University of Washington – Computer Science & Engineering

Winter 2020 Instructor: Justin Hsia 2020-02-14

CSE333 MIDTERM

Last Name:	**Perfect**	
First Name:	**Perry**	
Student ID Number:	1234567	
Name of person to your Left | Right	Samantha Student	Larry Learner
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.

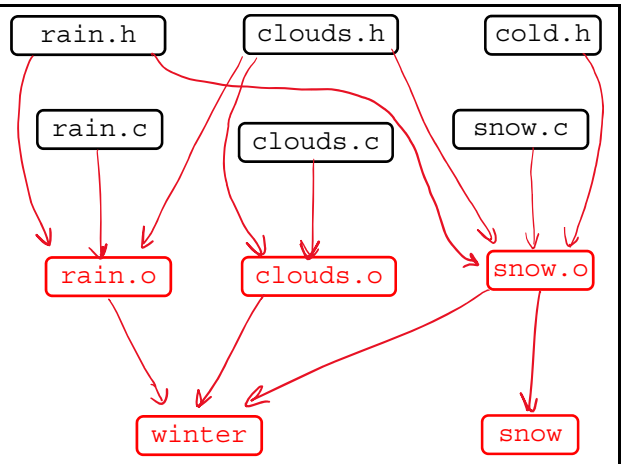
Question	1	2	3	4	5	Total
Possible Points	19	10	24	32	19	**104**

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]

```
winter: rain.o snow.o clouds.o
   gcc $(CFLAGS) $^

snow: snow.o
   gcc $(CFLAGS) -o snow $^

rain.o: rain.c rain.h clouds.h
   gcc $(CFLAGS) -c rain.c

clouds.o: clouds.c clouds.h
   gcc $(CFLAGS) -c clouds.c

snow.o: snow.c clouds.h rain.h cold.h
   gcc $(CFLAGS) -c snow.c

clean:
   rm -f rain.o clouds.o winter snow
```



(B) Starting with only the source files (`.c` and `.h`) and `Makefile`, what should happen to the following files if we run "`make`" followed by "`make clean`"? Use "**C**" for created, "**CD**" for created and then deleted, and "**U**" for untouched (*i.e.* unchanged or not created). [4 pt]

`rain.o` **_CD_** `clouds.o` **_CD_** `snow.o` **_C_** `winter` **_U_**

`make` runs the 1st target in the Makefile (`winter`), which builds all of the object files but produces the default executable name (`a.out`). `make clean` doesn't remove `snow.o`.

(C) Do we need a phony `all` target in `Makefile`? *Briefly* justify your response. [2 pt]

(Yes) / No Since we want to produce two different executables (winter, snow), we need a target to invoke both of those targets.

(D) [1] We run "`make`". [2] We modify `rain.h`. [3] What should happen to the following files when we run "`make`" again? Use "**M**" for modified and "**U**" for untouched. [4 pt]

`rain.c` **_U_** `clouds.o` **_U_** `snow.o` **_M_** `snow` **_U_**

Follow the DAG from `rain.h` to see that `rain.o` and `snow.o` are affected, but `clouds.o` is not. Since we ran the `winter` target, we don't attempt to rebuild `snow`.

(E) Assuming that the two executables do different things, it turns out that there is something inherently wrong with our project setup that will cause 1 of 2 possible compilation errors. Identify the compilation errors and which target will cause them. Hint: what does *every* C executable need? [4 pt]

Possible error: redefinition of `main`	Target: `winter`
Possible error: missing `main`	Target: `snow`

Every executable needs a `main` function. `winter` and `snow` must have different `main`s in order to do different things. `snow.o` is linked into both executables, so either it (and `snow`) doesn't have code for `main`, or two `main`s are linked into `winter`.

Possible error: missing symbols/functions from `rain.o` and `clouds.o`	Target: `snow`

The `snow.o` target includes `rain.h` and `clouds.h`, but the `snow` target only includes `snow.o`, meaning that it would be missing the implementations/definitions of anything it needs from those interfaces.

Question 2: PREPROCESS This! [10 pts]

Suppose we have the following files:

twoface.h:

```
#ifdef  DSWITCH
#define FACE(f) NULL
#else
#define FACE(f) (f * -2)
typedef int my_type;
#endif
```

twoface.c:

```
#include <stdio.h>
#define f 2.0
#include "twoface.h"
int main(int argc, char** argv) {
  printf("%ld\n", (long) FACE(f) );
  return 0;  // EXIT_SUCCESS
}
```

(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]

TWOFACE_H_

(B) Complete the result of `cpp -P -DSWITCH twoface.c` below. Ignore the output of the `#include <stdio.h>` directive. [5 pt]

```
typedef int my_type;
int main(int argc, char **argv) {
  printf("%ld\n", (long) (2.0 * -2) );
  return 0;
}
```

We have defined the symbol `SWITCH` in the command-line arguments to `cpp`, meaning `DSWITCH` is *not* defined. The preprocessor also removes all comments.

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

compiler error	output -4	output 0	output 4

The syntax is good, so will compile and execute as expected.

Question 3: ORDER Up [24 pts]

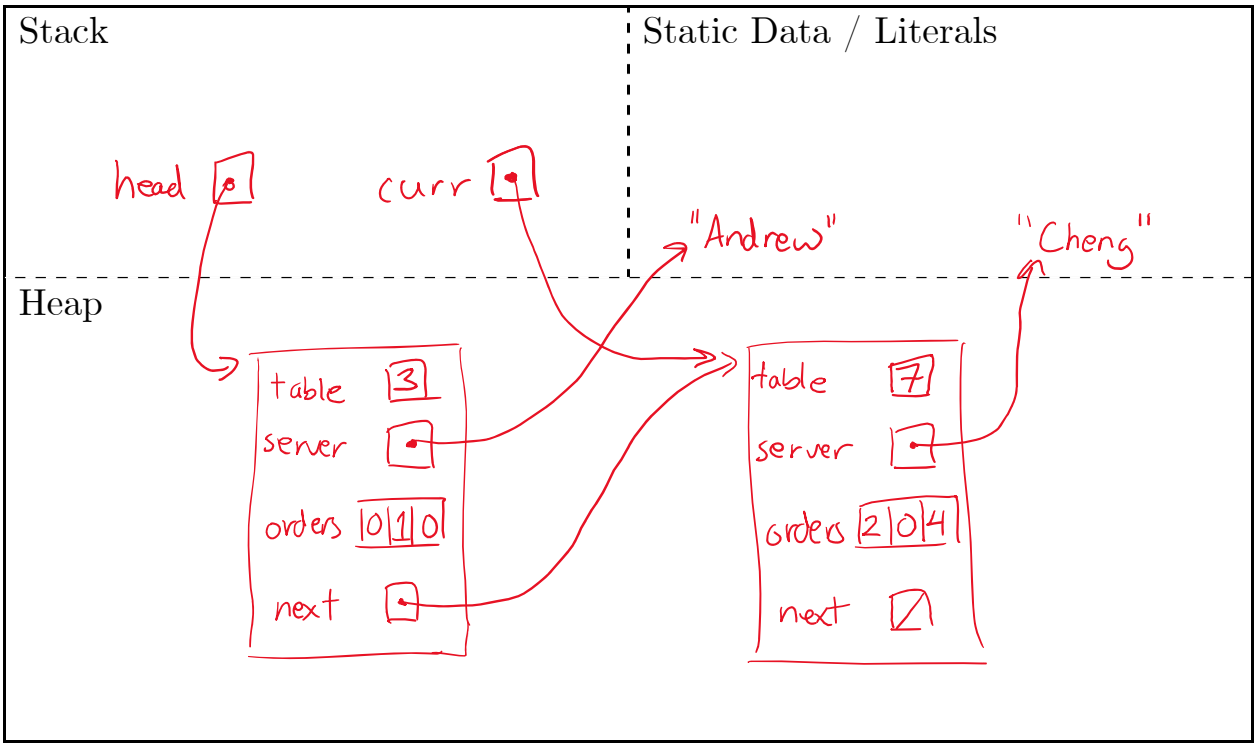
We're writing C software for restaurants to track orders using the following typedef-ed struct:

```
#define NUM_MENU_ITEMS 3

typedef struct order_st {
  int table;                    // table number
  char* server;                 // name of server
  int orders[NUM_MENU_ITEMS];   // # of each menu item ordered
  struct order_st* next;        // next order in linked list
} Order;
```

```
// order of 3 of menu item #0 for table 333, served by Justin
Order example = {333, "Justin", {3, 0, 0}, NULL};
```

We use `Order* head` to track *all* orders and `Order* curr` to track the current order. Assume both are defined in `main`. Because we cannot predict how many orders we will get, `Orders` must be allocated individually on the heap.

(A) Draw a memory diagram for a small linked list of two orders. The first order is for table 3, served by `"Andrew"`, and is for 1 of menu item #1. The second (and current) order is for table 7, served by `"Cheng"`, and is for 2 of menu item #0 and 4 of menu item #2. **Character arrays can be written as string literals. Don't forget to include variable and field names.** [8 pt]



(B) Below, complete the helper function `CreateOrder()` that generates a new, empty order (*i.e.*, 0 quantity of all menu items) with some specified field values. Assume that `*server` doesn't need to be deep-copied. `NUM_MENU_ITEMS` is `#define`-d. [8 pt]

```
// Returns a pointer to an empty order, or NULL on error.
Order* CreateOrder(int table, char* server) {
  Order* order = (Order*) malloc(sizeof(Order));
  if (order != NULL) {
    order->table = table;
    order->server = server;
    for (int i = 0; i < NUM_MENU_ITEMS; i++) {
      order->orders[i] = 0;
    }
    order->next = NULL;
  }
  return order;

  // ALTERNATE SOLUTION:
  // Order* order = (Order*) calloc(1, sizeof(Order));
  // if (order != NULL) {
  //   order->table = table;
  //   order->server = server;
  // }
  // return order;
}
```

(C) Recall that `head` and `curr` are local pointers in `main`. We are writing **`AddOrder`** that takes a specified heap-allocated `Order` (*e.g.* the return value from `CreateOrder`) and adds it to the end of the `head` list. If either `head` or `curr` is `NULL`, then they need to be updated to point to this new `Order`, meaning we may need to update the values of both `head` and `curr` in this function. Following good style guidelines, propose a suitable declaration: [4 pt]

Google preferred:
```
Order* AddOrder(Order* new_order, Order** curr);
Order* AddOrder(Order* new_order, Order** head);
```

Accepted:
```
void AddOrder(Order* new, Order** head, Order** curr);
```

Return values preferred to output params; input params come before output params.

(D) If we want to create a module for our `Order` system, indicate which file the following would go in (checkmark): [4 pt]

	`Order.h`	`Order.c`	`Restaurant.c`
`Order` typedef from problem description	✔		
`CreateOrder()` definition from part B		✔	
`CreateOrder()` declaration	✔		
`main()`			✔

Question 4: Time to Get in SHAPE [32 pts]

Abbrev: constructor (**ctor**), copy constructor (**cctor**), assignment (**op**=), destructor (**dtor**).

```
struct Point {
  Point() : x(0), y(0) { }
  Point(int x, int y) : x(x), y(y) { }
  int x, y;
};  // struct Point

class Shape {
 public:
  Shape() : num_pts_(1), points_(new Point) { }
  Shape(const Shape& s);  // DEEP copies data members
  Shape& operator=(const Shape& rhs);  // DEEP copies
  ...  // other methods mentioned in this question

 private:
  Point* points_;    // array of num_pts_ points [Heap]
  size_t num_pts_;   // # of points in shape
  uint8_t color[3];  // RGB values of shape color
};  // class Shape
```

(A) Do we need accessor methods for `Point`? *Briefly* explain why or why not. [2 pt]

No, because the data members in `Point` are publicly-accessible by default.

(B) Write out a line of code that will disable the cctor inside the definition `Point`. [2 pt]

```
Point(const Point& p) = delete;
```

(C) What does a default `Shape` describe? [2 pt]

A point at the origin (0, 0) with random/garbage color.

(D) The member function **`Area`** returns the area of the `Shape` as a `double`. Propose a suitable function signature (for the *implementation* file): [3 pt]

```
double Shape::Area() const {
```

(E) The member function **`ChangeColor`** sets the `Shape`'s color to specified red, green, and blue values. Propose a suitable function signature (for the *implementation* file): [3 pt]

```
void Shape::ChangeColor(const uint8_t red, const uint8_t green,
                        const uint8_t blue) {
```

(F) `points_` points to an array on the heap. Define a `Shape` member function **`Union()`** that *appends* the points from a second `Shape` to `points_` in `this`. Don't worry about duplicate points or self-unions. [10 pt]

```
void Shape::Union(const Shape& s) {
  Point *old = points_;
  points_ = new Point[num_pts_ + s.num_pts_];   // def ctor
  for (size_t i = 0; i < num_pts_; i++)         // copy old
    num_pts_[i] = old[i];
  for (size_t j = 0; j < s.num_pts_; j++)       // append new
    num_pts_[num_pts_ + j] = s.points_[j];
  num_pts_ += s.num_pts_;                       // increase size
  delete[] old;                                 // deallocate old
}  // many valid solutions exist
```

(G) The inline definition of the `Shape` destructor is given below, but leads to a memory error in our code! *Briefly* describe the issue and the fix (which may not be in the dtor): [4 pt]

```
~Shape() { delete[] points_; }
```

Issue:	Mismatched delete for a default-constructed `Shape` (*i.e.*, `delete[]` on `Point`).
Fix:	Update def ctor initializer list to use `points_(new Point[1])` instead.

(H) Assume that the `Shape` cctor (definition not shown) does a *deep* copy of data members. If `s` is a `Shape` with 2 points, how many times are each of the following invoked (count *both* `Shape` and `Point` methods) during the execution of the `friend` non-member function **`Reverse(s)`**? [6 pt]

```
Shape Reverse(const Shape& s) {
  Shape out = s;
  for (size_t i = 0; i < s.num_pts_; i++) {
    out.points_[i] = s.points_[s.num_pts_-1-i];
  }
  return out;
}
```

ctor __4__ cctor __2__ op= __6__ dtor __3__

cctor of `Shape` is called twice (`out`, `return`), each time calling 2 def ctor & 2 op= of `Point`. There are an additional 2 op= of `Point` in the for-loop. The `Shape` dtor is called on `out` after `Reverse` returns, which also destructs the 2 `Points` in its array.

Question 5: INPUT and OUTPUT and ERRORS, oh my! [19 pts]

(A) Assume that the C std lib is using an internal write buffer of **1024 bytes** and we are trying to write 2048 bytes total in **256-byte chunks**. Assuming that all writes are successful (*i.e.* no partial writes or errors), how many system calls do we invoke using C std lib vs. POSIX? [4 pt]

`write` will invoke a system call every time (2048/256 = 8 times). `fwrite` will only invoke a system call when it flushes its buffer (2048/1024 = 2 times).

`write()`	**8**
`fwrite()`	**2**

(B) Name a C function that we have used in this class that fits the descriptions: [4 pt]

Part of the C standard library, but doesn't invoke a system call.	*e.g.*, `strncpy`, `sqrt`
A POSIX system call that doesn't have a C std lib equivalent.	*e.g.*, `opendir`

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

POSIX:
```
int fd = open("midterm.txt", O_RDONLY);
ssize_t n = read(fd, buf, 333*sizeof(int32_t));
```

C Std Lib:
```
_FILE* file = fopen("midterm.txt", "r")_____________________;
_size_t n = fread(buf, sizeof(int32_t), 333, file)_________;
```

(D) Before exiting/terminating a C program, name the three categories of *resources* that we have seen in this class that we need to make sure are cleaned up/closed: [3 pt]

dynamically-allocated memory	files / streams	directories

(E) *Briefly* describe in what situations you prefer to use `perror` instead of `fprintf` to `stderr`. [3 pt]

When there are *multiple* possible causes of the error, as `perror` will print out an additional message related to `errno`. If there is a single cause of error, then a helpful `fprintf` message will suffice.