CS33: Intro Computer Organization
Fall 2019 Midterm

Name: [redacted]

UID:

IMPORTANT INSTRUCTIONS: You must write your name on both the FRONT AND BACK of the exam. You may do so now. Do not open the exam.

This is an open book, open notes exam, but you cannot share books/notes. Please follow the university guidelines in reporting academic misconduct.

Please wait until everyone has their exam to begin. We will let you know when to start.

Good luck!

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Question 1. C Puzzles (8pts)

You are running the following program on the cs33.seas.ucla.edu machine (ISA is x86-64).

```
// Create some random values
int x = random();
int y = random();
int z = random();
/* convert to other forms */
unsigned ux = (unsigned) x;
unsigned uy = (unsigned) y;
double dx = (double) x;
double dy = (double) y;
double dz = (double) z;
```

x

For each of the following C-puzzles, in the column marked answer, either mark true if the expression always holds (ie. always yields 1), or give a counterexample (eg. TMIN) which breaks the rule.

Expression	Answer ("True" or describe a counterexample)
(x<y) == (-x>-y)	(example) x=Tmin, y=0
ux-uy == -(y-x)	(a) x > 0 y < 0
(x >= 0) || (x < ux)	(b) True
ux & (~(1 << 31)) < 0	(c) ux = 0
~x + ~y + 1 == ~(x+y)	(d) x = 1 y = 1
dx*dy == x*y	(e) False x = T_{max} y = T_{max}
dx*y == x*dy	(f) True
dx+dy+dz == dz+dy+dx	(g) True
((x >> 31) << 31) <= x	(h) True

4

Question 2. Multiple Choice (10pts)

For the following multiple choice questions, select all that apply.

✓ 1. Which of the following registers are guaranteed to have the same value before and after a call instruction in x86-64?

- (a) rax
- [✓ (b) rbx]
- (c) rdi
- [✓ (d) rbp]
- (e) rsp

✓ 2. Which of the following instructions read memory?

- (a) movq %rbx, %rbp
- (b) cvtsi2ssl %rdi,%xmm0
- (c) leaq 4(%rax,%rbx,2), %rcx
- (d) cmov %rbx, %rcx
- [✓ (e) subq %rax, (%rbx)]

✗ 3. Assuming our ISA is x86-64, which of the following operations could we identify as modifying the ***values on*** the program stack?

- (a) call <func>
- (b) addq $8, %rsp
- [✓ (c) movq %rax, (%rbp)]
- (d) movq 20(%rsp), %rax
- (e) pushq %rbp
- [✓ (f) addq %rax, 8(%rsp)]

✓ 4. What hexadecimal bit pattern would be found in memory in an x86-64 machine, for the number negative 33, when the corresponding datatype is an "int" in C?

- (a) `0x80 0x00 0x00 0x33`
- (b) `0x80 0x00 0x00 0x21`
- (c) `0x21 0x00 0x00 0x80`
- (d) `0x33 0x00 0x00 0x80`
- (e) `0xFF 0xFF 0xFF 0x21`
- [✓ (f) `0xDF 0xFF 0xFF 0xFF`]
- ~~(g)~~ `0xFF 0x21`
- (h) `0xDF 0xFF`

E 111 1

4294967263

13

0000 0000 0

0010

2147483615

5. If a,b,c are n-bit signed integers, and c is the result of a+b, under what conditions can we be *guaranteed* that c **is not** the true result under full precision arithmetic?

(a) $a >= 2^{n-2}$ && $b >= 2^{\wedge n-2}$

(b) $a <= -2^{n-2}$ && $b <= -2^{\wedge n-2}$

(c) $a - b > 0$

(d) $a + b > 0$

[✓ (e)] $a > 0$ && $b > 0$ && $c < 0$

[✓ (f)] $a < 0$ && $b < 0$ && $c > 0$

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Question 3. This Bytes (8pts)

For this question, either interpret the value as a bit pattern, or write down the corresponding value. Write impossible

For floating point questions, use the following 8-bit floating point representation based on the IEEE floating point format: $\underbrace{0}\ \underbrace{0000}\ \underbrace{000}$

- There is a sign bit in the most significant bit.
- The next 4 bits are the exponent. The exponent bias is: 2^{4-1}-1=7
- The last 3 bits are the fraction.
- The representation encodes numbers of the form: V = $(-1)^s \times M \times 2^E$, where M is the significand and E is the biased exponent.

bias $2^3 - 1$ exp$-7 = 5$

Bit Pattern	Value Description	
(a) 0000 0000	Negative of smallest possible signed integer (ie. -TMin)	
✓ (b) 0100 000	Largest signed integer that is a power-of-2	
✓ (c) 1 111 1111	TMin + Tmax	
(d) 0 1100 000	Floating Point value: 32	
0 0 1 0 0 0 0 1	✓ (e) 33	(interpret as "char"-sized integer)
1 1 0 1 1 1 1 0 $^{1\,2\,8\,64}$ 0 16 8 4 2	✓ (f) -34	(interpret as "char"-sized integer)
0 0 1 1 1 0 0 0	✓ (g) 1	(interpret as "8-bit float")
1 0 1 1 1 1 1 1	✓ (h) -1.875	(interpret as "8-bit float")

7 - 7

-1. 5
25
125

Question 4. Be the compiler! (6 pts)

Suppose we have the following C code:

```
if(a>b) { a+=b;}
```

Also assume that a and b are "int", **a** is in %eax, **b** is in %ebx. You can use other registers as temporaries.

(a) Write an x86-64 assembly snippet that is equivalent to this statement in C, while making sure to use a jump (aka branch) instruction. Please use a label (.eg L1) as the target of the jump. **(4 pts)**

```
       cmpl      %ebx , -1 %eax
-1     jmpg       .L1
     .L1
        addl      %ebx , %eax
```

(b) Write an x86-64 assembly snippet that is equivalent to this statement in C, while making sure ***NOT*** to use a jump (aka branch) instruction. **(2 pts)**

```
leal  (%ebx, %eax), %ebp
cmpl   %eax ,  %ebx
cmoveg   %ebp , %eax

                 -1
```

Question 5: Interpreting Assembly (6 pts)

For each of the functions in x86-64 assembly below, convert them into a plausible version of the C code.

Assembly of function	Write a plausible C-code for the function

`movq %rdi,%rax`
`salq $4,  %rax`
`addq %rdi,%rax`
`addq %rax,%rax`
`ret`
x·2^4
	long fun(long x) {
	return 2* (x*16 + x);
	}
	3

`movl (%rdi),%edx`
`addl %edx,(%rsi)`
`movl %edx,%eax`
`ret`
	int fun(int x, int y) {
	return x + y;
	}
	0

Question 6: (6 pts)

The C code and assembly is given below for a function, but without values of M and N.

`#define M __`
`#define N __`
 	
`int array1[M][N];`
`int array2[N][M];`
`int copy(int i, int j) {`
`  array1[i][j] = array2[j][i];`
`}`
	`movslq %edi,%rdi`
	`movslq %esi,%rax`
	`lea    (%rax,%rax,4),%rdx`
	`add    %rdi,%rdx`
	`mov    array2(,%rdx,4),%edx`
	`lea    0x0(,%rdi,8),%rsi`
	`sub    %rdi,%rsi`
	`add    %rax,%rsi`
	`mov    %edx,array1(,%rsi,4)`
	`retq`
	5x

What are the values of M and N?

M = 7 x 5

N = 5 x 7

2

5j + i

20j + 4i

28i + 4j

0 + 8i

j + 7i

4

Question 7. ISA Design (4 pts)

In one or two sentences only, why have 32-bit ISAs become less popular for personal computers (laptops/desktops/cell-phones) over the last two decades?

32-bit ISAs have become less popular because we are requiring more memory and thus need a larger address space to store that memory. ISAs are in charge of address space.

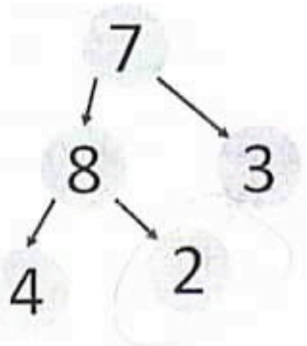
Question 8: Stack Structures (12pts)

Considered an *unordered* tree represented with this struct. The function "smallest" will retrieve the smallest element from the tree.

```
struct node {
  int value;
  struct node* left, *right;
} node;

int smallest(node * n) {
  int temp, ret = n->value;
  if(n->left) {
      temp=smallest(n->left);
      if(temp<ret) ret = temp;
  }
  if(n->right) {
      temp=smallest(n->right);
      if(temp<ret) ret = temp;
  }
  return ret;
}
```

Assume this is the input data-structure stored using node structs:



```
smallest:
0x4004ed <+0>:   push   %rbp
0x4004ee <+1>:   push   %rbx
0x4004ef <+2>:   sub    $0x8,%rsp
0x4004f3 <+6>:   mov    %rdi,%rbp
0x4004f6 <+9>:   mov    (%rdi),%ebx
0x4004f8 <+11>:  mov    0x8(%rdi),%rdi
0x4004fc <+15>:  test   %rdi,%rdi
0x4004ff <+18>:  je     0x40050b <smallest+30>
0x400501 <+20>:  callq  0x4004ed <smallest>
0x400506 <+25>:  cmp    %eax,%ebx
0x400508 <+27>:  cmovg  %eax,%ebx
0x40050b <+30>:  mov    0x10(%rbp),%rdi
0x40050f <+34>:  test   %rdi,%rdi
0x400512 <+37>:  je     0x40051e <smallest+49>
0x400514 <+39>:  callq  0x4004ed <smallest>
0x400519 <+44>:  cmp    %eax,%ebx
0x40051b <+46>:  cmovg  %eax,%ebx
0x40051e <+49>:  mov    %ebx,%eax
0x400520 <+51>:  add    $0x8,%rsp
0x400524 <+55>:  pop    %rbx
0x400525 <+56>:  pop    %rbp
0x400526 <+57>:  retq
```

	Caller Return Address
	old rbp
	old rbx
	400506
	address of node7
	7
	400519
rsp →	

(assume 8 bytes wide!!)

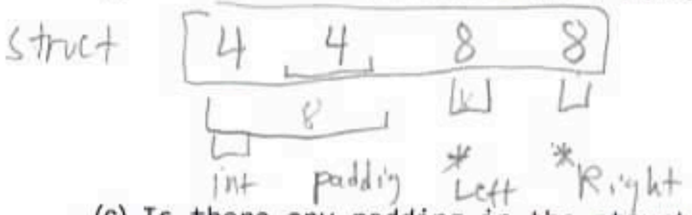
- Assume address is 8 bytes

(note, cmov is conditional move)

draw everything you know

(a) Draw what is on the stack, provided in the space above, when smallest(2) is entered (ie. when it is called, and just before the instruction at 0x4004ed is executed) . Assume the root of the pictured tree is the input.
Note: If you don't know what a register value is, just mark it as "old rbp" etc. If you know what a register value is, write the corresponding value. **(6pts)**

(b) What is the size of the node struct? **(2pts)**



24 bytes

(c) Is there any padding in the struct "node" due to alignment rules? **(1pts)**

Yes there is 4 bytes of padding

(d) Can you rearrange the elements of "node" to reduce its size? **(1pts)**

~~No~~ No There will always be a 4 byte padding

(e) Which of the following are possible starting addresses for a node: **(2pts)**

(i) 0x7ffe4d3be87c
(ii) 0x7ffe4d3be874
(iii) 0x000444444440
[✓ (iv)] 0xfffff1234568

-0.5

Question 9 (Bonus): Your points overfloweth! (5pts)

Consider the following code (a variation on a hopefully-familiar example).

```
#include <stdio.h>
#include <stdlib.h>

typedef struct {
  int a[2];
  double d;
} struct_t;

double fun(int i, int j) {
  volatile struct_t s;
  s.d = 12345.0;
  s.a[i] = j;
  return s.d;
}
```

(-2 4420

What input arguments to function "fun" would return the value 33.0?

$\boxed{i = 0 \quad j = 0\times 80404}$
= 525316
4

double precision → k = 11

Bias = 1023

0

convert 12345 → binary point

$2^{13} \cdot 1.1000\ 0001\ 1100\ 1$

0

find the exp → 13 = exp - 1023   exp = 1036

so 12345 → 0 1000 000 1100 1 000 0001 1100 1

One int → 4 bytes → 32 bits → more than enough to cover 12345 → 24bits

convert 33 into binary point

Read 33 float into int

~~01~~ 0 4 0 8 → $\boxed{0\times 80408}$

33 → float exp = 1028

E = exp - bias

E = 5   M = 0000 1   1023 + 5 = exp

exp = 1036

exp   frac →

12345 d → 0 1000 0001 1001 0000 0011 1001 000

4 0 4 0 8

33 d → 10 1 001 0000 0100 0000 1000

Question 10 (bonus): (5pts)

The following is a student's submission from a previous year's question on the datalab.

```
int function(int x) {
    int m1 = 0x11 | (0x11 << 8);
    int mask = m1 | (m1 << 16);
    int s = x & mask;
    s += x>>1 & mask;
    s += x>>2 & mask;
    s += x>>3 & mask;
    s = s + (s >> 16);
    mask = 0xF | (0xF << 8);
    s = (s & mask) + ((s >> 4) & mask);
    return (s + (s>>8)) & 0x3F;
}
```

0001 0001

0001 0001 0001 0001

1011

1

3

1111 1111

11 1111

What does this function do?

This function checks the amount of bits of a 32-bit integer that are 1s

essentially it is a 1 bit counter

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Back of Exam

Name: [redacted]

UID:

	Score	Points Possible
1	6	8
2	4	10
3	6	8
4	3	6
5	5	6
6	2	6
7	4	4
8	11.5	12
9 (ec)	0	5
10 (ec)	5	5
Total	46.5	60 +10ec