Chapter 7: Classes Part II

Outline

7.1 Introduction

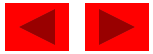
- Chapters 6 through 8 discuss object-based programming (OBP)
- Chapters 9 and 10 discuss inheritance and polymorphism

7.2 const (Constant) Objects and const Member Functions

- Principle of least privilege
  - Only give objects permissions they need, no more
- Keyword **`const`**
  - Specify that an object is not modifiable
  - Any attempt to modify the object is a syntax error
  - Example

```
const Time noon( 12, 0, 0 );
```

    - Declares a **`const`** object **`noon`** of class **`Time`** and initializes it to 12



7.2 const (Constant) Objects and const Member Functions

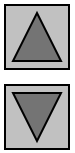
- **`const`** objects require **`const`** functions
  - Member functions declared **`const`** cannot modify their object
  - **`const`** must be specified in function prototype and definition
  - Prototype:

    ReturnType FunctionName(param1,param2…) const;
  - Definition:

    ReturnType FunctionName(param1,param2…) const { …}
  - Example:

```
int A::getValue() const { return
   privateDataMember };
```

    - Returns the value of a data member but doesn't modify anything so is declared **`const`**
- Constructors / Destructors cannot be **`const`**
  - They need to initialize variables, therefore modifying them

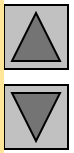


Outline


```
1  // Fig. 7.1: time5.h
2  // Declaration of the class Time.
3  // Member functions defined in time5.cpp
4  #ifndef TIME5_H
5  #define TIME5_H
6
7  class Time {
8  public:
9     Time( int = 0, int = 0, int = 0 );  // default constructor
10
11    // set functions
12    void setTime( int, int, int );  // set time
13    void setHour( int );     // set hour
14    void setMinute( int );   // set minute
15    void setSecond( int );   // set second
16
17    // get functions (normally declared const)
18    int getHour() const;     // return hour
19    int getMinute() const;   // return minute
20    int getSecond() const;   // return second
21
22    // print functions (normally declared const)
23    void printMilitary() const;  // print military time
24    void printStandard();        // print standard tim
25 private:
26    int hour;              // 0 - 23
27    int minute;            // 0 - 59
28    int second;            // 0 - 59
29 };
30
31 #endif
```

const functions

non-**const** functions



Outline

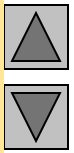
Source Code

1. Load Header

1.1 Function definitions

```
32 // Fig. 7.1: time5.cpp
33 // Member function definitions for Time class.
34 #include <iostream>
35
36 using std::cout;
37
38 #include "time5.h"
39
40 // Constructor function to initialize private data.
41 // Default values are 0 (see class definition).
42 Time::Time( int hr, int min, int sec )
43    { setTime( hr, min, sec ); }
44
45 // Set the values of hour, minute, and second.
46 void Time::setTime( int h, int m, int s )
47 {
48    setHour( h );
49    setMinute( m );
50    setSecond( s );
51 }
52
53 // Set the hour value
54 void Time::setHour( int h )
55    { hour = ( h >= 0 && h < 24 ) ? h : 0; }
56
57 // Set the minute value
58 void Time::setMinute( int m )
59    { minute = ( m >= 0 && m < 60 ) ? m : 0; }
60
61 // Set the second value
62 void Time::setSecond( int s )
63    { second = ( s >= 0 && s < 60 ) ? s : 0; }
```

The constructor is non-**const** but it can be called for **const** objects.



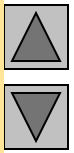
Outline

1.2 Purposely leave out **const** keyword for printStandard

```
64
65 // Get the hour value
66 int Time::getHour() const { return hour; }
67
68 // Get the minute value
69 int Time::getMinute() const { return minute; }
70
71 // Get the second value
72 int Time::getSecond() const { return second; }
73
74 // Display military format time: HH:MM
75 void Time::printMilitary() const
76 {
77    cout << ( hour < 10 ? "0" : "" ) << hour <<
78         << ( minute < 10 ? "0" : "" ) << minut
79 }
80
81 // Display standard format time: HH:MM:SS AM (or PM)
82 void Time::printStandard()  // should be const
83 {
84    cout << ( ( hour == 12 ) ? 12 : hour % 12 ) << ":"
85         << ( minute < 10 ? "0" : "" ) << minute << ":"
86         << ( second < 10 ? "0" : "" ) << second
87         << ( hour < 12 ? " AM" : " PM" );
88 }
```

Keyword **const** in function definition and prototype.

Non-**const** functions cannot use **const** objects, even if they don't modify them (such as **printStandard**).



Outline

1. Initialize variables

2. Attempt to use non-**const** functions with **const** objects

```
// Fig. 7.1: fig07_01.cpp
// Attempting to access a const object with
// non-const member functions.
#include "time5.h"

int main()
{
   Time wakeUp( 6, 45, 0 );       // non-constant object
   const Time noon( 12, 0, 0 );   // constant object

                            // MEMBER FUNCTION   OBJECT
   wakeUp.setHour( 18 );    // non-const         non-const

   noon.setHour( 12 );      // non-const         const

   wakeUp.getHour();        // const             non-const

   noon.getMinute();        // const             const
   noon.printMilitary();    // const             const
   noon.printStandard();    // non-const         const
   return 0;
}
```

Compiler errors generated.

Program Output

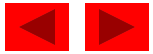
```
Compiling...
Fig07_01.cpp
d:fig07_01.cpp(14) : error C2662: 'setHour' : cannot convert 'this'
pointer from 'const class Time' to 'class Time &'
Conversion loses qualifiers
d:\fig07_01.cpp(20) : error C2662: 'printStandard' : cannot convert
'this' pointer from 'const class Time' to 'class Time &'
Conversion loses qualifiers
Time5.cpp
Error executing cl.exe.

test.exe - 2 error(s), 0 warning(s)
```

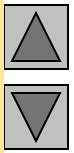
7.2 const (Constant) Objects and const Member Functions

- Member initializer syntax
  - Data member increment in class **`Increment`**
  - constructor for **`Increment`** is modified as follows:

```
Increment::Increment( int c, int i )
   : increment( i )
{ count = c; }
```

  - **`: increment( i )`** initializes increment to **`i`**
  - All data members can be initialized using member initializer syntax
  - **`const`**s and references must be initialized using member initializer syntax
  - Multiple member initializers
    - Use comma-separated list after the colon





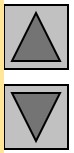
Outline

1. Class definition

1.1 Function definitions

```
1  // Fig. 7.2: fig07_02.cpp
2  // Using a member initializer to initialize a
3  // constant of a built-in data type.
4  #include <iostream>
5
6  using std::cout;
7  using std::endl;
8
9  class Increment {
10 public:
11    Increment( int c = 0, int i = 1 );
12    void addIncrement() { count += increment; }
13    void print() const;
14
15 private:
16    int count;
17    const int increment;   // const data member
18 };
19
20 // Constructor for class Increment
21 Increment::Increment( int c, int i )
22    : increment( i ) // initializer for const member
23 { count = c; }
24
25 // Print the data
26 void Increment::print() const
27 {
28    cout << "count = " << count
29         << ", increment = " << increment << endl;
30 }
31
32 int main()
33 {
```

If we try to initialize **`increment`** with an assignment statement (such as **`increment = i`**) instead of a member initializer we get an error.



Outline

1.2 Initialize variables

2. Function calls

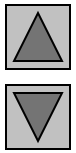
3. Output results

```
34    Increment value( 10, 5 );
35
36    cout << "Before incrementing: ";
37    value.print();
38
39    for ( int j = 0; j < 3; j++ ) {
40       value.addIncrement();
41       cout << "After increment " << j + 1 << ": ";
42       value.print();
43    }
44
45    return 0;
46 }
```

```
Before incrementing: count = 10, increment = 5
After increment 1: count = 15, increment = 5
After increment 2: count = 20, increment = 5
After increment 3: count = 25, increment = 5
```

7.3 Composition: Objects as Members of Classes

- Composition
  - Class has objects of other classes as members
- Construction of objects
  - Member objects constructed in order declared
    - Not in order of constructor's member initializer list
  - Constructed before their enclosing class objects (host objects)



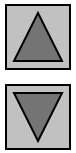
Outline

1. Class definition

1.1 Member functions

1.2 Member variables

```
1  // Fig. 7.4: date1.h
2  // Declaration of the Date class.
3  // Member functions defined in date1.cpp
4  #ifndef DATE1_H
5  #define DATE1_H
6
7  class Date {
8  public:
9     Date( int = 1, int = 1, int = 1900 ); // default constructor
10    void print() const;  // print date in month/day/year format
11    ~Date();  // provided to confirm destruction order
12 private:
13    int month;  // 1-12
14    int day;    // 1-31 based on month
15    int year;   // any year
16
17    // utility function to test proper day for month and year
18    int checkDay( int );
19 };
20
21 #endif
```



Outline

1. Load header

1.1 Function definitions

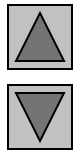
1.2 `Date` constructor

```
22 // Fig. 7.4: date1.cpp
23 // Member function definitions for Date class.
24 #include <iostream>
25
26 using std::cout;
27 using std::endl;
28
29 #include "date1.h"
30
31 // Constructor: Confirm proper value for month;
32 // call utility function checkDay to confirm proper
33 // value for day.
34 Date::Date( int mn, int dy, int yr )
35 {
36    if ( mn > 0 && mn <= 12 )       // validate the month
37       month = mn;
38    else {
39       month = 1;
40       cout << "Month " << mn << " invalid. Set to month 1.\n";
41    }
42
43    year = yr;                      // should validate yr
44    day = checkDay( dy );           // validate the day
45
46    cout << "Date object constructor for date ";
47    print();         // interesting: a print with no arguments
48    cout << endl;
49 }
50
```

Constructor will print a line when called.

```
51 // Print Date object in form  month/day/year
52 void Date::print() const
53    { cout << month << '/' << day << '/' << year; }
54
55 // Destructor: provided to confirm destru
56 Date::~Date()
57 {
58    cout << "Date object destructor for date ";
59    print();
60    cout << endl;
61 }
62
63 // Utility function to confirm proper day value
64 // based on month and year.
65 // Is the year 2000 a leap year?
66 int Date::checkDay( int testDay )
67 {
68    static const int daysPerMonth[ 13 ] =
69       {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};
70
71    if ( testDay > 0 && testDay <= daysPerMonth[ month ] )
72       return testDay;
73
74    if ( month == 2 &&      // February: Check for leap year
75         testDay == 29 &&
76         ( year % 400 == 0 ||
77           ( year % 4 == 0 && year % 100 != 0 ) ) )
78       return testDay;
79
80    cout << "Day " << testDay << " invalid. Set to day 1.\n";
81
82    return 1;  // leave object in consistent state if bad value
83 }
```

Destructor will print a line when called.



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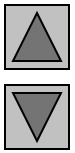


Outline

1. Load header

1.1 Class definition

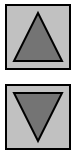
1.2 Member functions

1.3 Member variables

1.3.1 Include **const** variables from **Date** class

```
84 // Fig. 7.4: emply1.h
85 // Declaration of the Employee class.
86 // Member functions defined in emply1.cpp
87 #ifndef EMPLY1_H
88 #define EMPLY1_H
89
90 #include "date1.h"
91
92 class Employee {
93 public:
94    Employee( char *, char *, int, int, int, int, int, int );
95    void print() const;
96    ~Employee();  // provided to confirm destruction order
97 private:
98    char firstName[ 25 ];
99    char lastName[ 25 ];
100   const Date birthDate;
101   const Date hireDate;
102};
103
104#endif
```

Composition - including objects of other classes.



Outline

1. Load header files

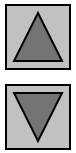
1.1 Function definitions

1.2 **Employee** constructor

1.2.1 Use member-initializer syntax for **const Date** members

```
105// Fig. 7.4: emply1.cpp
106// Member function definitions for Employee class.
107#include <iostream>
108
109using std::cout;
110using std::endl;
111
112#include <cstring>
113#include "emply1.h"
114#include "date1.h"
115
116Employee::Employee( char *fname, char *lname,
117                    int bmonth, int bday, int byear,
118                    int hmonth, int hday, int hyear )
119   : birthDate( bmonth, bday, byear ),
120     hireDate( hmonth, hday, hyear )
121{
122   // copy fname into firstName and be sure that it fits
123   int length = strlen( fname );
124   length = ( length < 25 ? length : 24 );
125   strncpy( firstName, fname, length );
126   firstName[ length ] = '\0';
127
128   // copy lname into lastName and be sure that it fits
129   length = strlen( lname );
130   length = ( length < 25 ? length : 24 );
131   strncpy( lastName, lname, length );
132   lastName[ length ] = '\0';
133
134   cout << "Employee object constructor: "
135        << firstName << ' ' << lastName << endl;
136}
```

Constructor will print a line when called.



Outline

1.3 `print` definition

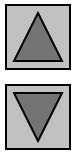
1.4 `Employee` destructor

```
137
138 void Employee::print() const
139 {
140    cout << lastName << ", " << firstName << "\nHired: ";
141    hireDate.print();
142    cout << "  Birth date: ";
143    birthDate.print();
144    cout << endl;
145 }
146
147 // Destructor: provided to confirm destruction order
148 Employee::~Employee()
149 {
150    cout << "Employee object destructor: "
151         << lastName << ", " << firstName << endl;
152 }
```

The **`print`** function is **`const`** and will print whenever a **`Date`** object is created or destroyed. It can print **`const`** objects because it is a **`const`** function.

`Print` requires no arguments, it is linked implicitly to the object that calls it.

Destructor will print a line when called.



Outline

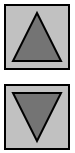
1. Load header files

2. Create **Employee** object

2.1 Attempt invalid **Date** setting

```
153// Fig. 7.4: fig07_04.cpp
154// Demonstrating composition: an object with member objects.
155#include <iostream>
156
157using std::cout;
158using std::endl;
159
160#include "emply1.h"
161
162int main()
163{
164   Employee e( "Bob", "Jones", 7, 24, 1949, 3, 12, 1988 );
165
166   cout << '\n';
167   e.print();
168
169   cout << "\nTest Date constructor with invalid values:\n";
170   Date d( 14, 35, 1994 );  // invalid Date values
171   cout << endl;
172   return 0;
173}
```

Only **emply.h** has to be loaded; that file has the command to load **date.h**.



Outline

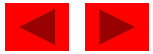
Program Output

```
Date object constructor for date 7/24/1949
Date object constructor for date 3/12/1988
Employee object constructor: Bob Jones

Jones, Bob
Hired: 3/12/1988  Birth date: 7/24/1949

Test Date constructor with invalid values:
Month 14 invalid. Set to month 1.
Day 35 invalid. Set to day 1.
Date object constructor for date 1/1/1994

Date object destructor for date 1/1/1994
Employee object destructor: Jones, Bob
Date object destructor for date 3/12/1988
Date object destructor for date 7/24/1949
```

Notice how inner objects are created first and destroyed last.

7.4 friend Functions and friend Classes

- **`friend`** function and **`friend`** classes
  - Can access **`private`** and **`protected`** members of another class
  - **`friend`** functions are not member functions of class
    - Defined outside of class scope
- Properties of friendship
  - Friendship is granted, not taken
  - Not symmetric (if **`B`** a **`friend`** of **`A`**, **`A`** not necessarily a **`friend`** of **`B`**)
  - Not transitive (if **`A`** a **`friend`** of **`B`**, **`B`** a **`friend`** of **`C`**, **`A`** not necessarily a **`friend`** of **`C`**)



7.4 friend Functions and friend Classes

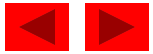
- **`friend`** declarations
  - To declare a **`friend`** function
    - Type **`friend`** before the function prototype in the class that is giving friendship

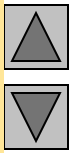
```
friend int myFunction( int x );
```

    should appear in the class giving friendship
  - To declare a **`friend`** class
  - Type **`friend class Classname`** in the class that is giving friendship
  - if **`ClassOne`** is granting friendship to **`ClassTwo`**,

```
friend class ClassTwo;
```

  - should appear in **`ClassOne`**'s definition





Outline

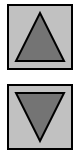

```
1  // Fig. 7.5: fig07_05.cpp
2  // Friends can access private members of a class.
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  // Modified Count class
9  class Count {
10    friend void setX( Count &, int ); // friend declaration
11 public:
12    Count() { x = 0; }                // constructor
13    void print() const { cout << x << endl; }  // output
14 private:
15    int x;  // data member
16 };
17
18 // Can modify private data of Count because
19 // setX is declared as a friend function of
20 void setX( Count &c, int val )
21 {
22    c.x = val; // legal: setX is a friend of Count
23 }
24
25 int main()
26 {
27    Count counter;
28
29    cout << "counter.x after instantiation: ";
30    counter.print();
```

setX a **friend** of class **Count** (can access **private** data).

setX is defined normally and is not a member function of **Count**.

Changing **private** variables allowed.

```
31    cout << "counter.x after call to setX friend function: ";
32    setX( counter, 8 );  // set x with a friend
33    counter.print();
34    return 0;
35 }
```



Outline

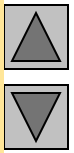
2. Modify object

3. Print results

```
counter.x after instantiation: 0
counter.x after call to setX friend function: 8
```

Program Output

`private` data was changed.



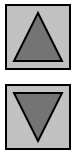
Outline

(Previous program without **friend** declared)

```
1  // Fig. 7.6: fig07_06.cpp
2  // Non-friend/non-member functions cannot access
3  // private data of a class.
4  #include <iostream>
5
6  using std::cout;
7  using std::endl;
8
9  // Modified Count class
10 class Count {
11 public:
12    Count() { x = 0; }                    // constructor
13    void print() const { cout << x << endl; }  // output
14 private:
15    int x;  // data member
16 };
17
18 // Function tries to modify private data of Count,
19 // but cannot because it is not a friend of Count.
20 void cannotSetX( Count &c, int val )
21 {
22    c.x = val;  // ERROR: 'Count::x' is not accessible
23 }
24
25 int main()
26 {
27    Count counter;
28
29    cannotSetX( counter, 3 ); // cannotSetX is not a friend
30    return 0;
31 }
```

cannotSetX is not a **friend** of class **Count**. It cannot access **private** data.

cannotSetX tries to modify a **private** variable…



Outline

Program Output

```
Compiling...
Fig07_06.cpp
D:\books\2000\cpphtp3\examples\Ch07\Fig07_06\Fig07_06.cpp(22) :
   error C2248: 'x' : cannot access private member declared in
   class 'Count'
        D:\books\2000\cpphtp3\examples\Ch07\Fig07_06\
        Fig07_06.cpp(15) : see declaration of 'x'
Error executing cl.exe.

test.exe - 1 error(s), 0 warning(s)
```

Expected compiler error - cannot access **`private`** data

7.5 Using the `this` Pointer

- **`this`** pointer
  - Allows objects to access their own address
  - Not part of the object itself
  - Implicit first argument on non-static member function call to the object
  - Implicitly reference member data and functions
  - The type of the **`this`** pointer depends upon the type of the object and whether the member function using **`this`** is **`const`**
  - In a non-**`const`** member function of **`Employee`**, **`this`** has type
    `Employee * const`
    - Constant pointer to an **`Employee`** object
  - In a **`const`** member function of **`Employee`**, this has type
    `const Employee * const`
    - Constant pointer to a constant **`Employee`** object

7.5 Using the this Pointer

- Examples using **`this`**
  - For a member function print data member **`x`**, either

```
this->x
```

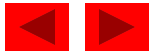
or

```
( *this ).x
```

- Cascaded member function calls
  - Function returns a reference pointer to the same object

```
{ return *this; }
```

  - Other functions can operate on that pointer
  - Functions that do not return references must be called last



7.5 Using the this Pointer

- Example of cascaded member function calls
  - Member functions **`setHour`**, **`setMinute`**, and **`setSecond`** all return **`*this`** (reference to an object)
  - For object **`t`**, consider

    ```
    t.setHour(1).setMinute(2).setSecond(3);
    ```

  - Executes **`t.setHour(1)`**, returns **`*this`** (reference to object) and the expression becomes

    ```
    t.setMinute(2).setSecond(3);
    ```

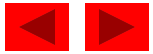
  - Executes **`t.setMinute(2)`**, returns reference and becomes

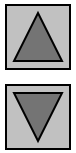
    ```
    t.setSecond(3);
    ```

  - Executes **`t.setSecond(3)`**, returns reference and becomes

    ```
    t;
    ```

  - Has no effect





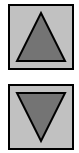
Outline


```
1  // Fig. 7.7: fig07_07.cpp
2  // Using the this pointer to refer to object members.
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  class Test {
9  public:
10    Test( int = 0 );              // default constructor
11    void print() const;
12 private:
13    int x;
14 };
15
16 Test::Test( int a ) { x = a; }  // constructor
17
18 void Test::print() const   // ( ) around *this
19 {
20    cout << "        x = " << x
21         << "\n  this->x = " << this->x
22         << "\n(*this).x = " << ( *this ).x << endl;
23 }
24
25 int main()
26 {
27    Test testObject( 12 );
28
29    testObject.print();
30
31    return 0;
32 }
```

Printing **x** directly.

Print **x** using the arrow **->** operator off the **this** pointer.

Printing **x** using the dot (**.**) operator. Parenthesis required because dot operator has higher precedence than *****. Without, interpreted incorrectly as ***(this.x)**.

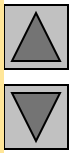


Outline

Program Output

```
       x = 12
  this->x = 12
(*this).x = 12
```

All three methods have the same result.

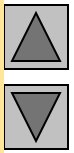


Outline

1. Class definition

```
1  // Fig. 7.8: time6.h
2  // Cascading member function calls.
3
4  // Declaration of class Time.
5  // Member functions defined in time6.cpp
6  #ifndef TIME6_H
7  #define TIME6_H
8
9  class Time {
10 public:
11    Time( int = 0, int = 0, int = 0 );  // default constructor
12
13    // set functions
14    Time &setTime( int, int, int ); // set hour, minute, second
15    Time &setHour( int );    // set hour
16    Time &setMinute( int );  // set min
17    Time &setSecond( int );  // set sec
18
19    // get functions (normally declared
20    int getHour() const;     // return
21    int getMinute() const;   // return minute
22    int getSecond() const;   // return second
23
24    // print functions (normally declared const)
25    void printMilitary() const;  // print military time
26    void printStandard() const;  // print standard time
27 private:
28    int hour;              // 0 - 23
29    int minute;            // 0 - 59
30    int second;            // 0 - 59
31 };
32
33 #endif
```

Notice the **`Time &`** - function returns a reference to a **`Time`** object. Specify object in function definition.



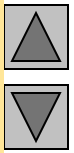
Outline

1. Load header file

1.1 Function definitions

```
34 // Fig. 7.8: time.cpp
35 // Member function definitions for Time class.
36 #include <iostream>
37
38 using std::cout;
39
40 #include "time6.h"
41
42 // Constructor function to initialize private data.
43 // Calls member function setTime to set variables.
44 // Default values are 0 (see class definition).
45 Time::Time( int hr, int min, int sec )
46    { setTime( hr, min, sec ); }
47
48 // Set the values of hour, minute, and second.
49 Time &Time::setTime( int h, int m, int s )
50 {
51    setHour( h );
52    setMinute( m );
53    setSecond( s );
54    return *this;   // enables cascading
55 }
56
57 // Set the hour value
58 Time &Time::setHour( int h )
59 {
60    hour = ( h >= 0 && h < 24 ) ? h : 0;
61
62    return *this;   // enables cascading
63 }
64
```

Returning ***this** enables cascading function calls

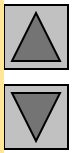


Outline

1.1 Function definitions

```
65 // Set the minute value
66 Time &Time::setMinute( int m )
67 {
68    minute = ( m >= 0 && m < 60 ) ? m : 0;
69
70    return *this;   // enables cascading
71 }
72
73 // Set the second value
74 Time &Time::setSecond( int s )
75 {
76    second = ( s >= 0 && s < 60 ) ? s : 0;
77
78    return *this;   // enables cascading
79 }
80
81 // Get the hour value
82 int Time::getHour() const { return hour; }
83
84 // Get the minute value
85 int Time::getMinute() const { return minute; }
86
87 // Get the second value
88 int Time::getSecond() const { return second; }
89
90 // Display military format time: HH:MM
91 void Time::printMilitary() const
92 {
93    cout << ( hour < 10 ? "0" : "" ) << hour << ":"
94         << ( minute < 10 ? "0" : "" ) << minute;
```

Returning **`*this`** enables cascading function calls



Outline

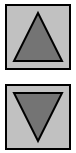

```
95 }
96
97 // Display standard format time: HH:MM:SS AM (or PM)
98 void Time::printStandard() const
99 {
100    cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
101         << ":" << ( minute < 10 ? "0" : "" ) << minute
102         << ":" << ( second < 10 ? "0" : "" ) << second
103         << ( hour < 12 ? " AM" : " PM" );
104}
105// Fig. 7.8: fig07_08.cpp
106// Cascading member function calls together
107// with the this pointer
108#include <iostream>
109
110using std::cout;
111using std::endl;
112
113#include "time6.h"
114
115int main()
116{
117   Time t;
118
119   t.setHour( 18 ).setMinute( 30 ).setSe
120   cout << "Military time: ";
121   t.printMilitary();
122   cout << "\nStandard time: ";
123   t.printStandard();
124
125   cout << "\n\nNew standard time: ";
126   t.setTime( 20, 20, 20 ).printStandard();
```

`printStandard` does not return a reference to an object.

Notice cascading function calls.

Cascading function calls. **`printStandard`** must be called after **`setTime`** because **`printStandard`** does not return a reference to an object.

`t.printStandard().setTime();` would cause an error.



Outline

```
127   cout << endl;
128
129   return 0;
130}
```

```
Military time: 18:30
Standard time: 6:30:22 PM

New standard time: 8:20:20 PM
```

Program Output

7.6 Dynamic Memory Allocation with Operators new and delete

- **`new`** and **`delete`**
  - Used for dynamic memory allocation
    - Superior to C's **`malloc`** and **`free`**
  - **`new`**
    - Creates an object of the proper size, calls its constructor and returns a pointer of the correct type
  - **`delete`**
    - Destroys object and frees space
  - Examples of **`new`**

```
TypeName *typeNamePtr;
```

    - Creates pointer to a **`TypeName`** object

```
typeNamePtr = new TypeName;
```

    - **`new`** creates **`TypeName`** object, returns pointer (which **`typeNamePtr`** is set equal to)

7.6 Dynamic Memory Allocation with Operators new and delete

- Examples of **delete**

```
delete typeNamePtr;
```

  - Calls destructor for **TypeName** object and frees memory

```
Delete [] arrayPtr;
```

  - Used to dynamically delete an array

- Initializing objects

```
double *thingPtr = new double( 3.14159 );
```

  - Initializes object of type **double** to **3.14159**

```
int *arrayPtr = new int[ 10 ];
```

  - Creates a ten element **int** array and assigns it to **arrayPtr**

7.7 `static` Class Members

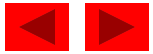
- **`static`** class members
  - Shared by all objects of a class
    - Normally, each object gets its own copy of each variable
  - Efficient when a single copy of data is enough
    - Only the **`static`** variable has to be updated
  - May seem like global variables, but have class scope
    - only accessible to objects of same class
  - Initialized at file scope
  - Exist even if no instances (objects) of the class exist
  - Both variables and functions can be **`static`**
  - Can be **`public`**, **`private`** or **`protected`**

7.7 `static` Class Members

- **`static`** variables
  - Static variables are accessible through any object of the class
  - **`public static`** variables
    - Can also be accessed using scope resolution operator(**`::`**)

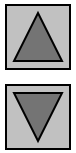
      `Employee::count`
  - **`private static`** variables
    - When no class member objects exist, can only be accessed via a **`public static`** member function
      - To call a **`public static`** member function combine the class name, the **`::`** operator and the function name

        `Employee::getCount()`



7.7 `static` Class Members

- **`Static`** functions
  - **`static`** member functions cannot access non-**`static`** data or functions
  - There is no **`this`** pointer for **`static`** functions, they exist independent of objects



Outline

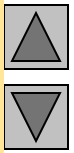
1. Class definition

1.1 Function prototypes

1.2 Declare variables

```
1  // Fig. 7.9: employ1.h
2  // An employee class
3  #ifndef EMPLOY1_H
4  #define EMPLOY1_H
5
6  class Employee {
7  public:
8     Employee( const char*, const char* );  // constructor
9     ~Employee();                           // destructor
10    const char *getFirstName() const;  // return first name
11    const char *getLastName() const;   // return last name
12
13    // static member function
14    static int getCount();  // return # objects instantiated
15
16 private:
17    char *firstName;
18    char *lastName;
19
20    // static data member
21    static int count;  // number of objects instantiated
22 };
23
24 #endif
```

static member function and variable declared.



Outline

1. Load header file

1.1 Initialize `static` data members

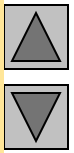
1.2 Function definitions

```
25 // Fig. 7.9: employ1.cpp
26 // Member function definitions for class Employee
27 #include <iostream>
28
29 using std::cout;
30 using std::endl;
31
32 #include <cstring>
33 #include <cassert>
34 #include "employ1.h"
35
36 // Initialize the static data member
37 int Employee::count = 0;
38
39 // Define the static member function that
40 // returns the number of employee objects instantiated.
41 int Employee::getCount() { return count; }
42
43 // Constructor dynamically allocates space for
44 // first and last name and uses strcpy to copy
45 // the first and last names into the object
46 Employee::Employee( const char *first, const char *last )
47 {
48    firstName = new char[ strlen( first ) + 1 ];
49    assert( firstName != 0 );   // ensure memory allocated
50    strcpy( firstName, first );
51
52    lastName = new char[ strlen( last ) + 1 ];
53    assert( lastName != 0 );    // ensure memory allocated
54    strcpy( lastName, last );
55
56    ++count;  // increment static count of employees
```

`static` data member **`count`** and function **`getCount( )`** initialized at file scope (required).

Note the use of **`assert`** to test for memory allocation.

`static` data member **`count`** changed when a constructor/destructor called.



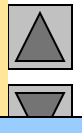
Outline

1.2 Function definitions

```
57    cout << "Employee constructor for " << firstName
58         << ' ' << lastName << " called." << endl;
59 }
60
61 // Destructor deallocates dynamically allocated memory
62 Employee::~Employee()
63 {
64    cout << "~Employee() called for " << firstName
65         << ' ' << lastName << endl;
66    delete [] firstName;  // recapture memory
67    delete [] lastName;   // recapture memory
68    --count;  // decrement static count of employees
69 }
70
71 // Return first name of employee
72 const char *Employee::getFirstName() const
73 {
74    // Const before return type prevents client from modifying
75    // private data. Client should copy returned string before
76    // destructor deletes storage to prevent undefined pointer.
77    return firstName;
78 }
79
80 // Return last name of employee
81 const char *Employee::getLastName() const
82 {
83    // Const before return type prevents client
84    // private data. Client should copy returned
85    // destructor deletes storage to prevent und
86    return lastName;
87 }
```

`static` data member **`count`** changed when a constructor/destructor called.

`Count` decremented because of destructor calls from **`delete`**.



Outline

1. ...e objects
2. Function calls
3. Print data

```
// Fig. 7.9: fig07_09.cpp
// Driver to test the employee class
#include <iostream>

using
using

#include "employ1.h"

int main()
{
   cout << "Number of employees before ins
        << Employee::getCount() << endl;

   Employee *e1Ptr = new Employee( "Susan", "Baker" );
   Employee *e2Ptr = new Employee( "Robert

   cout << "Number of employees after instantiation is "
        << e1Ptr->getCount();

   cout << "\n\nEmployee 1: "
        << e1Ptr->getFirstName()
        << " " << e1Ptr->getLastName()
        << "\nEmployee 2: "
        << e2Ptr->getFirstName()
        << " " << e2Ptr->getLastName() << "\n\n";

   delete e1Ptr;   // recapture memory
   e1Ptr = 0;
   delete e2Ptr;   // recapture memory
   e2Ptr = 0;
```

count incremented because of constructor calls from **new**.

If no **Employee** objects exist **getCount** must be accessed using the class name and (**::**).

```
Number of employees before instantiation is 0
```

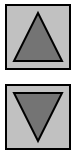
e2Ptr->getCount() or **Employee::getCount()** would also work.

```
Number of employees after instantiation is 2
```

```
Employee constructor for Susan Baker called.
Employee constructor for Robert Jones called.
```

```
Employee 1: Susan Baker
Employee 2: Robert Jones
```

```
~Employee() called for Susan Baker
~Employee() called for Robert Jones
```



Outline

```
119
120   cout << "Number of employees after deletion is "
121        << Employee::getCount() << endl;
122
123   return 0;
124}
```

count back to zero.

```
Number of employees before instantiation is 0
Employee constructor for Susan Baker called.
Employee constructor for Robert Jones called.
Number of employees after instantiation is 2

Employee 1: Susan Baker
Employee 2: Robert Jones

~Employee() called for Susan Baker
~Employee() called for Robert Jones
Number of employees after deletion is 0
```

Program Output

7.8 Data Abstraction and Information Hiding

- Information hiding
  - Classes hide implementation details from clients
  - Example: stack data structure
    - Data elements added (pushed) onto the bottom and removed (popped) from top
    - Last-in, first-out (LIFO) data structure
    - Client does not care how stack is implemented, only wants LIFO data structure
- Abstract data types (ADTs)
  - Model real world objects
    - **`int`**, **`float`** are models for a numbers
- C++ is an extensible language
  - Standard data types cannot be changed, but new data types can be created

7.8.1 Example: Array Abstract Data Type

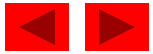
- Programmer can make an ADT array
  - Could include
    - Subscript range checking
    - An arbitrary range of subscripts instead of having to start with 0
    - Array assignment
    - Array comparison
    - Array input/output
    - Arrays that know their sizes
    - Arrays that expand dynamically to accommodate more elements

7.8.2 Example: String Abstract Data Type

- Strings in C++
  - C++ does not provide a built in string data type
    - Maximizes performance
  - Provides mechanisms for creating and implementing a string abstract data type
  - **`string`** class available in ANSI/ISO standard (Chapter 19)

7.8.3 Example: Queue Abstract Data Type

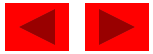
- Queue
  - Like waiting in line
    - FIFO — First in, first out
  - Enqueue
    - Put items in a queue one at a time, from the back
  - Dequeue
    - Remove items from a queue one at a time, from the front
  - Implementation hidden from clients
- Queue ADT
  - Clients may not manipulate data structure directly
  - Only queue member functions can access internal data



7.9 Container Classes and Iterators

- Container classes (collection classes)
  - Classes designed to hold collections of objects
  - Provide services such as insertion, deletion, searching, sorting, or testing an item
  - Examples:

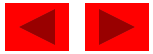
    Arrays, stacks, queues, trees and linked lists
- Iterator objects (iterators)
  - Object that returns the next item of a collection (or performs some action on the next item)
  - Can have several iterators per container
    - Book with multiple bookmarks
  - Each iterator maintains its own “position” information
  - Discussed further in chapter 20

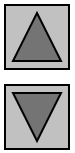


7.10 Proxy Classes

- Proxy class
  - Used to hide implementation details of a class
  - Class that knows only the **`public`** interface of the class being hidden
  - Enables clients to use class's services without giving access to class's implementation
- Forward class declaration
  - Used when class definition only uses a pointer to another class
  - Prevents the need for including the header file
  - Declares a class before it is referenced
  - Format:

```
class ClassToLoad;
```



Outline

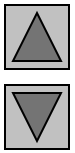

```
1  // Fig. 7.10: implementation.h
2  // Header file for class Implementation
3
4  class Implementation {
5     public:
6        Implementation( int v ) { value = v; }
7        void setValue( int
8        int getValue() con
9
10    private:
11       int value;
12 };
13 // Fig. 7.10: interface.h
14 // Header file for interface.cpp
15 class Implementation;   // forward class declaration
16
17 class Interface {
18    public:
19       Interface( int );
20       void setValue( int );  //
21       int getValue() const;  //
22       ~Interface();
23    private:
24       Implementation *ptr;   // requires previous
25                              // forward declaration
26 };
```

Implementation has **private** data we want to hide.

Forward class declaration.

Proxy class **Interface** has same public interface as class **Implementation.**

Only uses a pointer to class **Implementation**. This allows us to hide the implementation details.



Outline

1. Load header files

1.1 Function definitions

. Load interface eader file

1.1 Initialize objects

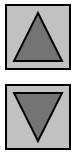
alls

```
27 // Fig. 7.10: interface.cpp
28 // Definition of class Interface
29 #include "interface.h"
30 #include "implementation.h"
31
32 Interface::Interface( int v )
33    : ptr ( new Implementation( v ) ) { }
34
35 // call Implementation's setValue function
36 void Interface::setValue( int
37
38 // call Implementation's getVa
39 int Interface::getValue() cons
40
41 Interface::~Interface() { dele
42 // Fig. 7.10: fig07_10.cpp
43 // Hiding a class's private data with a proxy class.
44 #include <iostream>
45
46 using std::cout;
47 using std::endl;
48
49 #include "interface.h"
50
51 int main()
52 {
53    Interface i( 5 );
54
55    cout << "Interface contains
56         << " before setValue"
57    i.setValue( 10 );
58    cout << "Interface contains: " << i.getValue()
59         << " after setValue" << endl;
60    return 0;
61 }
```

Implementation file **`interface.cpp`** contains member functions for proxy class **`Interface`**. It is the only file that has header file **`implementation.h`**, which contains class **`Implementation`**.

`interface.cpp` is precompiled and given with the header file **`interface.h`**. The client cannot see the interactions between the proxy class and the proprietary class.

Only the header **Interface.h** — no mention of class **`Implementation`**. The client never sees the **`private`** data.



Outline

```
Interface contains: 5 before setVal
Interface contains: 10 after setVal
```

Program Output