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

Welcome back to section! We're glad that you're here :)

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;
}
```