COMP 230: Computer Architecture and Organization	October 6, 2017
Homework 4	
Instructor: Robert Utterback	*Due: October 20, 2017*

Test your solutions to the first two questions using the MIPS simulator `SPIM`. `SPIM` is installed on the department server (`cs.monm.edu`), and can be installed on personal computers by following the directions here: `http://spimsimulator.sourceforge.net/`.

Complete the last two quesions in a single text file, and submit all three files as *hwk4* using `handin` with the course *comp230*.

1. Write a MIPS assembly program that reads in a string, replaces all 'a' characters with commas, and prints the resulting string. You may assume the input string is at most 32 characters long.

2. Write a MIPS assembly program that reads in a series of integers, adds them, and prints the sum. Your program should read each integer from the user and check if it is zero. If so, your program should print the sum and finish. Otherwise, your program should add the integer to the accumulated sum and prompt for the next integer.

3. One section of an object file contains relocation information, which contains an entry describing each instruction that references an absolute, rather than relative, memory address. This is necessary because the compiler cannot know the memory addresses for instructions until all the object files are combined during the linking process. Which MIPS instructions must be included in this relocation info?

   Hint: Think about the addressing mode required for each instruction.

4. Considering the following program:

   ```
   void foo(int n) {
      if (n == 0) {
        return;
      }
      ... foo(n-1) ...
   }
   ```

   Assume `foo` needs to push 4 registers onto the stack for each non-base-case call and 0 registers for a base case call. The only procedure call `foo(n)` makes is the recursive call to `foo(n-1)`. How much stack memory does a call to `foo(3)` need? Assuming the stack for `foo(3)` starts at address `0xffffffff`, what is the ending memory address of the last procedure frame?