Poll Everywhere

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About how long did Exercise 5 take you?

A. [0, 2) hours
B. [2, 4) hours
C. [4, 6) hours
D. [6, 8) hours
E. 8+ Hours
F. I didn't submit / I prefer not to say

C++ Constructor Insanity (cont'd)

CSE 333 Fall 2023

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Relevant Course Information

- Exercise 6 released yesterday, due next ~~Monday~~ Wednesday (10/25)
  - Write a substantive class in C++
- Midterm in next Friday's class (10/27)
  - See course website for details & sample midterms
  - Review session will go forward Monday evening (zoom); see Ed post tomorrow with details
- Homework 2 due on 10/30
  - See Ed post about partner finding & confirmation

Lecture Outline

- Constructors *(covered last lecture)*
- Copy Constructors *(covered last lecture)*
- **Assignment**
- Destructors

Assignment != Construction

- "=" is the assignment operator
  - Assigns values to an *existing, already constructed* object

```
Point w;          // default ctor
Point x(1, 2);    // two-ints-argument ctor
Point y(x);       // copy ctor
Point z = w;      // copy ctor
y = x;            // assignment operator
```

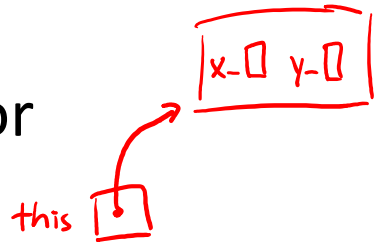
z did not exist → `Point z = w;`

y exists → `y = x;`

`// assignment operator` (method operator=( ))

Overloading the "=" Operator

- You can choose to define the "=" operator
  - But there are some rules you should follow:




```
Point& Point::operator=(const Point& rhs) {
  if (this != &rhs) {  // (1) always check against this
    x_ = rhs.x_;
    y_ = rhs.y_;
  }
  return *this;        // (2) always return *this from op=
}

Point a;          // default constructor
a = b = c;        // works because = return *this
a = (b = c);      // equiv. to above (= is right-associative)
(a = b) = c;      // "works" because = returns a non-const
```

more important when dealing with dynamically allocated memory

returns reference to class object (allows for chaining)

a.operator=(b.operator=(c))

Synthesized Assignment Operator

- If you don't define the assignment operator, C++ will synthesize one for you
  - It will do a *shallow* copy of all of the fields (*i.e.*, member variables) of your class
  - Sometimes the right thing; sometimes the wrong thing

Usually wrong whenever class owns a resource (e.g., dynamically allocated data)

```
#include "SimplePoint.h"

... // definitions for Distance() and SetLocation()

int main(int argc, char** argv) {
  SimplePoint x;
  SimplePoint y(x);
  y = x;              // invokes synthesized assignment operator
  return EXIT_SUCCESS;
}
```

Lecture Outline

- Constructors
- Copy Constructors
- Assignment
- **Destructors**

Destructors

- C++ has the notion of a destructor (dtor)
  - Invoked automatically when a class instance is deleted, goes out of scope, etc. (even via exceptions or other causes!)
  - Place to put your cleanup code – free any dynamic storage or other resources owned by the object
  - Standard C++ idiom for managing dynamic resources
    - Slogan: "*Resource Acquisition Is Initialization*" (RAII)

tilde → ~Point() ← no parameters

```
Point::~Point() {    // destructor
  // do any cleanup needed when a Point object goes away
  // (nothing to do here since we have no dynamic resources)
}
```

executed in reverse order as ctor: ① body of dtor
② destruct members in reverse order of declaration

Destructor Example

```
class FileDescriptor {
 public:
  FileDescriptor(char* file) {          // Constructor
    fd_ = open(file, O_RDONLY);
    // Error checking omitted
  }
  ~FileDescriptor() { close(fd_); }     // Destructor
  int get_fd() const { return fd_; }    // inline member function
 private:
  int fd_;  // data member
};  // class FileDescriptor
```

dtor automatically closes file for the user!

FileDescriptor.h

```
#include "FileDescriptor.h"

int main(int argc, char** argv) {
  FileDescriptor fd("foo.txt");
  return EXIT_SUCCESS;
}
```

destruct object when it falls out of scope (here, when we return)

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- How many times does the ***destructor*** get invoked?
  - Assume `Point` with everything defined (ctor, cctor, =, dtor)
  - Assume no compiler optimizations

test.cc

```
Point PrintRad(Point& pt) {
  Point origin(0, 0);
  double r = origin.Distance(pt);
  double theta = atan2(pt.get_y(), pt.get_x());
  cout << "r = " << r << endl;
  cout << "theta = " << theta << " rad" << endl;
  return pt;
}

int main(int argc, char** argv) {
  Point pt(3, 4);
  PrintRad(pt);
  return EXIT_SUCCESS;
}
```

A. 1
B. 2
C. 3
D. 4
E. We're lost…

Class Definition (from last lecture)

Point.h

```
#ifndef POINT_H_
#define POINT_H_

class Point {
 public:
  Point(int x, int y);                    // constructor
  int get_x() const { return x_; }        // inline member function
  int get_y() const { return y_; }        // inline member function
  double Distance(const Point& p) const;  // member function
  void SetLocation(int x, int y);         // member function

 private:
  int x_;  // data member
  int y_;  // data member
};  // class Point

#endif  // POINT_H_
```

this const means that this function is not allowed to change the object on which it is called (the implicit "this" pointer)

function definitions

declarations

compiler may choose to expand inline (like a macro) instead on an actual function call

naming convention for class data members (Google C++ style guide)

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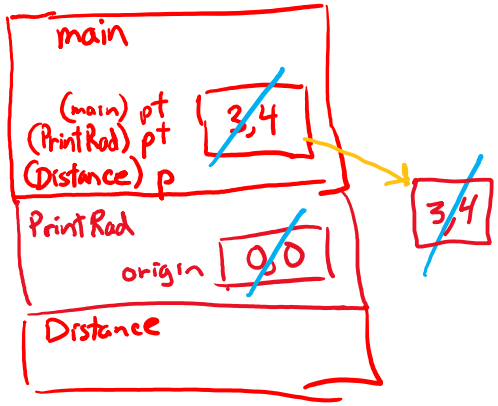
- How many times does the ***destructor*** get invoked?

ctor	cctor	op=	dtor
2	1	0	3



test.cc

```
Point PrintRad(Point& pt) {
  Point origin(0, 0);          // ② ctor called
  double r = origin.Distance(pt);      // Distance takes ref, so object NOT copied
  double theta = atan2(pt.get_y(), pt.get_x());
  cout << "r = " << r << endl;
  cout << "theta = " << theta << " rad" << endl;
  return pt;                   // ③ PrintRad returns an object, so cctor is called to create a temp
}                              // ④ while cleaning up, origin is destructed

int main(int argc, char** argv) {
  Point pt(3, 4);              // ① ctor called
  PrintRad(pt);                // PrintRad takes ref, so pt is NOT copied
  return EXIT_SUCCESS;         // ⑤ return value of PrintRad ignored; temp is destructed
}                              // ⑥ while cleaning up, pt is destructed
```

Preview for Next Lecture

```
class FileDescriptor {
 public:
  FileDescriptor(char* file) {          // Constructor
    fd_ = open(file, O_RDONLY);
    // Error checking omitted
  }
  ~FileDescriptor() { close(fd_); }     // Destructor
  int get_fd() const { return fd_; }    // inline member function
 private:
  int fd_;  // data member
};  // class FileDescriptor
```

FileDescriptor.h

```
#include "FileDescriptor.h"

int main(int argc, char** argv) {
  FileDescriptor fd1(foo.txt);
  FileDescriptor fd2(fd);       // Invokes synthesized cctor
  return EXIT_SUCCESS;
}
```

just copies data members (fd_)

What happens when we return and destruct our objects?

(This won't crash the program, but what if we were using heap allocation instead of file descriptors?)

Extra Exercise #1

- Write a C++ program that:
  - Has a class representing a 3-dimensional point
  - Has the following methods:
    - Return the inner product of two 3D points
    - Return the distance between two 3D points
    - Accessors and mutators for the `x`, `y`, and `z` coordinates

Extra Exercise #2

- Write a C++ program that:
  - Has a class representing a 3-dimensional box
    - Use your Extra Exercise #1 class to store the coordinates of the vertices that define the box
    - Assume the box has right-angles only and its faces are parallel to the axes, so you only need 2 vertices to define it
  - Has the following methods:
    - Test if one box is inside another box
    - Return the volume of a box
    - Handles `<<`, `=`, and a copy constructor
    - Uses `const` in all the right places

Extra Exercise #3

- Modify your Point3D class from Extra Exercise #1
  - Disable the copy constructor and assignment operator
  - Attempt to use copy & assignment in code and see what error the compiler generates
  - Write a `CopyFrom()` member function and try using it instead
    - (See details about `CopyFrom()` in next lecture)

Extra Exercise #4

- Write a C++ class that:
  - Is given the name of a file as a constructor argument
  - Has a `GetNextWord()` method that returns the next whitespace- or newline-separated word from the file as a copy of a `string` object, or an empty string once you hit EOF
  - Has a destructor that cleans up anything that needs cleaning up