CS33: Intro Computer Organization
Fall 2019 Midterm
ANSWER SHEET

Name: _____

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!

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;
```

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) True
(x >= 0) || (x < ux)	(b) False (eg. x = -1. Comparison x < ux is never true.)
ux & (~(1 << 31)) < 0	(c) False (any number)
~x + ~y + 1 == ~(x+y)	(d) True ((-x-1)+(-y-1)+1 == -(x+y)-1)
dx*dy == x*y	(e) False (eg. 50000 * 50000, or any case that overflows ints)
dx*y == x*dy	(f) True (because you convert to double before comparison)
dx+dy+dz == dz+dy+dx	(g) True (because ints are perfectly representable in doubles)
((x >> 31) << 31) <= x	(h) True (clear positive bits only)

(who graded: Tony)

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 B was ignored.If you marked the other 3, regardless of B, it was correct.
(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`

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 **<u>is not</u>** 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

Question 3. This Bytes (8pts)

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

For floating point questions, use the following 8-bit floating point representation based on the IEEE floating point format:

- 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.

Bit Pattern	Value Description
(a) 1 0 0 0 0 0 0 0 Any other representation of a 1 in the MSB followed by all 0's is accepted (2^{31}, 2^7, Tmin, -2147483648) Impossible is also acceptable	Negative of smallest possible signed integer (ie. -TMin)
(b) 0 1 0 0 0 0 0 0 Any other representation of a 1 in the second most significant bit followed by all 0's is accepted (2^{30}, 2^6)	Largest signed integer that is a power-of-2
(c) 1 1 1 1 1 1 1 1 Also accept the answer -1	TMin + Tmax
(d) 0 1 1 0 0 0 0 0	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	(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) $-1\frac{7}{8}$ (interpret as "8-bit float")

If it is not possible to convert between a value and it's bit pattern, mark not possible.

We also accepted answers with different bit widths.

Any answers in this color were marked incorrect but can be given credit (you may give to any TA for regrade).
(who graded:Tyler)

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)**

```
// several accepted solutions, most concise:

cmp %ebx, %eax
jle .L1             // if a < or = to b: skip add
add %ebx, %eax
.L1
```

(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)**

```
// several accepted solutions, most concise:

movslq %eax, %rdi      // %rdi = a
add    %ebx, %rdi      // %rdi = a + b
cmp    %ebx, %eax
cmovg  %rdi, %rax      // if a > b: a = a + b
```

(who graded: Yugo)

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`
	`long fun(  long x  )`
	`{`
	`  return 34*x;`
	`}`

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

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
```

What are the values of M and N?

M = 5

N = 7

(who graded: Mathanky)

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 only support an address space size of 2^32-bits (4GB), limiting the effective memory size to about that much. Modern applications can benefit from much more.

Anything related to total storage size usually got 4 pts, unless it was too vague. I generally gave 2 pts for articulating benefits of natively larger datatypes. I gave 1 pt for backwards compatibility.

(who graded: Tony)

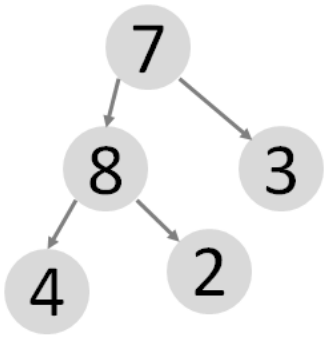
Question 8: Stack Structures (12pts)

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
```

(note, cmov is conditional move)

Caller Return Address
Old rpb
Old rbx
unused
0x400506
Address of node 7 (rbp)
7 (rbx)
unused
0x400519

(assume 8 bytes wide!!)

(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

value (4 byte)	padding (4 byte)	left (8 byte)	right (8 byte)

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

Yes

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

No

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

(i) **0x7ffe4d3be87c**
(ii) **0x7ffe4d3be874**
(iii) **0x000444444440**
(iv) **0xfffff1234568**

Possible starting addresses: (iii) and (iv)

(who graded: Atefeh)

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;
}
```

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

Rubrics:
i=3; 2 points
j=0x40408000; 3 points
Also accept j=0x00804040
(who graded: Minhao)

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;
}
```

What does this function do?

Counts number of ones in integer

(who graded: Minhao)

Back of Exam

Name: _____

UID: _____

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