University of Washington – Computer Science & Engineering
Spring 2019    Instructor: Justin Hsia    2019-05-10

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All work is my own. I had no prior knowledge of the exam contents nor will I share the contents with others in CSE333 who haven’t taken it yet. Violation of these terms could result in a failing grade. (please sign)

Do not turn the page until 5:00.

Instructions
• This exam contains 10 pages, including this cover page. Show scratch work for partial credit, but put your final answers in the boxes and blanks provided.
• The last page is a reference sheet. Please detach it from the rest of the exam.
• The exam is closed book (no laptops, tablets, wearable devices, or calculators). You are allowed one page (US letter, double-sided) of handwritten notes.
• Please silence and put away all cell phones and other mobile or noise-making devices. Remove all hats, headphones, and watches.
• You have 70 minutes to complete this exam.

Advice
• Read questions carefully before starting. Skip questions that are taking a long time.
• Read all questions first and start where you feel the most confident.
• Relax. You are here to learn.

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**Question 1:** You MAKE Me Whole  [19 pts]

Let CFLAGS = -Wall -g -std=c11. The symbol “$^” means all sources.

(A) Complete the corresponding directed acyclic graph for the Makefile. [5 pt]

```
may: april.o flowers.o
    gcc $(CFLAGS) -o may $^
april.o: april.c showers.h
    gcc $(CFLAGS) -c april.c
flowers.o: flowers.c showers.h sun.h
    gcc $(CFLAGS) -c flowers.c
soil.o: soil.c sun.h showers.h
    gcc $(CFLAGS) -c soil.c
garden: flowers.o soil.o
    gcc $(CFLAGS) -o garden $^
clean:
    rm -f *.o garden
```

(B) Starting with only the source files (.c and .h) and Makefile, we run “make” followed by “make clean”. What happens to the following files? Use “C” for created, “CD” for created and then deleted, and “U” for untouched (i.e. unchanged or not created). [4 pt]

```
may _C_ april.o _CD_ soil.o _U_ garden _U_
```

```
make runs the first target in the Makefile (may), which doesn’t reach soil.o or garden. make clean removes all object files and garden (never built), but not may.
```

(C) Write out a new all target that builds all the non-phony targets with the shortest source list possible. [2 pt]

```
all: may garden
```

(D) Where should we put the all target in Makefile? [2 pt]

```
At the top/beginning of the Makefile.
```

[3] What happens to the following files when we run “make all” again? Use “M” for modified and “U” for untouched. [4 pt]

```
may _M_ april.o _U_ flowers.c _U_ garden _M_
```

```
Follow the DAG from sun.h to see that may and garden are affected, but april.o is not. None of the source files (flowers.c) are affected by the commands in this Makefile.
```

(F) The given Makefile above has a subtle mistake (besides no all). Describe the fix. [2 pt]

```
Need to include the executable may in the rm command under the phony target clean.
```
Question 2: Love Your Food (PRE)PROCESSOR  [15 pts]

Suppose we have the following files:

food.h:
```c
#ifdef SWITCH
#define FOOD(a) ((a>0)-0.5)*2*y;
#else
#define FOOD(a) a
#endif
typedef int num;
```

food.c:
```c
#include <stdio.h>
#include "food.h"
#define x 3.5
int y = -7.5;
int main(int argc, char **argv) {
    printf("%d\n", (int) FOOD(x) );
    return 0;
}
```

(A) The header file is missing a header guard! Following the style guide for this class, what name should we use for the guard macro? [2 pt]

(B) If we compile with `gcc food.c`, what is output when we run `a.out`? [4 pt]

```
SWITCH is not defined, so it prints the value of (int) 3.5
```

3

(C) Complete the result of `cpp -P -DSWITCH food.c` below. Ignore the output of the `#include <stdio.h>` directive. [6 pt]

```c
typedef int num;
int y = -7.5;
int main(int argc, char **argv) {
    printf("%d\n", (int) ((3.5>0)-0.5)*2*y; );
    return 0;
}
```

(D) (Circle one) What will be happen when we try to compile `gcc -DSWITCH food.c` and run `a.out`? [3 pt]

<table>
<thead>
<tr>
<th>compiler error</th>
<th>output</th>
<th>output</th>
<th>output</th>
<th>output</th>
</tr>
</thead>
<tbody>
<tr>
<td>error</td>
<td>-7</td>
<td>0</td>
<td>7</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Notice the extra semicolon! Even without that, the (int) cast would round 
\(((3.5>0)-0.5) = 0.5\) down to 0, resulting in \(0*2*-7 = 0\) being printed.
Question 3: SHELTER Me From The C And The Storm  [25 pts]

We’re writing software in C to help a local animal shelter track their current (i.e. unadopted) and former (i.e. adopted) residents. We will use the following typedef-ed structs:

```c
typedef struct an {
    char *serial; // unique ID (variable length) [Heap]
    uint8_t adopted; // 0 – unadopted, 1 - adopted
} Animal;

typedef struct sh {
    Animal **residents; // pointer to array of Animal pointers [Heap]
    uint32_t num_res; // length of residents array
    char manager[7]; // manager’s name
} Shelter;
```

(A) Draw a memory diagram for a small Shelter Hsiadoption that has two residents: an unadopted cat with serial number "3DJc" and an adopted dog with serial number "xj1". The manager’s name is "Justin". Internal character arrays should have individual elements drawn out explicitly, but pointed-to c-strings can be written as string literals. Don’t forget to include variable/field names. [8 pt]
(B) An implementation of CloseShelter() is below, which is supposed to clean up all of the Heap memory managed by a Shelter instance. Describe three errors below. [5 pt]

```c
void CloseShelter(Shelter s) {
    for (int32_t i = 0; i < s.num_res; i++) {
        free(s.residents[i]->serial);
        free(s.residents[i]->adopted);
    }
}
```

Memory Errors:
- memory leak of s.residents
- memory leak of s.residents[i]
- invalid free of s.residents[i]->adopted (not malloc-ed)

Style Error:
- the Shelter should be passed as a pointer to avoid struct copying
- a variety of other style issues were given partial and full credit

(C) Below, complete the helper function GenSerial() that generates a new, random serial string of random length. Assume we have the following functions available to you: [9 pt]

```c
int32_t randLen(); // returns a random int in the range of 1-10
char randChar();   // returns a random printable character

// Returns a random serial # and its length. Returns -1 on error.
int32_t GenSerial(char **serial) {
    // generate random serial length
    int32_t len = randLen();
    // allocate space for c-string (including null terminator)
    *serial = (char *) malloc((len+1)*sizeof(char));
    // error checking for failed allocation
    if (*serial == NULL)
        return -1;
    // assign random characters
    for (int32_t i = 0; i < len; i++)
        (*serial)[i] = randChar();
    // add null terminator to end c-string
    (*serial)[len] = '\0';
    return len;
}
```

(D) Given a pointer Animal *a = (Animal *) malloc(sizeof(Animal)), set its fields to an unadopted animal and give it a serial using GenSerial(): [3 pt]

```c
__GenSerial(&a->serial)____________________;
__a->adopted = 0__________________________;
```

In real code, we should have error checked the return value of GenSerial (for -1), but this was overlooked for the purposes of this exam (only 2 lines given).
Question 4: Class DICTation  [31 pts]

Abbrev: constructor (ctor), copy constructor (cctor), assignment (op=), destructor (dtor).
All code written for this question will be graded on style.

(A) Given KVPair p1 and Dict d1, will the following work? Answer “Y” or “N”. [4 pt]

```
KVPair p2;  Y (def ctor)                Dict d2 = d1;  Y (cctor)
p1 = KVPair();  Y (synth op=)            d1 = Dict(0,nullptr);  N (2-arg ctor)
```

(B) (Circle one) Which field is initialized first during the construction of a Dict object? [2 pt]

```
key      entries_    size_      value
```

Data members are constructed/initialized in the order they are defined.

(C) Write out an inline definition of an accessor get_size() for Dict. [3 pt]

```
size_t get_size() const { return size_; }
```

(D) Briefly argue whether or not we should define an accessor for entries_ in Dict. [2 pt]

```
No. Returning a copy of entries_ will allow outside access to modify the contents of *entries_.
```
(E) entries_ points to an array on the Heap. Define a Dict member method Push() for
the implementation file (.cc) that adds a given KVPair to the end of entries_. [8 pt]

```cpp
void Dict::Push(const KVPair &p) {
    KVPair *old = entries_;
    entries_ = new KVPair[size_ + 1]; // def ctor
    for (int i = 0; i < size_; i++)
        entries_[i] = old[i]; // op=
    entries_[size_] = p; // op=
    size_++; // increase size by one
    delete[] old; // clean up old memory
} // many valid solutions exist
```

(F) The inline definition of the Dict destructor is given below: [3 pt]

```cpp
~Dict() { delete[] entries_; }
```

(Circle one) Which destructor first completes during the destruction of a Dict object?

During the deletion of entries_, each KVPair in the array gets destructed. Data
members are destructed in the reverse order of definition.

(G) (Circle one) What type of function should the following be? [2 pt]

```cpp
Dict operator+(const Dict &a, const Dict &b) {
    Dict out;
    out.entries_ = new KVPair[a.size_ + b.size_];
    for (int i = 0; i < a.size_; i++)
        out.entries_[i] = a.entries_[i];
    for (int j = 0; j < b.size_; j++)
        out.entries_[j + a.size_] = b.entries_[j];
    return out;
}
```

The function prototype takes 2 parameters, so it must be non-member. But it directly
accesses private members, so it has to be a friend function.

(H) Assume that the Dict cctor (definition not shown) does a deep copy of data members.
If d1 and d2 are both Dicts of size 1, how many times are each of the following invoked
(count both Dict and KVPair methods) during d1 + d2? [7 pt]

CTOR: out (1, Dict), new (2, KVPair), return (2, KVPair during cctor of Dict).
CTOR: return (1, Dict). DCTOR: return (1, Dict and 2, KVPair during Dict dctor).

op=: for-loop assignments (2, KVPair), return (2, KVPair during cctor of Dict).

CTOR: return (1, Dict). DCTOR: return (1, Dict and 2, KVPair during Dict dctor).
Question 5: The INs and OUTs  [13 pts]

(A) Briefly explain why the C standard library file I/O functions are considered more portable than the POSIX library file I/O functions. [2 pt]

The C standard library is specified as part of the C programming language, and is therefore found in every implementation of C on any system. The POSIX library is defined for just Unix-like variants. On systems without POSIX, the C standard library file I/O functions will invoke the appropriate other library functions (e.g. Windows API) instead.

(B) Convert the following two lines of C code into their POSIX library equivalents. Do NOT add any other lines (e.g. error checking): [5 pt]

C Std Lib: `FILE *file = fopen("midterm.txt", "w");
size_t n = fwrite(buf, sizeof(long), 10, file);`

POSIX: `_int fd = open("midterm.txt", O_WRONLY)____________________;
__ssize_t n = write(fd, buf, 10*sizeof(long))______________;`

(C) When we find an unrecoverable error in the following function calls, do we need to close the associated file descriptor during our error handling? Answer “Y” for yes and “N” for no. [3 pt]

open  _N_  read  _Y_  write  _Y_  close  _N_
On open, nothing to close! On close, likely won’t work on repeated attempts.

(D) For the following I/O function return types, what is the common indicator of an error? [3 pt]

`FILE * ___NULL____`

`size_t ____0____`

`ssize_t ____-1____`