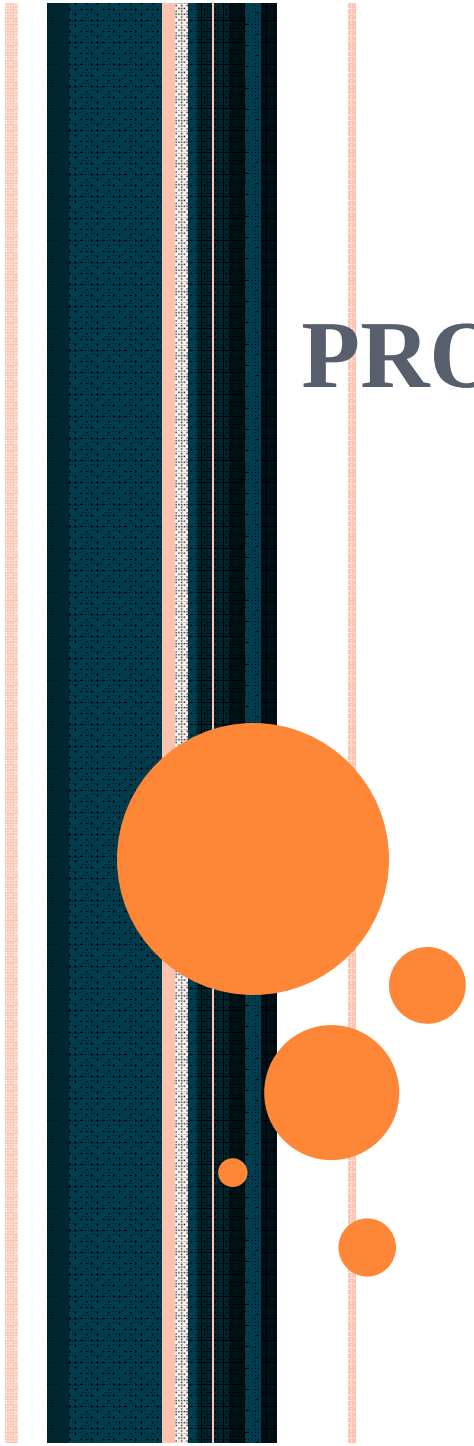


OBJECT ORIENTED PROGRAMMING USING C++

Chapter 17 - C++ Classes: Part II

Outline

17.1 Introduction

- Chapters 16-18
  - Object-based programming
- Chapter 19-20
  - Polymorphism and inheritance
  - Object-oriented programming

17.2 `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
  - For example:
    ```
    const time noon( 12, 0, 0 );
    ```
  - Declares a **`const`** object **`noon`** of class **`time`** and initializes it to 12 noon

17.2 const (Constant) Objects and const Member Functions (II)

- **`const`** objects require **`const`** functions
  - Functions declared **`const`** cannot modify the object
  - **`const`** specified in function prototype and definition

  Prototype: *ReturnType FunctionName(param1,param2…)* **`const;`**

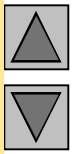
  Definition: *ReturnType FunctionName(param1,param2…)* **`const { …};`**

  Example:

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

  - Returns the value of a data member, and is appropriately declared **`const`**
- Constructors / Destructors cannot be **`const`**
  - They need to initialize variables (therefore modifying them)

```
1  // Fig. 17.1: 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 time
25 private:
26    int hour;              // 0 - 23
27    int minute;            // 0 - 59
28    int second;            // 0 - 59
29 };
30
31 #endif
```



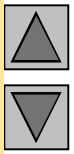
Outline

1. Class definition

1.1 Function prototypes

1.2 Member variables

```
32 // Fig. 17.1: 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; }
```



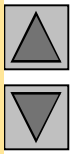
Outline

Source Code

1. Load Header

1.1 Function definitions

```
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" : "" ) << minute;
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 }
```

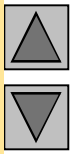


Outline

1.1 Function definitions

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

```
89 // Fig. 17.1: fig17_01.cpp
90 // Attempting to access a const object with
91 // non-const member functions.
92 #include "time5.h"
93
94 int main()
95 {
96    Time wakeUp( 6, 45, 0 );       // non-constant object
97    const Time noon( 12, 0, 0 );   // constant object
98
99                            // MEMBER FUNCTION   OBJECT
100   wakeUp.setHour( 18 );  // non-const         non-const
101
102   noon.setHour( 12 );    // non-const         const
103
104   wakeUp.getHour();      // const             non-const
105
106   noon.getMinute();      // const             const
107   noon.printMilitary();  // const             const
108   noon.printStandard();  // non-const         const
109   return 0;
110}
```



Outline

1. Initialize variables

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

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)
```

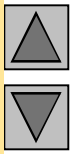
17.2 const (Constant) Objects and const Member Functions (III)

- 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 the value of **`i`**.
  - Any data member can be initialized using member initializer syntax
  - **`const`**s and references must be initialized this way
- Multiple member initializers
  - Use comma-separated list after the colon

```
1  // Fig. 17.2: fig17_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 {
```



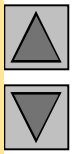
Outline

1. Class definition

1.1 Function definitions

```
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
```



Outline

1.2 Initialize variables

2. Function calls

3. Output results

17.3 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)
  - Constructors called inside out
  - Destructors called outside in

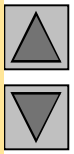
17.3 Composition: Objects as Members of Classes (II)

- Example:

```
Employee::Employee( char *fname, char *lname,
                    int bmonth, int bday, int byear,
                    int hmonth, int hday, int hyear )
   : birthDate( bmonth, bday, byear ),
     hireDate( hmonth, hday, hyear )
```

  - Insert objects from **`Date`** class (**`birthDate`** and **`hireDate`**) into **`Employee`** class
  - **`birthDate`** and **`hireDate`** have member initializers - they are probably **`const`**s in the **`Employee`** class

```
1  // Fig. 17.4: 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
```



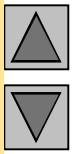
Outline

1. Class definition

1.1 Member functions

1.2 Member variables

```
22 // Fig. 17.4: 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
```



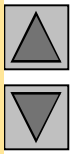
Outline

1. Load header

1.1 Function definitions

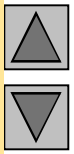
1.2 `Date` constructor

```
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 destruction order
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 }
```



Outline

```
84 // Fig. 17.4: 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
```



Outline

1. Load header

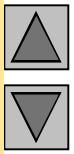
1.1 Class definition

1.2 Member functions

1.3 Member variables

1.3.1 Include `const` variables from `Date` class

```
105// Fig. 17.4: 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}
```



Outline

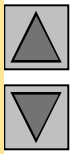
1. Load header files

1.1 Function definitions

1.2 `Employee` constructor

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

```
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 }
```

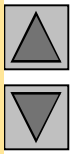


Outline

1.3 `print` definition

1.4 `Employee` destructor

```
153// Fig. 17.4: fig17_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}
```



Outline

1. Load header files

2. Create `Employee` object

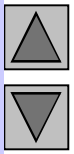
2.1 Attempt invalid `Date` setting

```
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
```



Outline

Program Output

17.4 `friend` Functions and `friend` Classes

- **`friend`** function and **`friend`** classes
  - Can access **`private`** and **`protected`** (more later) members of another class
  - **`friend`** functions are not member functions of class
    - Defined outside of class scope
- Properties
  - 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)

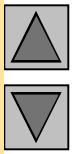
17.4 `friend` Functions and `friend` Classes (II)

- **`friend`** declarations
  - **`friend`** function
    - Keyword **`friend`** before function prototype in class that is giving friendship.
      - **`friend int myFunction( int x );`**
      - Appears in the class granting friendship
  - **`friend`** class
    - Type **`friend class`** *Classname* in class granting friendship
    - If **`ClassOne`** granting friendship to **`ClassTwo`**,

      `friend class ClassTwo;`

      appears in **`ClassOne`**'s definition

```
1  // Fig. 17.5: fig17_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 Count
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();
```



Outline

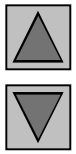
1. Class definition

1.1 Declare function a `friend`

1.2 Function definition

1.3 Initialize `Count` object

```
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 }
```



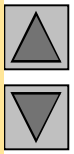
Outline

2. Modify object

3. Print results

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

Program Output



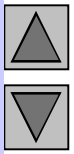
Outline

(Previous program without `friend` declared)

```
1  // Fig. 17.6: fig17_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 }
```

```
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)
```



Outline

Program Output

17.5 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
- Example: class **`Employee`**
  - For non-**`const`** member functions: type **`Employee * const`**
    - Constant pointer to an **`Employee`** object
  - For **`const`** member functions: type **`const Employee * const`**
    - Constant pointer to an constant **`Employee`** object

17.5 Using the this Pointer (II)

- 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

17.5 Using the this Pointer (III)

- Example
  - 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)`** and returns **`*this`** (reference to object), and expression becomes

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

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

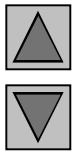
    ```
    t.setSecond(3);
    ```

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

    ```
    t;
    ```

  - Has no effect

```
1  // Fig. 17.7: fig17_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 required
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 }
```



Outline

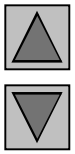
1. Class definition

1.1 Function definition

1.2 Initialize object

2. Function call

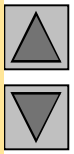
```
       x = 12
  this->x = 12
(*this).x = 12
```



Outline

Program Output

```
1  // Fig. 17.8: 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 minute
17    Time &setSecond( int );  // set second
18
19    // get functions (normally declared const)
20    int getHour() const;     // return hour
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
```

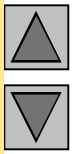


Outline

Cascading function calls

1. Class definition

```
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
```

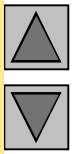


Outline

1. Load header file

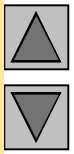
1.1 Function definitions

```
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;
```



1.1 Function definitions

```
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. 17.8: fig17_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 ).setSecond( 22 );
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();
```



Outline

1.1 Function definitions

Source File

1. Load header

1.1 Initialize Time object

2. Function calls

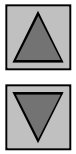
3. Print values

```
127   cout << endl;

128

129   return 0;

130}
```



Outline

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

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

Program Output

17.6 Dynamic Memory Allocation with Operators new and delete

- **`new`** and **`delete`**
  - Better dynamic memory allocation than C's **`malloc`** and **`free`**
  - **`new -`** automatically creates object of proper size, calls constructor, returns pointer of the correct type
  - **`delete`** - destroys object and frees space
- Example:
  - **`TypeName *typeNamePtr;`**
    - Creates pointer to a **`TypeName`** object
  - **`typeNamePtr = new TypeName;`**
    - **`new`** creates **`TypeName`** object, returns pointer (which **`typeNamePtr`** is set equal to)
  - **`delete typeNamePtr;`**
    - Calls destructor for **`TypeName`** object and frees memory

17.6 Dynamic Memory Allocation with Operators new and delete (II)

- Initializing objects

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

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

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

– Create ten element **int** array, assign to **arrayPtr**.

– Use

```
delete [] arrayPtr;
```

to **delete** arrays

17.7 `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
- Can be variables or functions
  - **`public`**, **`private`**, or **`protected`**

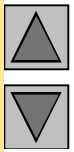
17.7 static Class Members (II)

- Accessing **`static`** members
  - **`public static`** variables: accessible through any object of the class
    - Or use class name and (**`::`**)

      `Employee::count`
  - **`private static`** variables: a **`public static`** member function must be used.
    - Prefix with class name and (**`::`**)

      `Employee::getCount()`
  - **`static`** member functions cannot access non-**`static`** data or functions
    - No **`this`** pointer, function exists independent of objects

```
1  // Fig. 17.9: 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
```



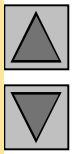
Outline

1. Class definition

1.1 Function prototypes

1.2 Declare variables

```
25 // Fig. 17.9: 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 the
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
```



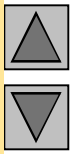
Outline

1. Load header file

1.1 Initialize `static` data members

1.2 Function definitions

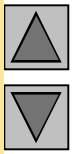
```
57    cout << "Employee constructor for " << firstName
58         << ' ' << lastName << " called." << endl;
59 }
60
61 // Destructor deallocates dynamically allocated memory
62 Employee::~Employee()
63 {
64    cout << "~Employee() called for " << firstName
65         << ' ' << lastName << endl;
66    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 from modifying
84    // private data. Client should copy returned string before
85    // destructor deletes storage to prevent undefined pointer.
86    return lastName;
87 }
```



Outline

1.2 Function definitions

```
88 // Fig. 17.9: fig17_09.cpp
89 // Driver to test the employee class
90 #include <iostream>
91
92 using std::cout;
93 using std::endl;
94
95 #include "employ1.h"
96
97 int main()
98 {
99    cout << "Number of employees before instantiation is "
100        << Employee::getCount() << endl;   // use class name
101
102   Employee *e1Ptr = new Employee( "Susan", "Baker" );
103   Employee *e2Ptr = new Employee( "Robert", "Jones" );
104
105   cout << "Number of employees after instantiation is "
106        << e1Ptr->getCount();
107
108   cout << "\n\nEmployee 1: "
109        << e1Ptr->getFirstName()
110        << " " << e1Ptr->getLastName()
111        << "\nEmployee 2: "
112        << e2Ptr->getFirstName()
113        << " " << e2Ptr->getLastName() << "\n\n";
114
115   delete e1Ptr;   // recapture memory
116   e1Ptr = 0;
117   delete e2Ptr;   // recapture memory
118   e2Ptr = 0;
```



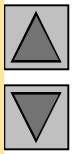
Outline

1. Initialize objects

2. Function calls

3. Print data

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



Outline

4. Output

```
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
```

17.8 Data Abstraction and Information Hiding

- Information hiding
  - Classes hide implementation details from clients
  - Example: stack data structure
    - Data elements like a pile of dishes - added (pushed) 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

17.8 Data Abstraction and Information Hiding (II)

- Abstract data types (ADTs)
  - Model real world objects
    - **`int, float`** are models for a numbers
    - Imperfect - finite size, precision, etc.
- C++ an extensible language
  - Base cannot be changed, but new data types can be created

17.8.1 Example: Array Abstract Data Type

- Array
  - Essentially a pointer and memory locations
- Programmer can make an ADT array
  - New capabilities
    - Subscript range checking, array assignment and comparison, dynamic arrays, arrays that know their sizes...
- New classes
  - Proprietary to an individual, to small groups or to companies, or placed in standard class libraries

17.8.2 Example: String Abstract Data Type

- C++ intentionally sparse
  - Reduce performance burdens
  - Use language to create what you need, i.e. a **`string`** class

- **`string`** not a built-in data type
  - Instead, C++ enables you to create your own **`string`** class

17.8.3 Example: Queue Abstract Data Type

- Queue - a waiting line
  - Used by computer systems internally
  - We need programs that simulate queues
- Queue has well-understood behavior
  - Enqueue - put things in a queue one at a time
  - Dequeue - get those things back one at a time on demand
  - Implementation hidden from clients
- Queue ADT - stable internal data structure
  - Clients may not manipulate data structure directly
  - Only queue member functions can access internal data

17.9 Container Classes and Iterators

- Container classes (collection classes)
  - Classes designed to hold collections of objects
  - – 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 some action)
  - – Can have several iterators per container
    - – Book with multiple bookmarks
  - – Each iterator maintains its own “position” information