Full Name:_______________________________________

A-number:_______________________________________

ECE 5720, Fall 2030

Mid Term 1

October 30, 2020

Instructions:

- Write your A-number on top of every sheet.
- Make sure that your exam is not missing any sheets, then write your full name on the front.
- Write your answers in the space provided below the problem. If you make a mess, clearly indicate your final answer.
- The exam has a maximum score of 50 points. You must show your steps clearly to get partial credit.
- The problems are of varying difficulty. The point value of each problem is indicated. Pile up the easy points quickly and then come back to the harder problems.
- This exam is OPEN BOOK and OPEN NOTES, but CLOSED INTERNET. You may use **electronic devices (PDA, Laptop, Smartphone) to only access electronic book and notes that you have downloaded previously.** Good luck!

1 (10):	
2 (10):	
3 (20):	
4 (10):	
TOTAL (50):	

Problem 1. (10 points):

Consider the source code below, where `M` and `N` are constants declared with `#define`.

```
int mat1[M][N];
int mat2[N][M];

int sum_element(int i, int j)
{
  return mat2[i][j] +=  mat1[j][i];
}
```

A. Suppose the above code generates the following assembly code:

```
sum_element:
        movslq  %edi, %rdi
        movslq  %esi, %rsi
        leaq    0(,%rdi,8), %rax
        subq    %rdi, %rax
        leaq    (%rdi,%rax,4), %rdx
        leaq    (%rsi,%rsi,8), %rax
        leaq    (%rsi,%rax,2), %rax
        addq    %rsi, %rdx
        leaq    (%rax,%rdi), %rdi
        movl    mat2(,%rdx,4), %eax
        addl    mat1(,%rdi,4), %eax
        movl    %eax, mat2(,%rdx,4)
        ret
```

What are the values of `M` and `N`?

M = 29

N = 19

Problem 2. (10 points):

Consider the following assembly code for a C `for` loop:

```
decode_me:
        cmpl    %esi, %edi
        jle     .L5
        leal    (%rdi,%rdi), %edx
        movl    $1, %eax
        subl    %esi, %edx
.L4:
        subl    $1, %edi
        addl    $4, %esi
        addl    %edx, %eax
        subl    $6, %edx
        cmpl    %esi, %edi
        jg      .L4
        addl    $46, %eax
        ret
.L5:
        movl    $47, %eax
        ret
```

Based on the assembly code above, fill in the blanks below in its corresponding C source code. (Note: you may only use the symbolic variables `x`, `y`, and `result` in your expressions below — *do not use register names.*)

```
int decode_me(int x, int y)
{
   int result;

   for (result = 1; __x > y_______; x--,y = y + 4 ) {

      ___________;   result = result + (2 * x - y);

   }

   return __result + 46____________;
}
```

Problem 3. Stack Discipline (20 points)

Examine the following recursive function:

```
long sunny(long a, long *b) {
  long temp;
  if (a < 1) {
    return *b - 8;
  } else {
    temp = a - 1;
    return temp + sunny(temp - 2, &temp);
  }
}
```

Here is the x86_64 assembly for the same function:

```
0000000000400536 <sunny>:
  400536:       test   %rdi,%rdi
  400539:       jg     400543 <sunny+0xd>
  40053b:       mov    (%rsi),%rax
  40053e:       sub    $0x8,%rax                          Breakpoint
  400542:       retq
  400543:       push   %rbx
  400544:       sub    $0x10,%rsp
  400548:       lea    -0x1(%rdi),%rbx
  40054c:       mov    %rbx,0x8(%rsp)
  400551:       sub    $0x3,%rdi
  400555:       lea    0x8(%rsp),%rsi
  40055a:       callq  400536 <sunny>
  40055f:       add    %rbx,%rax
  400562:       add    $0x10,%rsp
  400566:       pop    %rbx
  400567:       retq
```

We call **`sunny`** from **`main()`**, with registers %**`rsi`** = **`0x7ff`**…**`ffad8`** and %**`rdi`** = 6. The value stored at address **`0x7ff`**…**`ffad8`** is the long value 32 (0x20). We set a breakpoint at "**`return *b - 8`**" (i.e. we are just about to return from **`sunny()`** without making another recursive call). We have executed the **`sub`** instruction at **`40053e`** but have not yet executed the **`retq`**.

Fill in the register values on the next page and **draw what the stack will look like when the program hits that breakpoint**. Give both a description of the item stored at that location and the value stored at that location. If a location on the stack is not used, write "unused" in the Description for that address and put "-----" for its Value. You may list the Values in hex or decimal. Unless preceded by **`0x`** we will assume decimal. It is fine to use **`f`**…**`f`** for sequences of **`f`**'s as shown above for %**`rsi`**. Add more rows to the table as needed. Also, fill in the box on the next page to include the value this call to **`sunny`** will *finally* return to **`main`**.

Register	Original Value	Value at Breakpoint
rsp	0x7ff…ffad0	0x7ff…ffa90
rdi	6	0
rsi	0x7ff…ffad8	0x7ff…ffaa0
rbx	4	2
rax	5	-6

DON'T FORGET → What value is **finally** returned to **main** by this call? 1

Memory address on stack	Name/description of item	Value
0x7fffffffffffad8	Local var in **main**	0x20
0x7fffffffffffad0	Return address back to **main**	0x400827
0x7fffffffffffac8	Saved %rbx	*4*
0x7fffffffffffac0	*temp*	*5*
0x7fffffffffffab8	*Unused*	---------------
0x7fffffffffffab0	Return address to sunny	0x40055f
0x7fffffffffffaa8	Saved %rbx	5
0x7fffffffffffaa0	*temp*	2
0x7fffffffffffa98	*Unused*	---------------
0x7fffffffffffa90	Return address to sunny	0x40055f
0x7fffffffffffa88		
0x7fffffffffffa80		
0x7fffffffffffa78		
0x7fffffffffffa70		
0x7fffffffffffa68		
0x7fffffffffffa60		

Problem 4. (4+6 points):

A. Consider an implementation of a processor where the combinational circuit latency is α ns (nanosecond). You are going to pipeline this implementation, and in your system the latency of each pipeline register is β ns. If you are to divide this entire combinational circuit in k stages, what is the throughput of your pipelined implementation? What about the total latency of a single instruction?

New instructions graduate every [(alpha/k) + beta] ns
Throughput = 1/[(alpha/k)+ beta]

Latency = alpha + beta * k

B. Now, assume that the parameters α, β and k described above have the following relation:

$$\beta = \begin{cases} \alpha/10 & \text{if } k \leq 5, \\ \alpha/10 + k/50 \bullet 9\alpha/10 & \text{if } k > 5. \end{cases} \tag{1}$$

Based on the equation above, clearly present an analysis when would you pipeline this processor. Please consider three different values of k in your analysis: (i) k = 5; (ii) k = 50; and (iii) k = 500.

It is best to pipeline when pipeline register latency is (substantially) less than combinatorial latency.

i) Definitely pipeline
ii) may be pipelined. OK to not to pipeline too.
iii) Do not pipeline