

CSE 333 Section 5 - C++ Classes, Dynamic Memory, Midterm Review

Welcome back to section! We're happy you're here ♪•x•♪-+◇★

Member, Non-Member, and Friends, Oh My!

Exercise 1) Complete the following table (use objects obj1 and obj2, where appropriate):

	Member	Non-member
Access to Private Members:		
Function call (Func):		
Operator call (*):		
When preferred:		

Constructors, Destructors, what is going on?

- **Constructor:** Can define any number as long as they have different parameters. Constructs a new instance of the class. The *default constructor* takes no arguments.
- **Copy Constructor:** Creates a new instance of the class based on another instance (it's the constructor that takes a reference to an object of the same class). Automatically invoked when passing or returning a non-reference object to/from a function.
- **Assignment Operator:** Assigns the values of the right-hand-expression to the left-hand-side instance.
- **Destructor:** Cleans up the class instance, e.g., free dynamically allocated memory used by this class instance.

What happens if you don't define a copy constructor? Or an assignment operator? Or a destructor? Why might this be bad?

How can you disable the copy constructor/assignment operator/destructor?

Exercise 2) Order the execution of the following program:

```
class Bar {
public:
    Bar() : num_(0) { }                // 0-arg ctor
    Bar(int num) : num_(num) { }        // 1-arg ctor
    Bar(const Bar& other) : num_(other.num_) { } // cctor
    ~Bar() { }                          // dtor
    Bar& operator=(const Bar& other) = default; // op=
    int get_num() const { return num_; } // getter

private:
    int num_;
};
```

```
class Foo {
public:
    Foo() : bar_(5) { }                // 0-arg ctor
    Foo(const Bar& b) { bar_ = b; }     // 1-arg ctor
    ~Foo() { }                          // dtor

private:
    Bar bar_;
};
```

```
int main() {

    Bar b1(3);
    Bar b2 = b1;
    Foo f1;
    Foo f2(b2);
    return EXIT_SUCCESS;
}
```

Number the following starting with 1.

Each method may be called more than once (*i.e.*, you can put multiple numbers on the same line).

```
_____ Bar 0-arg ctor
_____ Bar 1-arg ctor
_____ Bar cctor
_____ Bar op=
_____ Foo 0-arg ctor
_____ Foo 1-arg ctor
_____ Foo dtor
_____ Bar dtor
```

Dynamically-Allocated Memory: New and Delete

In C++, memory can be heap-allocated using the keywords “new” and “delete”. You can think of these like `malloc()` and `free()` with some key differences:

- Unlike `malloc()` and `free()`, `new` and `delete` are operators, not functions.
- The implementation of allocating heap space may vary between `malloc` and `new`.

New: Allocates the type on the heap, calling the specified constructor if it is a class type. Syntax for arrays is “`new type[num]`”. Returns a pointer to the type.

Delete: Deallocates the type from the heap, calling the destructor if it is a class type. For anything you called “new” on, you should at some point call “delete” to clean it up. Syntax for arrays is “`delete[] name`”.

Just like baking soda and vinegar, you shouldn’t mix `malloc/free` with `new/delete`.

Exercise 3) Memory Leaks

```
class Leaky {
public:
    Leaky() { x_ = new int(5); }
private:
    int* x_;
};

int main(int argc, char** argv) {
    Leaky** dbl_ptr = new Leaky*;
    Leaky* lky_ptr = new Leaky();
    *dbl_ptr = lky_ptr;
    delete dbl_ptr;
    return EXIT_SUCCESS;
}
```

What is leaked by this program? How would you fix the memory leaks?

Exercise 4) Identify the memory error with the following code.

```
class BadCopy {
public:
    BadCopy() { arr_ = new int[5]; }
    ~BadCopy() { delete [] arr_; }
private:
    int* arr_;
};

int main(int argc, char** argv) {
    BadCopy* bc1 = new BadCopy;
    BadCopy* bc2 = new BadCopy(*bc1); // cctor

    delete bc1;
    delete bc2;

    return EXIT_SUCCESS;
}
```

Hint: Draw a memory diagram. What happens when bc1 gets deleted?

Exercise 5) Classes usage [Extra Practice]. Consider the following classes:

```
class IntArrayList {
public:
    IntArrayList()
        : array_(new int[MAXSIZE]), len_(0), maxsize_(MAXSIZE) { }
    IntArrayList(const int* const arr, size_t len)
        : len_(len), maxsize_(len_*2) {
        array_ = new int[maxsize_];
        memcpy(array_, arr, len * sizeof(int));
    }

    IntArrayList(const IntArrayList& rhs) {
        len_ = rhs.len_;
        maxsize_ = rhs.maxsize_;
        array_ = new int[maxsize_];
        memcpy(array_, rhs.array_, maxsize_ * sizeof(int));
    }
    // synthesized destructor
    // synthesized assignment operator

private:
    int* array_;
    size_t len_;
    size_t maxsize_;
};

class Wrap {
public:
    Wrap() : p_(nullptr) {}
    Wrap(IntArrayList* p) : p_(p) { *p_ = *p; }
    IntArrayList* p() const { return p_; }
private:
    IntArrayList* p_;
};

struct List {
    IntArrayList v;
};
```

Here's an example program using these classes:

```
int main(int argc, char** argv) {  
    IntArrayList a;  
    IntArrayList* b = new IntArrayList();  
    struct List l { a };  
    struct List m { *b };  
    Wrap w(b);  
    delete b;  
    return EXIT_SUCCESS;  
}
```

Draw a memory diagram of the program:

How does the above program leak memory?

Fix the issue in the code above. You may write the solution here.

Extra Practice - Past Midterm Question

Consider the following (very unusual) C++ program which does compile and execute successfully. Write the output produced when it is executed.

```
#include <iostream>
using namespace std;
class foo {
public:
    foo()                { cout << "p"; }           // ctor
    foo(int i)           { cout << "a"; }           // ctor (1 int)
    foo(int i, int j)    { cout << "h"; }           // ctor (2 ints)
    ~foo()               { cout << "s"; }           // dtor
};
class bar {
public:
    bar(): foo_(new foo()) { cout << "g"; }           // ctor
    bar(int i): foo_(new foo(i)) { cout << "p"; }       // ctor (1 int)
    ~bar()               { cout << "e"; delete foo_; } // dtor
private:
    foo *foo_;
    foo otherfoo_;
};
class baz {
public:
    baz(int a,int b,int c) : bar_(a), foo_(b,c)
                                { cout << "i"; }           // ctor (3 ints)
    ~baz()                   { cout << "n"; }           // dtor
private:
    foo foo_;
    bar bar_;
};
int main() {
    baz b(1,2,3);
    return EXIT_SUCCESS;
}
```

Midterm Review

Topics: <https://courses.cs.washington.edu/courses/cse333/25su/exams/midtermtopics.html>

Past Exams: <https://courses.cs.washington.edu/courses/cse333/25su/exams/index.html>

Use this scratch work space for jotting down notes :)