CS33: Intro Computer Organization
Midterm, Form: A

Name: _____

ID: _____

This is an open book exam, with 1 page of notes allowed, but you cannot share books/notes. Please follow the university guidelines in reporting academic misconduct.

Note that there is an ASCII Table at the end of this exam. You will need it at some point.

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

Problem	Score	Points Possible
1		24
2		9
3		16
4		12
5		24
6		20
7		15
Total		100

Question 1. The bits are a lie. (24, 4 pts each)

You see the following bytes in increasing addresses on your x86-64 based laptop.

Table 1: My caption

Address	0xA0	0xA1	0xA2	0xA3	0xA4	0xA5	0xA6	0xA7	0xA8
Data	0x49	0x3C	0x33	0x63	0x73	0x33	0x33	0x00	0xFE

Interpret this data as different data types. You can write numbers using hexadecimal, and floating point numbers using hexadecimal + equations. Please don't convert to decimal.

Always assume the data type starts at 0xA0. (does not need to use all bytes)

1. `int` _____

2. Say we have the definition:
   `struct S1 {char a; short b; int c; char d;} instance;`.

   Say instance starts at 0xA0, interpret as `instance.d` as a char. _____

3. `unsigned short` _____

4. `float` _____

5. C string (ie, dereference a char*) _____

6. The first byte as a set of numbers. _____

Question 2. ISA Madness (9 pts)

1. Is the procedure calling convention specified by the instruction set architecture? (3 points)

2. Is the size of the address space determined by the instruction set architecture? (3 points)

3. Which part of x86-64 annoys you the most? (3 points)

Question 3. Hey, I've seen these before! (16, 4 pts each)

Match the following datalab implementations to their descriptions.

```
int func1(int x, int y) {
  return !!(x ^ y);
}
int func2(int x) {
  return !(x >> 31);
}
int func3(int x, int y) {
  return (~x) & (~y);
}

int func4(int x, int n) {
  return 0xff & (x >> (n << 3));
}

int func5(int x) {
 int wd16 = x ^ x>>16;
 int wd8 = wd16 ^ wd16>>8;
 int wd4 = wd8 ^ wd8>>4;
 int wd2 = wd4 ^ wd4>>2;
 int bit = (wd2 ^ wd2>>1) & 0x1;
 return bit;
}

int func6(int x) {
  int test = x >> 31;
  return (~test & x) | (test & (~x + 1));
}

int func7(int x) {
  int m8 = 0xAA;
  int m16 = m8 | m8 << 8;
  int m32 = m16 | m16 <<16;
  int fillx = x | m32;
  return !~fillx;
}
```

1. Return true if two numbers are not equal. _____
2. Return true if all even bits of a number are set. _____
3. Return true of a number is not negative. _____
4. Get a particular byte out of an integer. _____

Question 4. Addressing an Array (12 points)

Consider the following array declaration.

```
int *my_array[4][3];
```

1. If we do nothing else, will the program segfault if we access element [3][2]? (4 points)

2. Write a mathematical expression for accessing element [x][y] for this array. (4 poitns)

3. Can the above access be performed using one x86-64 mov instruction? (4 points)

Question 5. Stack of Lists (24)

The following is a program which constructs a linked list, and multiplies a value stored in each node together.

```
typedef struct S{ //Defining the linked list node
  unsigned val;
  struct S* next;
} X;

int mult(X* x, int y) { // Do a multiply
  return x->val * y;
}

int follow(X* x, int y) { // iterate over the linked list
   while(x) {
     y=mult(x,y);
     x = x->next;
   }
   return y;
}

X s1, s2, s3; //items in the linked list, of type X.

void setup_list() {
  s1.val = 1; //set up the linked list
  s2.val = 2;
  s3.val = 3;
  s1.next=&s2;
  s2.next=&s3;
  //Oops, should have set s3.next to 0
}

int main(int argc, char** argv) {
  setup_list();
  printf("%d\n",follow(&s1, 1));
}
```

1. What is the size of the struct X in bytes? (3 points)

2. What is type of the expression: x->val * y (3 points)

3. This code was supposed to print the value 6, but instead it segfaults (it crashes) because the last pointer of the list was not set to NULL. Looking at the assembly on the next page, what is the address of the instruction that the program segfaults on? (4 points)

4. In the box, draw the stack at the moment the program segfaults. The top of the page should have higher addresses; please indicate which values belong to which function. If you do not know a register's value that is pushed to the stack, write "old" register (eg. old rax). (10 points)

```
0000000000400546 <mult>:
 400546: 89 f0           mov    %esi,%eax
 400548: 0f af 07        imul   (%rdi),%eax
 40054b: c3              retq

000000000040054c <follow>:
 40054c: 53              push   %rbx
 40054d: 48 89 fb        mov    %rdi,%rbx
 400550: 89 f0           mov    %esi,%eax
 400552: eb 0e           jmp    400562 <follow+0x16>
 400554: 89 c6           mov    %eax,%esi
 400556: 48 89 df        mov    %rbx,%rdi
 400559: e8 e8 ff ff ff  callq  400546 <mult>
 40055e: 48 8b 5b 08     mov    0x8(%rbx),%rbx
 400562: 48 85 db        test   %rbx,%rbx
 400565: 75 ed           jne    400554 <follow+0x8>
 400567: 5b              pop    %rbx
 400568: c3              retq

000000000040059e <main>:
 40059e: 48 83 ec 08     sub    $0x8,%rsp
 4005a2: b8 00 00 00 00  mov    $0x0,%eax
 4005a7: e8 bd ff ff ff  callq  400569 <setup_list>
 4005ac: be 01 00 00 00  mov    $0x1,%esi
 4005b1: bf 60 10 60 00  mov    $0x601060,%edi
 4005b6: e8 91 ff ff ff  callq  40054c <follow>
 ...
```

List the address of any conditional branch. (4 points)

Question 6. Double recursion all the way ... across the sky! (20 pts)

Dump of assembler code for function func(unsigned int m, unsigned int n)

```
0x0000000000400546 <+0>:     test   %edi,%edi
0x0000000000400548 <+2>:     jne    0x40054e <func+8>
0x000000000040054a <+4>:     lea    0x1(%rsi),%eax
0x000000000040054d <+7>:     retq
0x000000000040054e <+8>:     push   %rbx
0x000000000040054f <+9>:     mov    %edi,%ebx
0x0000000000400551 <+11>:    test   %esi,%esi
0x0000000000400553 <+13>:    jne    0x400564 <func+30>
0x0000000000400555 <+15>:    lea    -0x1(%rdi),%edi
0x0000000000400558 <+18>:    mov    $0x1,%esi
0x000000000040055d <+23>:    callq  0x400546 <func>
0x0000000000400562 <+28>:    jmp    0x400576 <func+48>
0x0000000000400564 <+30>:    sub    $0x1,%esi
0x0000000000400567 <+33>:    callq  0x400546 <func>
0x000000000040056c <+38>:    lea    -0x1(%rbx),%edi
0x000000000040056f <+41>:    mov    %eax,%esi
0x0000000000400571 <+43>:    callq  0x400546 <func>
0x0000000000400576 <+48>:    pop    %rbx
0x0000000000400577 <+49>:    retq
```

1. Fill in the blanks in the function based on the assembly code. (18 Points)

```
unsigned int func(unsigned int m, unsigned int n)
{

    if(_____) {

      _____
    }

    if(_____) {

      _____
    }

    return _____(_____,_____(_____,_____));
}
```

2. How many instructions read a data value from memory? (2 points)

Question 7. The Digit Lock Bomb (15 pts)

The final question of the midterm, "I'm almost home free!" you think to yourself. After finishing the Bomblab at 11:59 last night, and then studying until 4:00am, you thought your troubles were just about to be over. However, as you skim over the last question, you realize you couldn't have been more wrong. Luckily, the evil professor left one helpful comment in the assembly...

Solve the final Bomblab phase.

The following is `void phase_8(char*)`:

```
0x00000000004007ac <+0>:    mov    $0x0,%edx
0x00000000004007b1 <+5>:    mov    $0x0,%ecx
0x00000000004007b6 <+10>:   jmp    0x4007f3 <phase_8+71>
0x00000000004007b8 <+12>:   movslq %edx,%rax
0x00000000004007bb <+15>:   movzbl (%rdi,%rax,1),%eax  //get ith char of input
0x00000000004007bf <+19>:   sub    $0x30,%eax          //convert ascii to int
0x00000000004007c2 <+22>:   cmp    $0x6,%al
0x00000000004007c4 <+24>:   ja     0x4007f0 <phase_8+68>
0x00000000004007c6 <+26>:   movzbl %al,%eax
0x00000000004007c9 <+29>:   jmpq   *0x4008f8(,%rax,8)
0x00000000004007d0 <+36>:   or     $0x1,%ecx
0x00000000004007d3 <+39>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007d5 <+41>:   or     $0x2,%ecx
0x00000000004007d8 <+44>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007da <+46>:   or     $0x4,%ecx
0x00000000004007dd <+49>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007df <+51>:   or     $0x8,%ecx
0x00000000004007e2 <+54>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007e4 <+56>:   or     $0x10,%ecx
0x00000000004007e7 <+59>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007e9 <+61>:   or     $0x20,%ecx
0x00000000004007ec <+64>:   jmp    0x4007f0 <phase_8+68>
0x00000000004007ee <+66>:   add    %ecx,%ecx
0x00000000004007f0 <+68>:   add    $0x1,%edx
0x00000000004007f3 <+71>:   cmp    $0x2,%edx
0x00000000004007f6 <+74>:   jle    0x4007b8 <phase_8+12>
0x00000000004007f8 <+76>:   sub    $0x8,%rsp
0x00000000004007fc <+80>:   cmp    $0x21,%cl
0x00000000004007ff <+83>:   jne    0x40080b <phase_8+95>
0x0000000000400801 <+85>:   mov    $0x0,%eax
0x0000000000400806 <+90>:   callq  0x400746 <phase_defused>
0x000000000040080b <+95>:   test   %cl,%cl
0x000000000040080d <+97>:   jns    0x400819 <phase_8+109>
0x000000000040080f <+99>:   mov    $0x0,%eax
0x0000000000400814 <+104>:  callq  0x400768 <secret_phase>
0x0000000000400819 <+109>:  mov    $0x0,%eax
0x000000000040081e <+114>:  callq  0x40078a <explode_bomb>
```

Also, you might need this: (gx just means print out "giant" 8 byte words)

```
(gdb) x/7gx 0x4008f8
0x4008f8:       0x00000000004007d0      0x00000000004007d5
0x400908:       0x00000000004007da      0x00000000004007df
0x400918:       0x00000000004007e4      0x00000000004007e9
0x400928:       0x00000000004007ee
```

1. What does the jmpq* instruction do, and what program control feature does it sometimes correspond to? (5 Points)

2. What input string would defuse the bomb? (5 Points)

3. What input string would activate the secret phase? (5 Points)

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

1.