

# CS 4400 Fall 2016

## Final Exam – Practice

Name: \_\_\_\_\_

**Instructions** You will have eighty minutes to complete the actual open-book, open-note exam. Electronic devices will be allowed only to consult notes or books from local storage; network use will be prohibited. The actual exam will be shorter than this practice exam **and will not include a problem like number 21.**

The first three questions refer to the code template

```
long f(long x, long y) {  
    return ....;  
}
```

and the code fragments

1.  $x*(2+y)$
2.  $x+8*y$
3.  $((\text{long } *)x)[y]$
4.  $*(\text{long } *)x = y$
6.  $x == y$

1. Which of the above code fragments most likely appears in place of .... if the generated machine code includes the following instruction?

```
leaq (%rdi, %rsi, 8), %rax
```

2. Which of the above code fragments most likely appears in place of .... if the generated machine code includes the following instruction?

```
movq (%rdi, %rsi, 8), %rax
```

3. Which of the above code fragments most likely appears in place of .... if the generated machine code includes the following sequence?

```
cmpq %rdi, %rsi  
sete %al  
movzbq %rax
```

The next four questions refer to the following assembly sequence:

```
leal (, %eax, 4), %ebx
shrl $0x2, %ebx
subl %ebx, %eax
cmpl $0x0, %eax
jg .L1
andl $0x7FFFFFFF, %eax
.L1:
shrl $29, %eax
ret
```

4. If %eax starts as 0, what is the ending value of register %eax?
  
  
  
  
  
  
  
  
  
  
5. If %eax starts as -1, what is the ending value of register %eax?
  
  
  
  
  
  
  
  
  
  
6. If %eax starts as 0x4FFFFFFF, what is the ending value of register %eax?
  
  
  
  
  
  
  
  
  
  
7. If %eax starts as unknown, what are all the possible ending values of %eax?

8. Given that

```
int sum_element(int c,
                long mat1[][M],
                long mat2[][N]) {
    int k;
    long sum = 0;
    for (k = 0; k < c; k++)
        sum += mat1[k][c] - mat2[k][c];
    return sum;
}
```

compiles as

```
testl    %edi, %edi
jle      zero
movslq   %edi, %rax
subl     $1, %edi
leaq     0(,%rax,8), %r8
leaq     (%rax,%rdi,4), %rax
leaq     (%rsi,%r8), %rcx
addq     %r8, %rdx
leaq     32(%rsi,%rax,8), %rsi
xorl     %eax, %eax
loop:
addq     (%rcx), %rax
addq     $32, %rcx
subq     (%rdx), %rax
addq     $40, %rdx
cmpq     %rsi, %rcx
jne      loop
ret
zero:
xorl     %eax, %eax
ret
```

then what are the values of the constants M and N among the following possibilities?

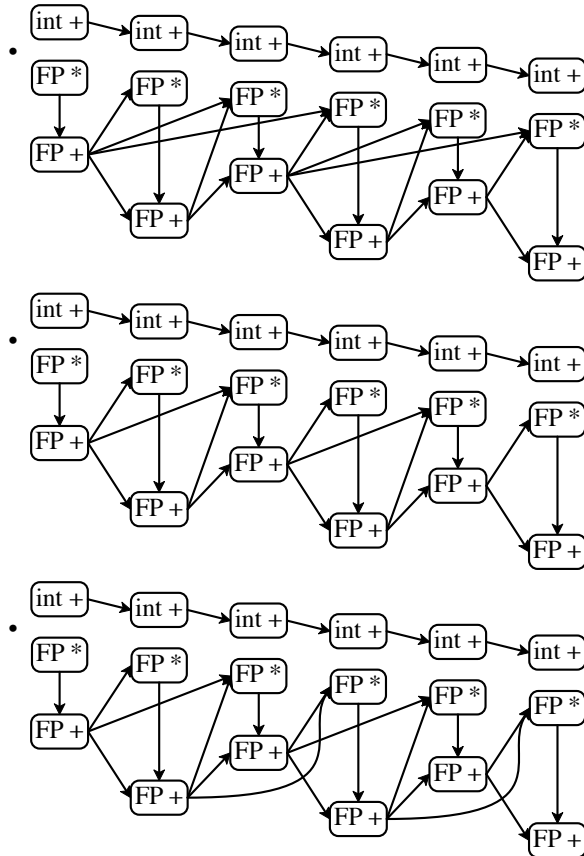
- M = 10 and N = 6
- M = 12 and N = 2
- M = 3 and N = 5
- M = 4 and N = 5
- M = 5 and N = 12
- M = 8 and N = 17

To enable partial credit, show your reasoning for how the assembly code corresponds to elements of the C code.

The next two questions refer to the `iterate` function defined as

```
double iterate(double x, double y, double z, int steps) {
    int i;
    for (i = 0; i < steps; i++) {
        z = x * y;
        if (!(i & 0x1))
            x = y + z;
        else
            y = x + z;
    }
    return z;
}
```

9. Which of the following correctly represents the dependency graph of `iterate` over six iterations, where each column corresponds to a single iteration?



10. Based on the dependency graph, how many cycles will `iterate` take (expressed as a multiple of steps)?

The following four questions refer to the following declarations:

```
typedef struct jumble {
    struct {
        int i;
    } r;
    double d;
    char c;
    union {
        int i;
        char *s;
    } u;
    short s;
} jumble;

jumble ja[7][5];
```

For the questions, assume that ja starts at address 0x10000.

**11.** What is `sizeof(jumble)`?

**12.** What is the address of `ja[0][2].d`?

**13.** What is the address of `ja[4][2].u.s`?

**14.** What is the address of `ja[4][2].s`?

The next two questions refer to the following declarations and function:

```
typedef struct {
    int a[2];
} pair;

pair p[32][32];

int sum(int how_many) {
    int i, j, k, a = 0;

    for (i = 0; i < 32; i++)
        for (j = 0; j < 32; j++) {
            for (k = 0; k < how_many; k++) {
                a += s[i][j].a[k];
            }
        }

    return a;
}
```

For each question below, assume a 1kB direct-mapped cache that uses 16-byte blocks, the cache is initially empty, and local variables are in registers. Also assume that the array p is at the address 0x10000 in memory.

15. For each of first five memory accesses via p in sum(1), what is the accessed element, what is the accessed address, and is the access a cache hit or miss?

Access expression	Access address	Hit or miss
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

16. What is the overall expected cache-miss rate of sum(1)?

**17.** For each of first five memory accesses via `p` in `sum(2)`, what is the accessed element, what is the accessed address, and is the access a cache hit or miss?

Access expression	Access address	Hit or miss
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

**18.** What is the overall expected cache-miss rate of `sum(2)`?

**19.** What are all of the possible outputs of the following program?

Assume that the program runs on Linux, where the child process created by `fork` does *not* include all the threads of the parent process. The child process includes only the thread that called `fork`.

In case you don't list all of the possible outputs correctly, to improve opportunities for partial credit, show how you arrived at your answer by sketching one or more process/thread graphs.

```
#include "csapp.h"

static sem_t done;

static void *go(void *p) {
    pid_t pid = Fork();
    if (pid == 0) {
        Write(1, "c", 1);
        V(&done);
        exit(0);
    } else {
        Write(1, "p", 1);
        Waitpid(pid, NULL, 0);
        V(&done);
        return NULL;
    }
}

int main() {
    pid_t pid;
    pthread_t th1, th2;

    Sem_init(&done, 0, 0);

    Write(1, "+", 1);
    Pthread_create(&th1, NULL, go, NULL);
    Pthread_create(&th2, NULL, go, NULL);

    P(&done);
    P(&done);
    Write(1, "-", 1);

    return 0;
}
```





The last page contains a server implementation that implements a vote-counting service, except that many parts of the program have been deleted and replaced with blanks. Your task is to fill in each blank with a number that corresponds to one of the following program fragments. Each fragment can be used multiple times, and not all fragments need to be used, but you can only fill in blanks with these fragments. If you use a fragment that itself has blanks, then those blanks must be filled in, too; blanks in unused fragments do not need to be filled in.

The server listens for both TCP connections and UDP connections at a given port. Each message sent to the server by UDP is received as a vote, which is recorded by incrementing a counter for the message string as stored in a dictionary. For example, a client could send the message `apple` to increase the `apple` count. For each connection made to the server via TCP, the server sends back vote results so far. Vote results are reported as an `int` for the number of voted-on strings, then, for each voted-on string: each string's length as an `int`, its content as bytes, and its vote count as an `int`.

The server must listen for UDP and TCP connections concurrently. Since each UDP message can be handled immediately, there's no need to have multiple messages processed concurrently to each other. Each TCP connection may take a while to receive all the votes, however, so the server is meant to support multiple TCP connections concurrently. Finally, each TCP connection should be sent a snapshot of vote tallies at the time of the connection, and new votes via UDP should be allowed meanwhile.

The server uses a dictionary library with the following property: the dictionary makes its own copy of keys, but when a value is installed into the dictionary with `dictionary_set`, the dictionary takes ownership of the value and is responsible for deallocating it when the value is replaced (or when the dictionary is destroyed, but that never happens in this server). A client *does not* take ownership of a value that is extracted from the dictionary with `dictionary_get`; that value can be deallocated if it is meanwhile replaced.

1. `Close(s);`
2. `ls = Open_listenfd(portno);`
3. `struct sockaddr_storage addr;`  
`unsigned int len = sizeof(addr);`  
`s = Accept(ls, (struct sockaddr *)&addr, &len);`
4. `s = Socket(addr->ai_family, addr->ai_socktype, addr->ai_protocol);`
5. `amt = Sendto(s, buffer, MAXBUF-1, 0,`  
`(struct sockaddr *)&addr, &len);`
6. `char buffer[MAXBUF];`  
`size_t amt;`  
`amt = Recv(s, buffer, MAXBUF-1, 0);`  
`buffer[amt] = 0;`

```

7. free(new_p);
8. free(p);
9. static int make_socket(char *portno) {
    int s;
    struct addrinfo hints, *addrs;

    memset(&hints, 0, sizeof(struct addrinfo));
    hints.ai_family = AF_INET;
    hints.ai_socktype = SOCK_STREAM;
    Getaddrinfo("localhost", portno, &hints, &addrs);

    _____a

    Connet(s, addrs->ai_addr, addrs->ai_addrlen);
    Freeaddrinfo(addrs);

    return s;
}
10. static int make_socket(char *portno) {
    int s;
    struct addrinfo hints, *addrs;

    memset(&hints, 0, sizeof(struct addrinfo));
    hints.ai_family = AF_INET;
    hints.ai_socktype = SOCK_DGRAM;
    hints.ai_flags = AI_PASSIVE;
    Getaddrinfo(NULL, portno, &hints, &addrs);

    _____b

    Bind(s, addrs->ai_addr, addrs->ai_addrlen);
    Freeaddrinfo(addrs);

    return s;
}
11. s
12. ls
13. Sem_init(&db_lock, 0, 1);
14. static void sigchld_handler(int sig) {
    while (waitpid(-1, NULL, WNOHANG) < 0)
        ;
}

```

```
15.  Signal(SIGCHLD, sigchld_handler);
16.  V(&db_lock);
17.  P(&db_lock);
18.  Waitpid(-1, NULL, 0);
19.  exit(0);
20.  receive_votes
21.  serve_counts
22.  static void write_entry(dictionary_t *db, int i, int s) {
        const char *key = dictionary_key(db, i);
        int len = strlen(key);
        int votes = *(int *)dictionary_value(db, i);
        Rio_writen(s, &len, sizeof(len));
        Rio_writen(s, (void *)key, len);
        Rio_writen(s, &votes, sizeof(votes));
    }
23.  /* A million threads isn't cool... */
```

21. Fill in the blanks with numbers for fragments on the previous pages:

```

#include "csapp.h"
#include "dictionary.h"

static dictionary_t *db;
static sem_t db_lock;

_____c
_____d
_____e

static void receive_votes(char *portno) {
    int s = make_socket(portno);
    while (1) {
        int *p, *new_p;
        _____f
        new_p = malloc(sizeof(int));
        *new_p = 1;
        _____g
        p = dictionary_get(db, buffer);
        if (p) *new_p += *p;
        dictionary_set(db, buffer, new_p);
        _____h
    }
}

static void *serve_counts(void *portno) {
    int ls, s;
    _____i
    while (1) {
        _____j
        _____k
        if (Fork() == 0) {
            int i, count = dictionary_count(db);
            Rio_writen(s, &count, sizeof(count));
            for (i = 0; i < count; i++)
                write_entry(db, i, s);
            _____l
        }
        _____m
        Close(s);
    }
}

int main(int argc, char **argv) {
    pthread_t th;
    if (argc != 2) app_error("need <port>");
    db = make_dictionary(COMPARE_CASE_SENS, free);
    Sem_init(&db_lock, 0, 1);
    _____n
    Pthread_create(&th, NULL, _____o, argv[1]);
    Pthread_detach(th);
    _____p(argv[1]);
    return 0;
}

```

## Answers

1.  $x+8*y$

2.  $((\text{long } *)x)[y]$

3.  $x == y$

4. 0

5. 2

6. 2

7. 0 and 2

8.  $M = 4$  and  $N = 5$

```
testl  %edi, %edi           # check whether c is 0
jle    zero                 # if c is zero, just return 0
movslq %edi, %rax           # copy c to rax
subl   $1, %edi             # rdi = c-1
leaq   0(,%rax,8), %r8      # r8 = c*sizeof(long)
leaq   (%rax,%rdi,4), %rax  # rax = 5*(c-1)
leaq   (%rsi,%r8), %rcx     # rcx = matrix1 + c*sizeof(long)
addq   %r8, %rdx            # rdx = matrix2 + c*sizeof(long)
leaq   32(%rsi,%rax,8), %rsi # rsi = matrix1 + 5*(c-1)*8+32; used as end condition
xorl   %eax, %eax          # sum = 0
loop:
addq   (%rcx), %rax         # sum += rcx[0]
addq   $32, %rcx           # rcx += 4 * sizeof(long) => M = 4
subq   (%rdx), %rax        # sum -= rdx[0]
addq   $40, %rdx           # rdx += 5 * sizeof(long) => N = 5
cmpq   %rsi, %rcx          # rcx == matrix1+c*sizeof(long)?
jne    loop                # if we haven't reached last row....
ret
zero:
xorl   %eax, %eax
ret
```

9. The third one

10. 8, since there's a path that goes through both FP\* and FP+ at each iteration.

11. 40

```
typedef struct jumble {
    struct {
        int i;           // size 4, alignment 4 => offset 0
    } r;                 // also size 4, offset 0
    double d;           // size 8, alignment 8 => offset 8
    char c;             // size 1, alignment 1 => offset 16
    union {
        int i;          // size 4, alignment 2 => offset 20... but 24 for s
```

```

    char *s;    // size 8, alignment 8 => offset 24
  } u;        // so, size 8, offset 24
  short s;    // size 2, alignment 2 => offset 32
} jumble;    // size >= 34, alignment 8 => size 40

```

jumble ja[7][5]; // each row is 40\*5 bytes

12.  $0x10000 + 80 + 8 = 0x10058$

13.  $0x10000 + 40 \times 5 \times 4 + 80 + 24 = 0x10388$

14.  $0x10000 + 40 \times 5 \times 4 + 80 + 32 = 0x10390$

15.

Access expression	Access address	Hit or miss
<code>s[0][0].a[0]</code>	<code>0x10000</code>	<b>miss</b>
<code>s[0][1].a[0]</code>	<code>0x10008</code>	<b>hit</b>
<code>s[0][2].a[0]</code>	<code>0x10010</code>	<b>miss</b>
<code>s[0][3].a[0]</code>	<code>0x10018</code>	<b>hit</b>
<code>s[0][4].a[0]</code>	<code>0x10020</code>	<b>miss</b>

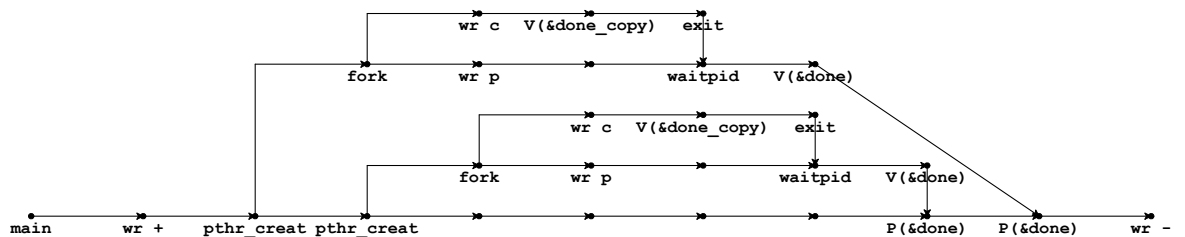
16. 50%

17.

Access expression	Access address	Hit or miss
<code>s[0][0].a[0]</code>	<code>0x10000</code>	<b>miss</b>
<code>s[0][0].a[1]</code>	<code>0x10004</code>	<b>hit</b>
<code>s[0][1].a[0]</code>	<code>0x10008</code>	<b>hit</b>
<code>s[0][1].a[1]</code>	<code>0x1000c</code>	<b>hit</b>
<code>s[0][2].a[0]</code>	<code>0x10010</code>	<b>miss</b>

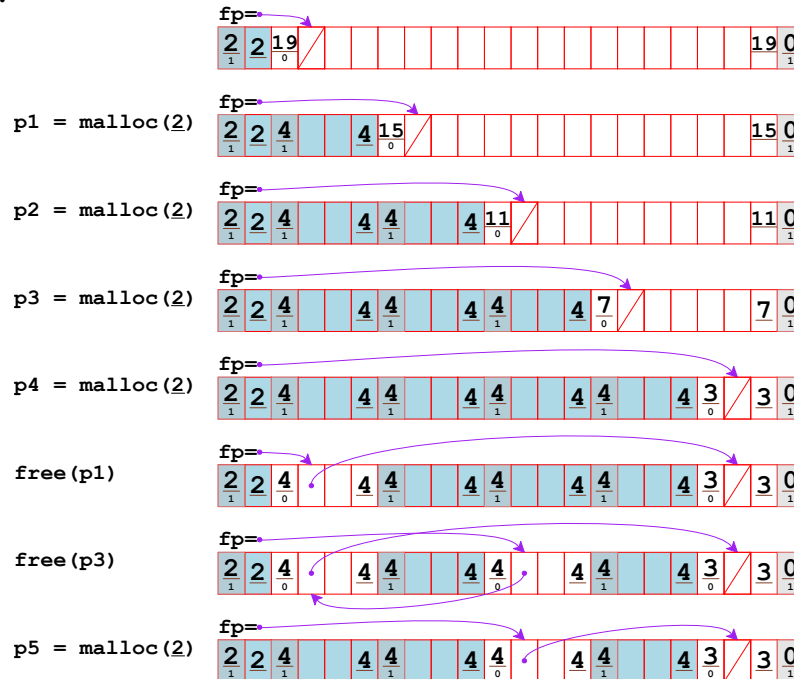
18. 25%

19. Six possible outputs: +ppcc-, +pcpc-, +ccpp-, +pccp-, +cpcp-, and +ccpp-. The outputs reflect that + must be first, - must be last, and the two cs and two ps can be in any order. A possible progress/thread graph is



It's also possible for the Vs and Ps to pair up in the other way, but that makes no difference to the output. The  $V(\&done\_copy)$  nodes reflect that the child processes perform a semaphore post on done, but it has no effect since the semaphore is not shared with the parent process.

20.



In the last step, allocating the middle free block would also be valid.

21.

- b = 4
- c = 14
- d = 10
- e = 22
- f = 6
- g = 17
- h = 16
- i = 2
- j = 3
- k = 17
- l = 19
- m = 16
- n = 15
- o = 21
- p = 20