This part of the exam is taken-home and is due at the time of the final exam on Tuesday, December 20 at 1:30pm, when you will take part 1 of this exam. Over the weekend you may discuss the questions with the other students or work alone, as you choose, but your answers must be unique and in your own words.

You are allowed and encouraged to type in your answers into a word processor such as Microsoft Word, but if you do please follow these guidelines:
1. Put your name in the header/footer region so it appears on every page,
2. Put automatic page numbers in the header/footer as well,
3. Write your answers in the same order as the questions in this document,
4. Write all text in 12-point Times New Roman, except:
5. Use the Courier New typeface for any ARM code,
6. Staple your printout to this exam before you turn it in.
25 Points – In a computer with a 20-bit address space (addressing up to $2^{20}$ bytes), there is a direct-mapped cache system, arranged as follows:

A. 1 Point – How many blocks in the cache are there?
B. 1 Point – How many bytes are in each block?
C. 1 Point – How many blocks of primary memory map onto each block in the cache?

Currently in primary memory is a small program that starts at location $00000$ and takes up exactly 2 kilobytes of memory just for the executable code. It references a 64-kilobyte two-dimensional array of bytes, called MyData, that starts at fixed location $A0000$. The array contains 256 rows and 256 columns, both indexed by values from 1 to 256, and the cells in the array are stored in row-major order. In Pascal, this would be allocated with the following declaration:

```pascal
Var MyData : Array [1..256,1..256] Of Byte Absolute $A0000 ;
```

Here are two approaches to storing zeroes in every element of the array:

```pascal
For R := 1 To 256 Do For C := 1 To 256 Do
  MyData[R,C] := 0 ;
```

D. 1 Point – What is the mapping function for the array, which maps row $R$ and column $C$ onto a linear byte offset (0…65535) relative to the start of the array in physical memory?
E. 1 Point – How many blocks of primary memory does the array occupy?
F. 1 Point – How many blocks of the array map onto each corresponding cache block?
G. 1 Point – Which block numbers in the cache will be used by the array?
H. 1 Point – Which block numbers in the cache will be used by the program?
I. 7 Points – Essay: Of the two approaches to clearing the array shown above, which one will result in the least amount of “cache thrashing”? Why?
J. 10 Points – Essay: How would changing the cache mechanism to \textit{two-way set associative} improve overall performance in this particular example?