CSE 333 26su

Final Exam

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

First Name	
Last Name	
UW NetID	

Instructions

- The exam is closed book.
- You are allowed two pages of handwritten notes. Double -sided is ok.
- Silence and put away all cell phones and other mobile or noise-making devices.
- Remove all hats, headphones, smart glasses, watches, and other digital wearables.
- Keep your exam booklet on the table so the people behind you cannot see your answers.
- You will have 1 hour and 55 minutes to complete this exam.

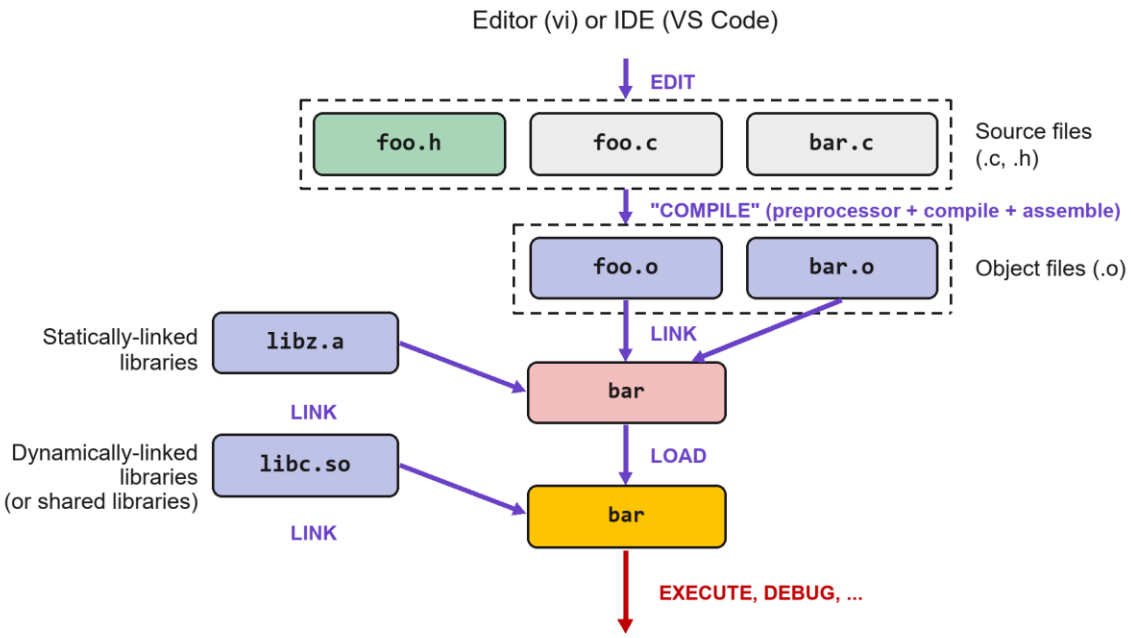
Advice

- Read all questions first and start where you feel the most confident.
- Read questions carefully before starting.
- Skip questions that are taking a long time.
- Show scratch work for partial credit, but put your final answers in the boxes and blanks provided.
- Relax. If you've been practicing, you got this! If you haven't, you'll learn something new!

Question	1	2	3	4	5	6	7	8*	9*	Total
Possible Points	10	12	16	14	10	8	12	8	10	100

* Questions 8 and 9 will be personalized to each student. We will hand this out once this exam starts.

Question 1. Compilation (10 pts)



Part A. The diagram groups preprocessing, compilation, and assembly into the "COMPILE" phase. Explain what happens in each of these three parts and what is passed to the next part. [6 pts]

Part B. Explain what happens during the linking phase. Then, explain the difference shown between a static library and a dynamic/shared library. [4 pts]

Question 2. OSI Model (12 pts)

#	OSI layer name
7	
6	
5	
4	
3	
2	
1	

Part A. Fill in the name of each numbered layer in the seven-layer OSI model. [7 pts]

Part B. For each layer listed below, explain its primary responsibility. Be specific about what kind of information or delivery the layer provides. [5 pts]

(i) Layer 1

(ii) Layer 3

(iii) Layer 4

Question 3. Inheritance (16 pts)

The following class hierarchy represents several kinds of performers. The program compiles without error.

```cpp
class Performer {
 public:
    virtual ~Performer() = default;

    void Introduce() {
        std::cout << "Performer::Introduce" << std::endl;
        Act();
    }

    virtual void Act() {
        std::cout << "Performer::Act" << std::endl;
    }

    void Encore() {
        std::cout << "Performer::Encore" << std::endl;
    }
};

class Magician : public Performer {
 public:
    void Introduce() {
        std::cout << "Magician::Introduce" << std::endl;
        Reveal();
    }

    void Act() override {
        std::cout << "Magician::Act" << std::endl;
    }

    void Encore() {
        std::cout << "Magician::Encore" << std::endl;
    }

    virtual void Reveal() {
        std::cout << "Magician::Reveal" << std::endl;
    }
};

class Juggler : public Performer {
 public:
    void Act() override {
        std::cout << "Juggler::Act" << std::endl;
    }
};

class Illusionist : public Magician {
 public:
    void Act() override {
        std::cout << "Illusionist::Act" << std::endl;
        Magician::Act();
    }

    void Encore() {
        std::cout << "Illusionist::Encore" << std::endl;
    }

    void Reveal() override {
        std::cout << "Illusionist::Reveal" << std::endl;
    }
};
```

Part A. Write the complete output, in order, exactly as it is printed. You do NOT need to write code. [8 pts]

```
1  Performer* pp = new Performer();
2  Performer* pm = new Magician();
3  Magician*  mi = new Illusionist();
4  Performer* pj = new Juggler();
5  Magician*  mm = new Magician();
6
7  pp->Introduce();  // (1)
8  pm->Introduce();  // (2)
9  mi->Introduce();  // (3)
10 pm->Encore();     // (4)
11 mi->Encore();     // (5)
12 pj->Act();        // (6)
13 mm->Reveal();     // (7)
14 mi->Act();        // (8)
```

Part B. Briefly state the difference between static and dynamic dispatch. [4 pts]

Part C. For each statement in Part A, circle either static or dynamic to indicate the type of dispatch. [4 pts]

(1)	Static	Dynamic	**(5)**	Static	Dynamic
(2)	Static	Dynamic	**(6)**	Static	Dynamic
(3)	Static	Dynamic	**(7)**	Static	Dynamic
(4)	Static	Dynamic	**(8)**	Static	Dynamic

Question 4. Object Slicing and STL (14 pts)

The code below is used by a museum to keep track of its exhibits. Note the virtual functions.

```
class Exhibit {                                                    // Base class
 public:
    explicit Exhibit(const std::string& name) : name_(name) {}
    virtual ~Exhibit() = default;

    void Rename(const std::string& name) {
        name_ = name;
    }

    virtual void Print() const {                                   // virtual function
        std::cout << "Exhibit: " << name_ << std::endl;
    }

 protected:
    std::string name_;
};

class Artifact : public Exhibit {                                  // Derived class
 public:
    Artifact(const std::string& name, const int year)
            : Exhibit(name), year_(year) {}

    void Print() const override {
        std::cout << "Artifact: " << name_ << " (" << year_ << ")" << std::endl;
    }

 private:
    const int year_;
};
```

To use this code, they create an STL map to keep track of which exhibit is in which room of the museum.

```
int main() {
    Exhibit fossil("Dinosaur Skeleton");
    Artifact moon_rock("Moon Rock", 1969);

    // Map of room # to exhibit
    std::map<int, Exhibit> catalog;
    catalog.emplace(2, fossil);
    catalog.emplace(3, moon_rock);

    // CHECKPOINT

    moon_rock.Rename("Apollo Sample");

    moon_rock.Print();
    catalog[3.Print();
}
```

Read the complete program on this page, then answer some questions on the next page.

Part A. What is printed at the end of the program (i.e. after line 16 of main)? [2 pts]

Part B. Do STL containers store their elements by-reference or by-value? Explain how this relates to "object slicing" and how your previous answers support this claim. (Hint: consider lines 6-8). [3 pts]

Part C. One way to fix "object slicing" is to store pointers instead of base-class objects. Explain why. [3 pts]

Part D. Rewrite the main function using `std::unique_ptr<Type>` and `std::make_unique<Type>`.

You will need to preserve the functionality of main, including to create new objects, write a new map declaration, rename the moon rock Artifact, and to call Print on different objects. [6 pts]

Question 5. Templates (10 pts)

The following two files are compiled together. Some functions compile, while others do not compile because of template errors. Read both files before answering the questions.

combine.h

```
#ifndef COMBINE_H_
#define COMBINE_H_

template <typename T>
T CombineLargerFirst(const T& first, const T& second) {
    if (first < second) {
        return second + first;
    }
    return first + second;
}

#endif  // COMBINE_H_
```

combine.cc

```
#include "combine.h"

class Score {
 public:
    explicit Score(int points) : points_(points) {}

    bool operator<(const Score& other) const {
        return points_ < other.points_;
    }

 private:
    int points_;
};

int CombineInts() {
    return CombineLargerFirst(20, 22);                  // Call A
}

double CombineMixed() {
    return CombineLargerFirst(20, 22.5);                // Call B
}

double CombineMixedExplicitly() {
    return CombineLargerFirst<double>(20, 22.5);        // Call C
}

Score CombineScores() {
    return CombineLargerFirst(Score(20), Score(22));    // Call D
}
```

Note that some of these template calls will produce compilation errors. Next, you will explain why.

Part A. Complete the table for Calls A-D. If no template type `T` is selected, explain why. If a type `T` is selected, state whether that function compiles. [4 pts]

Call	type T	Does it compile? Why or why not?
A		
B		
C		
D		

Part B. Call D selects `T = Score`, but its specialization fails. List the operations required from `T`, identify which one `Score` provides, and write only the declaration for the missing operation. [4 pts]

Part C. Templates are nearly always defined in header files. Why? (Hint: think about what phase of compilation they are generated during. What does this mean about their access?) [2 pts]

Question 6. Concurrent Interleavings (8 pts)

The program below starts two threads that execute the same Worker function. Assume each labeled statement R, W, and P executes atomically. Answer the follow questions about which outputs are possible.

```
1  std::string message = "start";            // global variable
2
3  void* Worker(void* argument) {
4      char* suffix = static_cast<char*>(argument);
5
6      std::string snapshot = message;       // R: take a snapshot of our global
7      message = snapshot + suffix;          // W: replace global variable
8
9      std::printf("%s: %s\n", suffix + 1, message.c_str());         // P: print
10     return nullptr;
11 }
12
13 int main() {
14     pthread_t t1, t2;
15
16     char read_suffix[] = "-read";
17     char write_suffix[] = "-write";
18
19     pthread_create(&t1, nullptr, Worker, read_suffix);
20     pthread_create(&t2, nullptr, Worker, write_suffix);
21     pthread_join(t1, nullptr);
22     pthread_join(t2, nullptr);
23
24     std::printf("final: %s\n", message.c_str());                  // P: print
25 }
```

For each candidate below, circle YES if that exact three-line output could be produced by some legal interleaving under the stated execution model. Circle NO if it is impossible.

	Is it possible?	printf(...) output		
(a)	YES NO	`read: start-read`	`write: start-write`	`final: start-write`
(b)	YES NO	`read: start-read`	`write: start-write`	`final: start-read-write`
(c)	YES NO	`write: start-write`	`read: start-read`	`final: start-read`
(d)	YES NO	`write: start-read`	`read: start-write`	`final: start-write`
(e)	YES NO	`read: start-read-write`	`write: start-read-write`	`final: start-read-write`
(f)	YES NO	`read: start-read-write`	`write: start-read-write`	`final: start-write`
(g)	YES NO	`write: start-write`	`read: start-write-read`	`final: start-write-read`
(h)	YES NO	`write: start-write-read`	`read: start-read-write`	`final: start-read-write`

Question 7. Execution Models (12 pts)

For each task, pick the execution model that best fits the task: single-threaded, event-driven, multi-threading, and multi-processing. In 1-2 sentences, describe why that execution model makes sense.

Task 1: Simple Server. A server maintains thousands of mostly idle client sockets. When a socket becomes ready, the server reads a short message and sends a short reply. The response message is very short and the server does not need to perform much work on the CPU for each response.

Task 2: File Copy. A command-line program opens one input file, copies its bytes to one output file, closes both files, and exits. It uses the POSIX API and calls read and write in a while loop.

Task 3: Cat Compression. A user uploads 100 cat images. For each image, our program needs to run a compression program that is very CPU-intensive. It compresses each input file and writes the bytes to a different output file. The compression program runs on each file independently.

Task 4: Grading Repositories. CSE 333 students push their code to GitLab. The TAs need to download all of the student repositories from GitLab onto Attu. They write a program that takes in a list of GitLab repositories and clones each one into a separate folder.

CSE 333 26su

Final Exam

Personalized Section

Please staple this to your other exam papers when turning in the exam.

Name	**First Last**
UW NetID	**StudentId**

This is the personalized section of your final exam. This quarter we have been giving you feedback on your exercise and homework submissions, working with you during office hours, and answering your questions on the discussion board.

Based on those interactions, we have written the following question just for you. It targets a concept that you've gotten feedback on previously in the course. This is a chance for you to show us that you've internalized that feedback and learned.

Personalized message page

Question 8. Personalized Question 1 (8 pts)

Question 9. Personalized Question 2 (10 pts)