University of Washington – Computer Science & Engineering

Winter 2026 Instructors: Justin Hsia, Amber Hu 2026-02-09

CSE 333 MIDTERM

Last Name:		
First Name:		
Student ID Number:		
Name of person to your Left | Right		
All work is my own. I had no prior knowledge of the exam content, nor will I share the content with others in CSE 333 who haven't taken it yet. Violation of these terms could result in a failing grade. **(please sign)**		

Do not turn the page until you are told to do so.

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. *Detach it from the rest of the exam when you are told to do so.*
- 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.

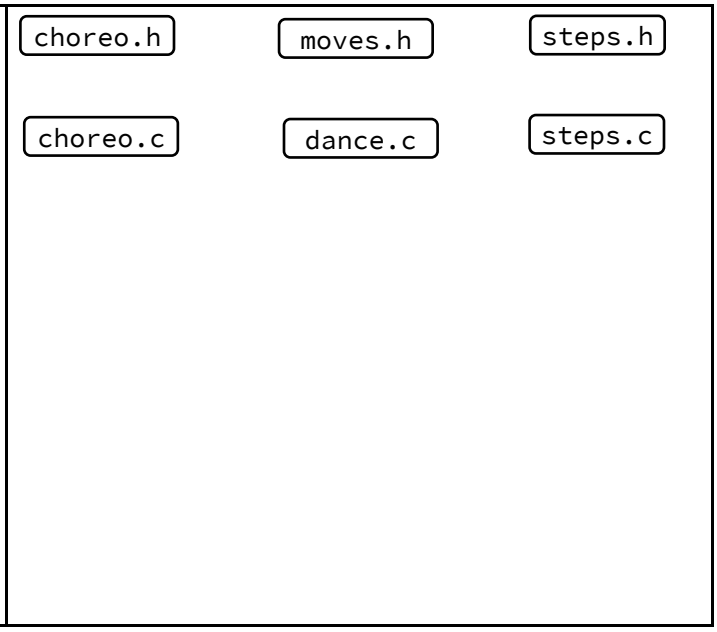
Question	1	2	3	4	5	Total
Possible Points	17	10	25	30	18	100

Question 1: MAKE a Song and Dance [17 pts]

Let `CFLAGS = -Wall -g -std=c17`. The automatic variables are defined on the reference sheet.

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

```
dance: dance.o steps.o
   gcc $(CFLAGS) -o dance $^

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

steps.o: steps.c steps.h moves.h
   gcc $(CFLAGS) -c $<

choreo.o: choreo.c choreo.h moves.h
   gcc $(CFLAGS) -c $<

dance.o: dance.c steps.h
   gcc $(CFLAGS) -c $<

clean:
   rm -f *.o choreo
```



(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]

`steps.o` ____ `choreo.o` ____ `dance.o` ____ `dance` ____

(C) Starting with only the source files (`.c` and `.h`) and `Makefile`, we run "`make choreo`" then modify `moves.h`. What will happen to the following files when we run "`make choreo`" again? Use "**M**" for modified and "**U**" for untouched. [4 pt]

`steps.o` ____ `choreo.c` ____ `dance.o` ____ `choreo` ____

(D) One of the target recipes/commands is incorrect! Name the fix. [2 pt]

(E) Based on the good conventions mentioned in this class, suggest one improvement to the `Makefile`. [2 pt]

Question 2: Trust the PREPROCESS [10 pts]

Suppose we have the following files (assume `stdio.h` and `stdlib.h` are linked but not shown):

os.h:
```
#ifdef TUX
char* os = "Linux";
#else
char* os = "Windows";
#endif
```

os.c:
```
#include "os.h"
#define TUX 1

int main(int argc, char** argv) {
  printf("%s %d\n", os, TUX);
  return 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]

(B) Complete the result of `cpp -P os.c` below. [5 pt]

```
int main(int argc, char** argv) {




}
```

(C) Is the output of `cpp -P -DTUX os.c` different than `cpp -P os.c` (Part B)? *Briefly* explain why or why not. [3 pt]

Question 3: Please Have PATIENTS [25 pts]

We're writing C software to help UW Medicine track patients in their hospitals using the following typedef-ed structs:

```
typedef struct patient_st {
  uint32_t med_rec;   // unique medical record number
  char* name;         // patient's name [Heap]
} Patient;
```

```
typedef struct hospital_st {
  char* addr;         // street address (string literal)
  Patient* rooms[NUM_FLOORS][NUM_ROOMS];  // room array (Patients on Heap)
                      // floors and rooms are 0-indexed
} Hospital;
```

(A) Draw a memory diagram for a small `Hospital hsiaspital`, defined in `main`, with address `"333 CSE St"`, `NUM_FLOORS` = 2, and `NUM_ROOMS` = 3. There is a single patient named Justin with medical record `14` in Floor `1`, Room `1` (the 2nd room on the 2nd floor); the rest of the rooms should be `NULL` (Ø). **Place data in the appropriate section of memory. Recall that C is row-major. Character arrays may optionally be written in string literal format** (*e.g.*, "hi"). **Don't forget to include variable and field names.** [8 pt]

Stack	Static Data / Literals
Heap	

(B) Complete the helper function `NewPatient()`, which generates a new patient with a Heap-allocated copy of the provided name, **in good C style**. The medical record number should be one greater than the last assigned number (can start at `0` or `1`). Assume `#include <string.h>` and `#include <stdlib.h>`. For this question, **you can skip error checking `malloc`**. [8 pt]

```
// Returns a pointer to a new patient with a Heap copy of name.
// Skip error checking of malloc.
Patient* NewPatient(char* name) {
  static uint32_t med_rec = 0;

  Patient* patient = ____________________________________________;

  patient->med_rec = ____________________________________________;

  patient->name = _____________________________________________;

  ____________________________________________________________;
  return patient;
}
```

(C) Assuming all patients are generated using `NewPatient()`, implement `CloseHospital()` below to clean up all of the Heap memory managed by a `Hospital` instance. [4 pt]

```
// Cleans up Hospital's Heap memory
void CloseHospital(Hospital* h) {
  for (size_t i = 0; i < NUM_FLOORS; ++i) {
    for (size_t j = 0; j < NUM_ROOMS; ++j) {

      if (_____________________________) {

        ____________________________________________________;

        ____________________________________________________;
      }
}
```

(D) We want a function `LocatePatient` to return the floor and room (`size_t`) of a patient with a matching `med_rec` number in a given `Hospital`, if found. Following **good C style** guidelines (no need for `const`), propose a suitable declaration below. **Add commas wherever needed in the parameter list.** Assume `#include <stdbool.h>`. [5 pt]

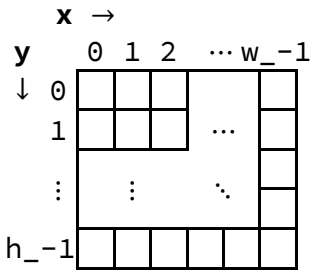
```
______ LocatePatient(_____________________________________

                     ____________________________________

                     ____________________________________);
```

Question 4: It's All About How You FRAME It [30 pts]

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

```
struct Pixel {
  Pixel() : r(0), g(0), b(0) { }
  Pixel(uint8_t r, uint8_t g, uint8_t b) : r(r), g(g), b(b) { }
  uint8_t r, g, b;  // red, green, blue
};  // struct Pixel

class Frame {
 public:
  Frame() : w_(1), h_(1), pixels_(new Pixel[1]) { }
  Frame(const Frame& fr);  // DEEP copies data members
  Frame& operator=(const Frame& rhs);  // DEEP copies
  ...  // other methods mentioned in this question

 private:
  size_t w_;       // width in pixels
  size_t h_;       // height in pixels
  Pixel* pixels_;  // 1-D Heap array representing
                   // width*height pixels (row major)
};  // class Frame
```

Frame coordinates:



(A) Given `Pixel p1` and `Frame f1`, will the following work? Answer "**Y**" or "**N**." [4 pt]

`Pixel p2;` _____ `Frame f2(f1);` _____

`Pixel p3 = p1;` _____ `f1 = new Frame;` _____

(B) Write out the inline definition of a `Frame` 2-arg ctor that takes `w` and `h` parameters. [3 pt]

(C) We want to add a member function `GetPixel` to get a copy of the `Pixel` at a specified (`x`, `y`) coordinate (see diagram above on the right). Write out the definition in the implementation (`.cc`) file **using good C++ style**. **No need for bounds/error checking**. [4 pt]

(D) The `Frame` destructor is defined inline as `~Frame() { delete[] pixels_; }`. Which data member is first *completely destroyed* during this destructor's execution? Circle one: [2 pt]

`b` `g` `h_` `pixels_` `r` `w_`

(E) `pixels_` points to a 1-D array that represents a row-major 2-D grid on the Heap. Define the `Frame` assignment operator function below. [8 pt]

```
Frame& Frame::operator=(const Frame& rhs) {









}
```

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

```
Frame BlendFrames(const Frame& f1, const Frame& f2) {
  Frame out = f1;
  for (size_t i = 0; i < out.w_*out.h_; ++i) {
    Pixel& p1 = out.pixels_[i];
    Pixel& p2 = f2.pixels_[i];
    // average pixel values (RHS creates temp object)
    p1 = {(p1.r+p2.r)/2, (p1.g+p2.g)/2, (p1.b+p2.b)/2};
  }
  return out;
}
```

non-friend + member | friend + member | non-friend + non-member | friend + non-member

(G) Assume that the `Frame` cctor (definition not shown) does a *deep* copy of data members. If `f1` and `f2` have width 2 and height 1, how many times are each of the following invoked (count *both* `Frame` and `Pixel` methods) during the execution of **`BlendFrames(f1, f2)`**? Assume no copy elision (*i.e.*, compiled with `-fno-elide-constructors`). [7 pt]

ctor _____ cctor _____ op= _____ dtor _____

Question 5: CASE ClOsEd? [18 pts]

The `ctype.h` library provides the functions `toupper()` and `tolower()`. We are writing a **C program** (*i.e.*, no C++ streams) that prints the contents of a file to `stdout` in AlTeRnAtInG CaPs.

(A) Complete the reading and writing loop in `main` below using the **Cstdio library**. [15 pt]

```
________ fd = fopen(argv[1], __________);
char c, caps = 1;
________ readlen;
while ((readlen = fread(______, _______, ______, ______)) > 0) {
  // check for error
  if (_____________________________________) {
    ____________________________________________________________;
    ____________________________________________________________;
    ____________________________________________________________;
  }
  if (caps) {
    printf("%c", ____________________________________________);
  } else {
    printf("%c", ____________________________________________);
  }
  caps = ____________________________________________;
}
_____________________________________________;
return EXIT_SUCCESS;
```

(B) For this application, would using POSIX `read` (not buffered) instead of `fread` (buffered) be beneficial? *Briefly* explain why or why not. [3 pt]