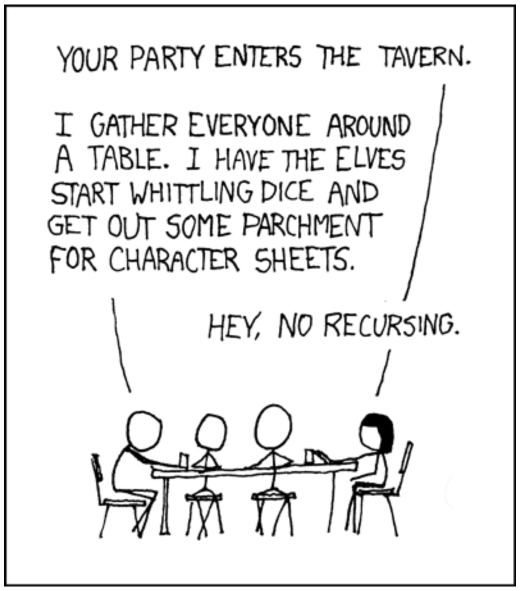
CS52 - Assignment 4

Due Monday 10/12 at 11:59pm


YOUR PARTY ENTERS THE TAVERN.
I GATHER EVERYONE AROUND A TABLE. I HAVE THE ELVES START WHITTLING DICE AND GET OUT SOME PARCHMENT FOR CHARACTER SHEETS.
HEY, NO RECURSING.

`https://xkcd.com/244/`

Getting Started

For this assignment we will be coding up functions in CS41B. Make sure you've read the CS41B manual on the course web page and refer to it as you work through this assignment.

Each problem will be in it's own file, so you will be creating four files: `positive.a41`, `power2.a41`, `ackermann.a41` and `smash.c`.

Aquamacs note: Often Aquamacs uses a variable-width font which makes it difficult to line up columns. To force it to use a fixed-width font, go to

`Options` $\longrightarrow$ `Appearance` $\longrightarrow$ `Auto Faces`

and uncheck `Auto Faces`.

Optional: Touching base

We're about a third of the way through the course and I wanted to touch base with you all, see how the course is going and see if there is any way we can make it better. I have created a *very* short survey. Please take 5 minutes and fill out the anonymous survey by the assignment due date (optional). I will briefly go over the results in class.

`https://docs.google.com/forms/d/1MZRWeB7ho8wEGoI6Dw0xSnLNIxK9a0D5LTTZ2Hr-0WM`

1 Warming up

Write a CS41B program `positive.a41` that:

- Prompts the user for a number
- then prints 1 if the number is positive, 0 otherwise.
- You *must* include in your program a separate function that takes a single parameters as "input" and "returns" 1 if the number is positive, 0 otherwise.

For example, if we ran the program in the simulator and input 10 we would see the following:

```
CS41B wants a value > 10
CS41B says > 1
```

2 If you push, you must pop

Write a CS41B program `power2.a41` that takes as input a number n and prints out 2^n. To accomplish this write a function that computes powers of 2 by following the recursive pattern suggested by the SML function below.

```
fun power2 k =
     if k < 0 then
          0
     else if k = 0 then
          1
     else
          double(power2(k-1));
```

"Doubling" may be implemented by adding a number to itself; there need not be a separate doubling function. On the other hand, the `power2` function itself *must* be implemented recursively. That is, the function must save the return address on the stack and eventually jump back to it, and the body of the function contains a call to itself.

For example,

```
CS41B wants a value > 5
CS41B says > 32
```

3 To understand recursion, you must understand recursion

The Ackermann function is defined as:

$$A(m,n) = \begin{cases} n+1 & \text{if } m = 0 \\ A(m-1,1) & \text{if } m \neq 0 \text{ and } n = 0 \\ A(m-1, A(m, n-1)) & \text{otherwise} \end{cases} \quad (1)$$

Write a CS41B program that takes two values, first m and then n, and prints out the corresponding value of the Ackermann function. Place your work in a file named `ackermann.a41`.

For completeness, let us specify that $A(m,n) = 0$ when m or n is negative

For example, here are two runs of the program:

```
CS41B wants a value > -3
CS41B wants a value > 1
CS41B says > 0

CS41B wants a value > 3
CS41B wants a value > 1
CS41B says > 13
```

The function grows very quickly, and your program will make *lots* of recursive calls. Below is s a table with some values of the function. The value $A(4,2)$ requires nearly 20,000 decimal digits!

	$n = 0$	$n = 1$	$n = 2$	$n = 3$	$n = 4$
$m = 0$	1	2	3	4	5
$m = 1$	2	3	4	5	6
$m = 2$	3	5	7	9	11
$m = 3$	5	13	29	61	125
$m = 4$	13	65533	...	...	...

Your program will actually only be able to produce results for only the smallest values of m and n. If you squeeze in as much stack space as you can, you ought to be able to compute $A(3, 2)$ but perhaps not $A(3, 3)$. Nevertheless, your code must be structured as an accurate representation of the recursive definition above.

4 C anyone?

This short exercise gives us a glimpse into unsafe languages, in this case, the language is the C programming language.

The program in Figure 1 at the end of this document declares a three-element array of integers, initializes all three values to 47, calls a procedure that does nothing, and then prints out the values.

Begin by creating a file `smash.c` with exactly the code in Figure 1. Then compile it with the terminal command

```
gcc -o smash smash.c
```

and run it with the command

```
./smash
```

Next, modify the program by changing the procedure `do_nothing` so that when you run the resulting program the output values are, in order, 47, 29, and 47. Make changes *only* between the braces of `do_nothing` (i.e. you're only writing the function `do_nothing`. For this exercise, we are not concerned with documentation, so you need not add comments.

The idea is to recognize that the elements of the array `a` are stored on the stack, and `do_nothing` can reach into the stack and change one of those values. You will only have to add a few lines of code, but it may take a little experimentation to find exactly the right lines. When you are finished, submit your modified version of `smash.c` in the usual way.

Here is what you need to know about the C programming language.

i. The syntax of C is very much like Java. Variables must be declared before they are used, and the equals sign is the assignment operator.

ii. The variable declarations

```
int k;
int* p;
```

declare an integer `k` and a "*pointer*" `p` to an integer. That is, `p` is a variable that holds the address in memory where an integer is stored. The expression `*p` refers to the integer *at* address `p`; it can be used on either sign of an assignment statement. Be sure that you understand the difference between the two assignment statements:

```
p = 8;
*p = 8;
```

The first sets the value of the variable `p` to be 8. The second sets the value *at the memory address stored in* `p` to be 8.

iii. It is possible to do arithmetic on addresses. For example, if `p` is the address of an integer in memory, then `p+1` is the address of the very next integer in memory. The compiler computes the right number of bytes to add to the address based on the word size. Be sure that you understand the difference between the two statements:

```
p = p + 8;
*p = *p + 8;
```

iv. Finally, the `&` operator returns the address of a variable, so that the assignment

```
p = &k;
```

stores the memory location of variable `k` in the pointer variable `p`. (More precisely, `p` receives the address in memory which has been reserved for `k`.) After that assignment, `k` and `*p` can be used interchangeably.

v. `printf` is a built-in function that prints values. It takes two parameters a string pattern and the value to be printed. There are many different patterns, but the one used in the code prints out the value as a number and followed by an end of line character. Adding some temporary print statements may help you in figuring out the solution, but make sure to remove these before you submit. Your submitted program should only print three numbers and this printing should happen with the `printf` statement already in the code.

When you're done

Make sure your code compiles. If it does not, you will not get any points for that problem.

Make sure you've properly commented your code. You should include:

- A comment header at the top of the file with your name, the date, the assignment number, etc.
- Almost every line of assembly should have a comment to the right of it.

When you're ready to submit, upload your assignment via the online submission mechanism. *You should upload each of the four problems separately*, that is, you should submit four files `positive.a41`, `power2.a41`, `ackermann.a41` and `smash.c`. You may submit as many times as you'd like up until the deadline. We will only grade the most recent submissions.

Grading

`positive.a41`	4
`power2.a41`	6
`ackermann.a41`	8
`smash.c`	3
comments/style	3
Total	24

```
#include <stdio.h>

void do_nothing(){
}

int main(){
  int j;
  int a[3];

  for (j = 0; j < 3; j++){
    a[j] = 47;
  }

  do_nothing();

  for (j = 0; j < 3; j++){
    printf("%d\n", a[j]);
  }

  return 0;
}
```

Figure 1: A “do nothing” program in the C language.