: 1 word.
- Cache access time: $t_{cache} = 2$ cycles.
- Main memory access time: $t_{MM} = 40$ cycles.

(a) (2 points) Consider the program with the memory accesses listed above. How many cache misses and how many cache hits will you generate?

Solution: 14 misses and 2 hits.

(b) (2 points) What is the total memory access time for the program in question

Solution: 14 misses each require 1 cache access + 1 memory access (42 cycles), and the 2 cache hits require 2x2 = 4 additional cycles. So the total is:

$$Total = 14 \times (40 + 2) + 2 \times 2Total = 588 + 4Total = 592$$

(c) (3 points) How many of these misses are compulsory, how many are conflict and how many are capacity misses

Solution: There are 4 compulsory misses, 10 conflict misses, and no capacity misses. Half the capacity of the cache is not used during the execution of the program.

(d) (3 points) For each of the following changes to the cache organization, state whether it will or not increase the cache hit ratio and explain why.

1. Increasing the cache capacity from 8 to 16 words
2. Making a 2-way set associative cache instead of direct mapped cache
3. Using a block size of 4.

Solution:

1. Will not work directly, unless used in combination with the other two methods.
2. Will work, 2-way set associative cache reduces conflict misses. However, there will be more compulsory misses. (5 hit/ 11 miss)
3. Will work, using a block size of 4 reduces the compulsory misses. Still there would be several conflict misses (6 hit/ 10 miss)

A better solution would be to use 2-way set associative with a block size of 4 (12 hit, 4 miss). Or increase the size to 16, and use 4 way set associative with block size 4 (13 hit / 3 miss).