

bCS33: Intro Computer Organization
Winter 2019

Name: _____

UID: _____

IMPORTANT INSTRUCTIONS: You must write your name on the back page of the exam (And above). 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.

Note that there is an ASCII Table at the end of this exam. You will need it at some point. Do NOT detach the ASCII table.

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

Good luck!

1) GDB Lies (10, 1pt each)

Suppose we debug the following program (assignments omitted), and break at the printf:

```
void main(int argc, char* argv) {  
    int i=...  
    unsigned u=...  
    float f=...  
    double d=...  
    printf("...",...)  
}
```

List any outputs from gdb that *must* have been tampered with. (ie. if it might not have been tampered with, then don't list it) For example, the output of the first command has been tampered with, because the return value is not expected:

```
(gdb) print sizeof(double)  
$0 = 37
```

```
(gdb) print sizeof(short)  
$1 = 2
```

```
(gdb) print sizeof(0)  
$2 = 4
```

```
(gdb) print (unsigned) -1 > 1  
$3 = 0
```

```
(gdb) print 0 - 1  
$4 = -1
```

```
(gdb) print 1U - 2  
$5 = 4294967295
```

```
(gdb) p (int)(float)i == i  
$6 = 1
```

```
(gdb) p (int)(double)i == i  
$7 = 0
```

```
(gdb) p (unsigned)(int) u == u  
$8 = 0
```

```
(gdb) p/f 0xC2040000  
$9 = 33
```

```
(gdb) p/x (int)3.14159  
$10 = 0x40490fd0
```

List GDB Outputs Tampered With: \$0,_____ .

2) One of a kind! (10, 1 pt each)

A. For each instruction below, write *one* alternate instruction which performs the same operation. The alternate should not use the same instruction type (known as an opcode). It is acceptable if the flags do not match.

1. `leaq (%rbx, %rbp), %rbp` _____

2. `leaq (, %rdi, 2), %rdi` _____

3. `mov %rax, %rax` _____

4. `add $0, %eax` _____

5. `xor %rbx, %rbx` _____

6. `cltq` _____

B. Rewrite the following with *one* instruction:

(assume x is in %rax, y is in %rbx, array a (declared as `int a[256]`) is in address in %rcx, and that array b (declared as `char b[100][4]`) is at address 0x100.

7. `x = (x < 0) ? -1 : 0` _____

8. `x = x+2*y+17` _____

9. `a[x]++` _____

10. `x = b[x][y]` _____

3) Bitwise Number Classification (10 pts, 2 pts each)

Match the following datalab implementations to their descriptions.

```
int func1(int x) {  
    return (x>>31) & 0x1;  
}
```

```
int func2(int x) {  
    return (!!x) & (!(x+x));  
}
```

```
int func3(int x) {  
    return !x;  
}
```

```
int func4(int x) {  
    int nx = ~x;  
    int nxnz = !!nx;  
    int nxovf = !(nx+nx);  
    return nxnz & nxovf;  
}
```

```
int func5(int x) {  
    int minus_x = ~x+1;  
    return ((minus_x|x) >> 31) & 1;  
}
```

1. isTmin: Returns 1 if $x == T_{min}$, 0 otherwise _____
2. isTmax: Returns 1 if $x == T_{max}$, 0 otherwise _____
3. isNegative: Returns 1 if $x < 0$, 0 otherwise _____
4. isNonZero: Returns 1 if $x \neq 0$, 0 otherwise _____
5. isZero: Returns 1 if $x == 0$, and 0 otherwise _____

Q4) Array of hope (10 pts). Consider the following code on the left, and answer the questions on the right:

```
typedef struct {
    char g ;
    short n[10];
    int o;
    double w;
    float r;
} struct_elem;

typedef union {
    char g;
    short n[10];
    int o;
    double w;
    float r;
} union_elem;

struct_elem struct_array[10];
union_elem union_array[10];

___ get_val(int x, int y) {
    ...
}

int main(int argc, char** argv) {
    int a[16][16];
    printf("%ld\n", sizeof(struct_elem));
    printf("%ld\n", sizeof(union_array));
    union_array[0].o=0x42040000;
    printf("%f\n", union_array[0].r);
}
```

1. What is printed? **(2 pts each, 6 pts total)**

2. Notice that `get_val` is missing a definition. The following is the disassembly from gdb:

Dump of assembler code for function `get_val`:

```
0x00000066a <+0>:    movslq %esi,%rsi
0x00000066d <+3>:    movslq %edi,%rdi
0x000000670 <+6>:    lea    (%rdi,%rdi,2),%rax
0x000000674 <+10>:   lea    (%rsi,%rax,8),%rdx
0x000000678 <+14>:   lea    0x2009c1(%rip),%rax
0x00000067f <+21>:   movzwl 0x2(%rax,%rdx,2),%eax
0x000000684 <+26>:   retq
```

What is the definition of `get_val`? **(3pts)**

(Hint: `0x2009c1(%rip)` is the address of either `struct_array` or `union_array`)

```
___ get_val(int x, int y) {
```

```
}
```

3. Which of the following orders minimizes the size of the struct? **(1pts)**

- a. g r o w n
- b. n w o r g
- c. w r o n g

5) Mutually assured instruction. (10 pts)

a) First, deduce the following functions. (4pts)

```
0000000000000064a <func1>:
64a: 48 83 ec 18      sub    $0x18,%rsp
64e: 89 7c 24 0c      mov    %edi,0xc(%rsp)
652: 83 7c 24 0c 00    cmpl   $0x0,0xc(%rsp)
657: 75 07            jne     660 <func1+0x16>
659: b8 01 00 00 00    mov    $0x1,%eax
65e: eb 0e            jmp     66e <func1+0x24>
660: 8b 44 24 0c      mov    0xc(%rsp),%eax
664: 83 e8 01          sub    $0x1,%eax
667: 89 c7            mov    %eax,%edi
669: e8 05 00 00 00    callq  673 <func2>
66e: 48 83 c4 18      add    $0x18,%rsp
672: c3              retq
```

```
00000000000000673 <func2>:
673: 48 83 ec 18      sub    $0x18,%rsp
677: 89 7c 24 0c      mov    %edi,0xc(%rsp)
67b: 83 7c 24 0c 00    cmpl   $0x0,0xc(%rsp)
680: 75 07            jne     689 <func2+0x16>
682: b8 00 00 00 00    mov    $0x0,%eax
687: eb 0e            jmp     697 <func2+0x24>
689: 8b 44 24 0c      mov    0xc(%rsp),%eax
68d: 83 e8 01          sub    $0x1,%eax
690: 89 c7            mov    %eax,%edi
692: e8 b3 ff ff ff    callq  64a <func1>
697: 48 83 c4 18      add    $0x18,%rsp
69b: c3              retq
```

```
int func1(unsigned int n)
{
    if ( _____ )
        _____;
    else
        _____;
}
```

```
int func2(unsigned int n)
{
    if ( _____ )
        _____;
    else
        _____;
}
```

b) Suppose we call func1(4), what is the return value? (1pt)

[problem continued on the next page]

Q6) Hex marks the spot (10 pts): As you finally navigate your way to the last problem of the exam, still reeling from the maze of increasingly difficult challenges you have solved to get here, you look down to see what you feared the most: your bomb is still active! Either find your way and deactivate the bomb, or risk exploding the entire class. **Solve the final bomblab phase:**

phase_8:

```

0x6d8 <+0>: sub    $0x8,%rsp
0x6dc <+4>: mov     $0x1,%esi
0x6e1 <+9>: mov     $0x1,%ecx
0x6e6 <+14>: mov     $0x0,%eax
0x6eb <+19>: jmp     0x715 <phase_8+61>
0x6ed <+21>: sub     $0x1,%esi
0x6f0 <+24>: mov     %ecx,%eax
0x6f2 <+26>: mov     %esi,%edx
0x6f4 <+28>: lea     0x200925(%rip),%r8          # 0x201020 <map>
0x6fb <+35>: lea     (%r8,%rdx,8),%rdx          rdx = rdx*8 + map
0x6ff <+39>: movzbl  (%rdx,%rax,1),%edx          %dex = map[rdx * 8 + rax]
0x703 <+43>: cmp     $0xff,%dl
0x706 <+46>: je      0x748 <phase_8+112>
0x708 <+48>: cmp     $0x3,%dl
0x70b <+51>: je      0x752 <phase_8+122>
0x70d <+53>: mov     %r9d,%eax
0x710 <+56>: cmp     $0x21,%dl
0x713 <+59>: je      0x75c <phase_8+132>
0x715 <+61>: lea     0x1(%rax),%r9d
0x719 <+65>: cltq
0x71b <+67>: movzbl  (%rdi,%rax,1),%eax
0x71f <+71>: cmp     $0x77,%al
0x721 <+73>: je      0x6ed <phase_8+21>
0x723 <+75>: cmp     $0x61,%al
0x725 <+77>: je      0x734 <phase_8+92>
0x727 <+79>: cmp     $0x73,%al
0x729 <+81>: je      0x739 <phase_8+97>
0x72b <+83>: cmp     $0x64,%al
0x72d <+85>: jne     0x73e <phase_8+102>
0x72f <+87>: add     $0x1,%ecx
0x732 <+90>: jmp     0x6f0 <phase_8+24>
0x734 <+92>: sub     $0x1,%ecx
0x737 <+95>: jmp     0x6f0 <phase_8+24>
0x739 <+97>: add     $0x1,%esi
0x73c <+100>: jmp     0x6f0 <phase_8+24>
0x73e <+102>: mov     $0x0,%eax
0x743 <+107>: callq   0x6a4 <explode_bomb>
0x748 <+112>: mov     $0x0,%eax
0x74d <+117>: callq   0x6a4 <explode_bomb>
0x752 <+122>: mov     $0x0,%eax
0x757 <+127>: callq   0x68a <phase_defused>
0x75c <+132>: mov     $0x0,%eax
0x761 <+137>: callq   0x6be <s3cret_phase>

```


Possibly helpful GDB interaction: (x/64bx just means print 64 bytes of memory in hex format)

```
(gdb) x/64bx map
0x201020 <map>:      0xff  0xff  0x00  0x00  0x00  0xff  0x00  0xff
0x201028 <map+8>:    0xff  0x00  0xff  0x00  0xff  0x00  0xff  0xff
0x201030 <map+16>:   0xff  0x00  0x00  0xff  0xff  0x00  0xff  0x00
0x201038 <map+24>:   0xff  0xff  0x00  0x00  0x03  0xff  0x00  0x00
0x201040 <map+32>:   0xff  0x00  0x00  0xff  0xff  0x00  0xff  0xff
0x201048 <map+40>:   0xff  0x00  0xff  0xff  0x00  0x00  0xff  0xff
0x201050 <map+48>:   0xff  0x00  0x00  0x00  0x00  0xff  0x00  0xff
0x201058 <map+56>:   0xff  0xff  0xfe  0xff  0xff  0xff  0x21  0xff
(gdb) x/16bx unimportant_array
0x201060 <unimportant_array>:  0x00  0x00  0x00  0x00  0x00  0x00  0x00  0x00  0x00  0x00
0x201068 <unimportant_array+8>: 0x00  0x00  0x00  0x00  0x00  0x00  0x00  0x00
```

1. What string will defuse the bomb? (7 pts)
2. What string will activate the secret phase? (3 pts)

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]

Back of Exam

Name: _____

UID: _____

	Score	Points Possible
1		10
2		10
3		10
4		10
5		10
6		10
Total		50 +10ec