CS33: Intro Computer Organization
Midterm, Form: $\boxed{A}$ 29

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Please wait until everyone has their exam to begin. We will let you [redacted]ow when to start. Good luck!

Problem	Score	Points Possible
1	15	18
2	8	8
3	3	12
4	20	20
5	15	15
6	3	0
7	14	17
8	20	10
	98	

Question 1. The bigger the better. (18, 3 pts each) 15

$n=4$

$0111=7$

1. Consider an n-bit signed number, what's the largest one? $2^{n-1}-1$
2. In C, what's the largest `int` plus one? TMin
3. Which can represent the largest number in C, the largest `float` or the largest `signed long` or largest `unisgned int`? float
4. Which integer type in C is large enough to store a pointer without loss of precision? long
5. What is the largest number that can be represented by a 7 bit floating point number (say with the same rules as IEEE 754 floating point), with a 1 bit sign, 3 bit exponent, and 3 bit significand (bias=3)? $(2-\varepsilon)\times 2^3$ X — Value?
6. In C, what's the smallest `unsigned int` minus one? UMax

$\underset{S}{0}$ 1 1 0 1 1 1

Exp frac

$Bias = 2^2-1 = 3$

$E: \cancel{6}-3 = \underline{3}$

$M = (2-\varepsilon)$

Question 2. Matchmaker (8 Pts, 1 pts each)

8

Pretend to be a compiler.
You are free to assign registers to variables however you choose. Assume x and y are of type int.
Remember, the compiler(me) may have done some optimizations.

h	x=(x < 0) ? -1 : 0	(a) `addl %edi %edi`
c	x=x*3+5	(b) `xorl %edi %edi`
f	x=x*32	(c) `leaq 5(%edi,%edi,2)`
b	x=0	(d) `imul %edi %edx`
e	x=1	(e) `movl $1 %eax`
g	x=x*5+3	(f) `shl $ 5 %edi`
d	x=x*y	(g) `leaq 3(%edi,%edi,4)` edi + 4xdi
a	y=x+y	(h) `shr $ 31 %edi`

Question 3. Unholy Union ~~(9~~ 12 pts)

3

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

void main(char** argv, int argc) {
  union U {
    char s[16];
    int i;
    char c;
  } u;

  strcpy(u.s,"evil_prof"); //Copy string to destination from source

  printf("%x\n", u.c);
  printf("%x\n", u.i);
}
```

x86-64

l= 6C
i= 69
v= 76
e= 65

0x6C697665

␣: 20
p: 70
r= 72
o= 6F
f: 66

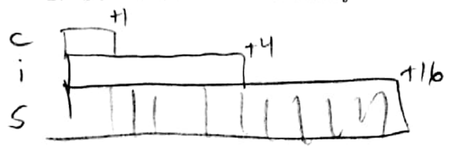
1. What does this program print? (6 pts)

~~6~~5 76 69 6c 20 70 72 6f 66

~~x6c69 76 65~~

2. To which addresses may this union be aligned? (3pts)

X



alignd @ starting addrss of i, c, s, or s[0]

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Question 4. Deconstructed (20 pts, 5 Each)

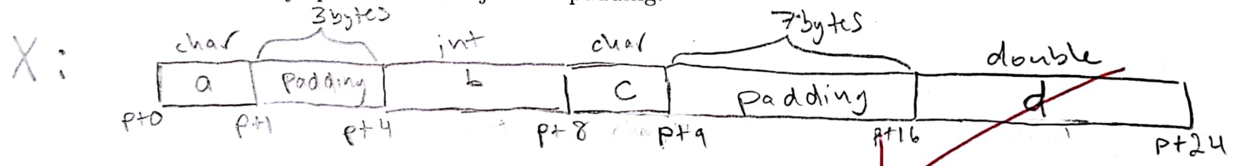
```
#include <stdio.h>

typedef struct {
   char a;
   int b;
   char c;
   double d;
} X;

void main(char** argv, int argc) {
   X x[10];
   printf("%d\n",(int)sizeof(X));
   printf("%d\n",(int)sizeof(x));
}
```

1. What does this program print?

   24
   240

   ✓

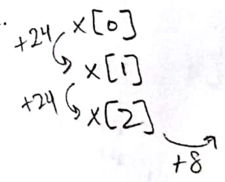
2. Draw the memory layout of X, where your diagram indicates which byte offset each variable is located at, as well as any space allocated just for padding:



3. Write an assembly snippet that performs x[10].c=0. Assume that x is in register $rdi.

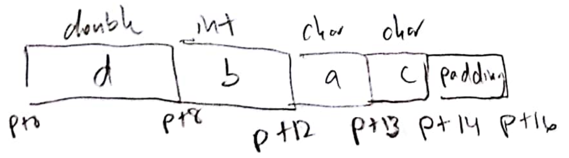
   movb $0 , 248($rdi)

   ✓



4. Describe how you would reduce the memory consumption of x. How small can you make x?

   Reduce by re-ordering variables in struct, try putting largest data type (double) first.



~~Declaring as~~ :
```
typedef struct {
    double d;
    int b;
    char a;
    char c;
} X;
```

Results in size of 16 bytes

Question 5. I can puzzle, (15 Pts, 2 pts each)

Answer these true false puzzles. Assume the following setup:

```
int x = foo();
int y = bar();
unsigned ux = x;
unsigned uy = y;
```

✓ T -x == ~x+1

✓ F x > 0 && y > 0 ⟹ x + y > 0

✓ F 5*ux > ux

✓ F x < 100 ⟹ 10*ux > ux

✓ F x >> 2 == x / 4 $-7 \quad 1001 \gg 2 \quad 1110 = -2 \neq \frac{-7}{4} = -1$

Question 6. ... and so can you! (Up to 4 pts Extra Credit)

1. Write a C Puzzle of the form above, give the solution, and explain why you think its cool.

Let
int x = rand();
float f = foo();

+3

((float)x + f) - f == (float) x ?

No

As discussed in lecture, sometimes precision may be loss when dealing with floats. It's interesting to think about because normally algebraically, these statements appear equivalent

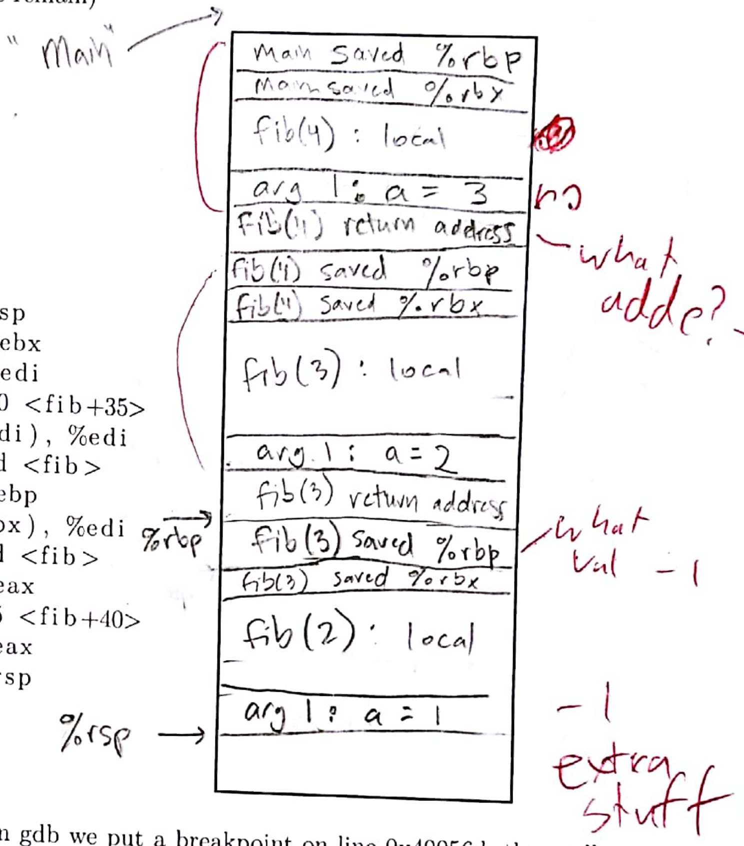
Question 7. Your fibs are stacking up (16 Pts)

Recall the fibbonacci code that we discussed in class, and its associated disassembly: (the instruction addresses are omitted for simplicity, just the offsets remain)

```
int fib(int a) {
  if(a < 2) {
    return 1;
  }
  return fib(a-1) + fib(a-2);
}
```

+8

```
fib: 0x40055d <+0>:  push  %rbp
     0x40055e <+1>:  push  %rbx
     0x40055f <+2>:  sub   $0x8,%rsp
     0x400563 <+6>:  mov   %edi, %ebx
     0x400565 <+8>:  cmp   $0x1, %edi
     0x400568 <+11>: jle   0x400580 <fib+35>
     0x40056a <+13>: lea   -0x1(%rdi), %edi
  →  0x40056d <+16>: callq 0x40055d <fib>
     0x400572 <+21>: mov   %eax, %ebp
     0x400574 <+23>: lea   -0x2(%rbx), %edi
     0x400577 <+26>: callq 0x40055d <fib>
     0x40057c <+31>: add   %ebp, %eax
     0x40057e <+33>: jmp   0x400585 <fib+40>
     0x400580 <+35>: mov   $0x1, %eax
     0x400585 <+40>: add   $0x8, %rsp
     0x400589 <+44>: pop   %rbx
     0x40058a <+45>: pop   %rbp
     0x40058b <+46>: retq
```



1. This function calls itself recursively. Imagine in gdb we put a breakpoint on line 0x40056d, then call fib(4). Furthermore we hit continue two more times in gdb, so that the stack frames of fib(4), fib(3), and fib(2) are all on the stack. Draw the contents of the stack in the box above, and be sure to indicate the stack pointer. Draw everything you know about the stack! If you know what the value is, write the value, otherwise indicate what it is. (10 pts)

+6

2. On which line(s) (specify as offset from fib please!) is/are callee saved registers being saved? (1pt) <+0>, <+1>
3. On which line(s) is/are callee saved registers being restored? (1pt) <+44>, <+45>
4. On which line(s) is/are the input argument to fib being set? (1pt) <+13>, <+23>
5. On which line(s) is/are the return value from fib being set (for the final time)? (1pt) <+31>, <+35>
6. On which line(s) is/are the stack being allocated? (1pt) <+2>
7. On which line(s) is/are the stack being de-allocated? (1pt) <+40>

Question 8. Oh Fuuuudge (10 pts)

You just finished your CS32 homework when all of a sudden you "`rm -f my_homework.c`". Thankfully, you didn't delete your binary file – phew. You forgot all the expressions in your source code, but you kind of remembered the overall structure. It's time to analyze the binary to fill out the remaining expressions.

```
<+0>:  mov     $0x1 ,  %r9d
<+6>:  jmp     <func+54>
<+8>:  movslq  %r9d ,  %rax
<+11>: mov     (%rdi , %rax , 4) ,   %r8d
<+15>: lea     -0x1(%r9) ,   %eax
<+19>: jmp     <func+28>
<+21>: mov     %edx ,   0x4(%rdi , %rcx , 4)
<+25>: sub     $0x1 ,  %eax
<+28>: test    %eax ,  %eax
<+30>: js      <func+43>
<+32>: movslq  %eax ,  %rcx
<+35>: mov     (%rdi , %rcx , 4) ,   %edx
<+38>: cmp     %r8d ,  %edx
<+41>: jg      <func+21>
<+43>: cltq
<+45>: mov     %r8d ,   0x4(%rdi , %rax , 4)
<+50>: add     $0x1 ,  %r9d
<+54>: cmp     %esi ,  %r9d
<+57>: jl      <func+8>
<+59>: repz  retq
```

%r9d = 1
go to: L54

L54 [%r9d < %esi
goto: L8

L8 [ret = ~~arr~~ i
key %r8d = i + 4*ret
ret = r9 −1
j
goto: L28

ret & ret ⇒ (ret < 0)
goto: L43

rcx = ret
rdx = rdi + 4* rcx
rdx > r8d
goto 21

rcx = j

edx = a[j]

edx > r8d

edx = arr[j]

1. Fill in the code (2 Pts each .. Extra Credit Possible)

```
void func(int arr[], int n)
{
    int i, key, j;  ✓
    for (i = 1 ✓; i < n ✓; i++)
    {
        key = arr[ i ✓ ];
        j = i−1;

        while ( j ✓ >=0 && a[j] > key ✓)
        {
            arr[ j+1 ✓ ] = arr[ j ✓ ];
            j = j+1 ✓;
        }
        arr[ j+1 ✓ ] = key;
    }
}
```

2. What well-known algorithm is this? (2 Pts Extra Credit)

Replaces all array elements with greatest value in array, to right of the element

n: 4
key 2

1 5 ~~2~~5 3

key=1
key=2

5