Classes
Chapters 3 & 9

Object Oriented Programming

- data and their procedures as a single object

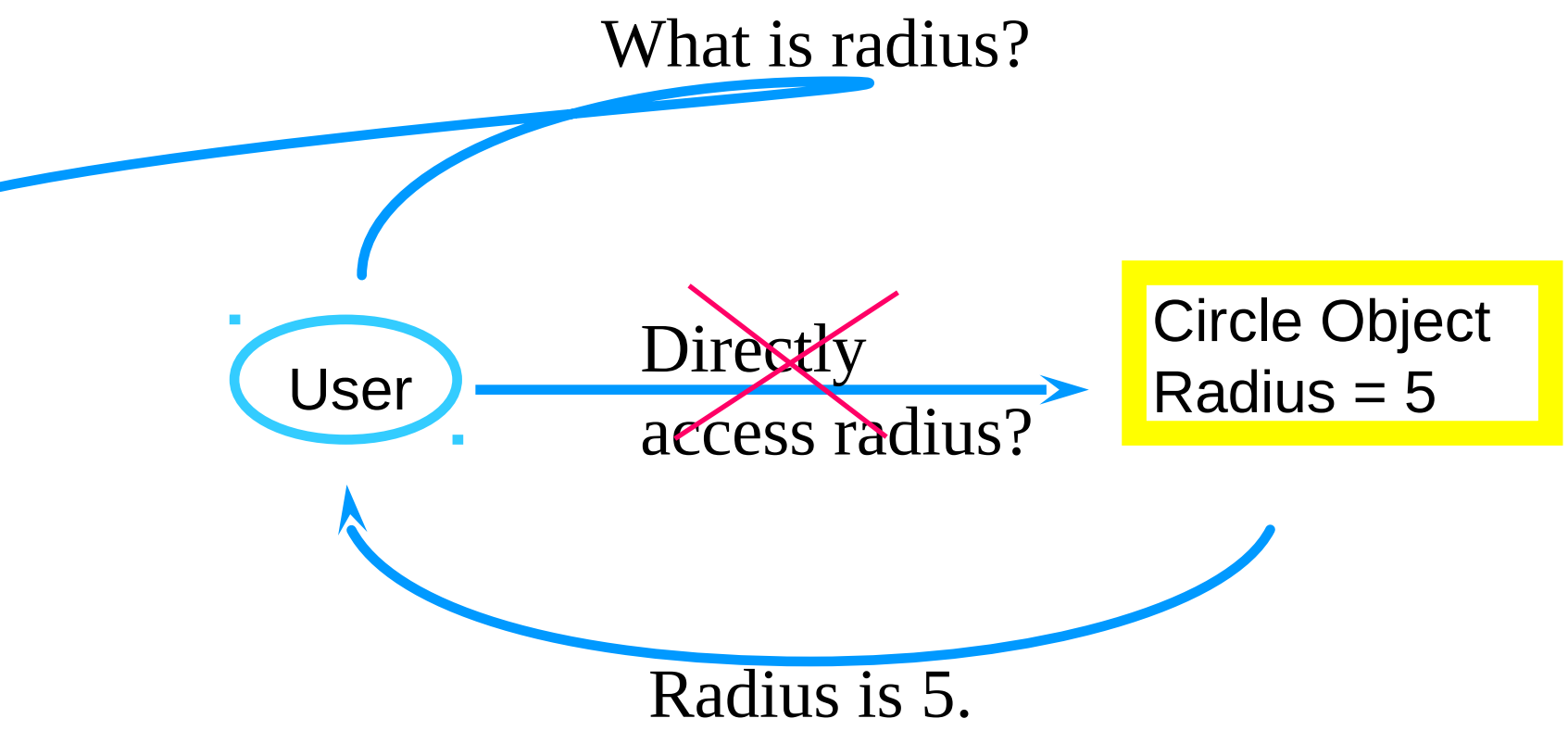
Key features

- Encapsulation
- Data hiding
- Inheritance
- Polymorphism

Classes

- A *class* is a programmer-defined data type. It consists of data structure and functions which operate on that data.

Object Oriented Programming



Example of a Class Declaration

FUNCTIONS

VARIABLES

```
class Student
{
  public:
        void PrintGrade();
        void addGrade(double grade);
        double getGPA();
        void chngAddr (char addr[ ]);
        void chngAddr (char addr [ ], char city [ ]);

   private:
        double GPA;
        string address1, address2;
         int num_of_grades;
        string fullName;
};
```


Class Declaration Syntax

```
class Name                          // usually capitalized
{
   public:
        public members;             // usually functions

   private:
        private members;            // usually variables
};
```

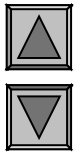
Note

9.2 Implementing a `Time` Abstract Data Type with a `class`

- Classes
  - Model objects
    - Attributes (data members)
    - Behaviors (member functions)
  - Defined using keyword **`class`**
  - Member functions
    - Methods
    - Invoked in response to messages
- Member access specifiers
  - **`public:`**
    - Accessible wherever object of class in scope
  - **`private:`**
    - Accessible only to member functions of class
  - **`protected:`**

9.2 Implementing a `Time` Abstract Data Type with a `class`

- Constructor function
  - Special member function
    - Initializes data members
    - Same name as class
  - Called when object instantiated
  - Several constructors
    - Function overloading
  - No return type



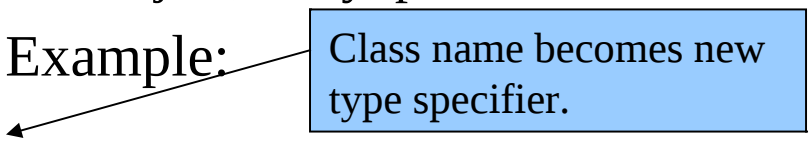
Outline

Class `Time` definition (1 of 1)

```
1   class Time {
2
3   public:
4      Time();                          // constructor
5      void setTime( int, int, int );   // set hour, minute, second
6      void printUniversal();           // print universal-time format
7      void printStandard();            // print standard-time format
8
9   private:
10     int hour;     // 0 - 23 (24-hour clock format)
11     int minute;   // 0 - 59
12     int second;   // 0 - 59
13
14  }; // end class Time
```

9.2 Implementing a `Time` Abstract Data Type with a `class`

- Objects of class
  - After class definition
    - Class name new type specifier
      - C++ extensible language
    - Object, array, pointer and reference declarations
  - Example:



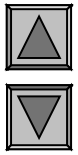

```
Time sunset;                    // object of type Time
Time arrayOfTimes[5];          // array of Time objects
Time *pointerToTime;            // pointer to a Time object
Time &dinnerTime = sunset;      // reference to a Time object
```


9.2 Implementing a `Time` Abstract Data Type with a `class`

- Member functions defined outside class
  - Binary scope resolution operator (`::`)
    - "Ties" member name to class name
    - Uniquely identify functions of particular class
    - Different classes can have member functions with same name
  - Format for defining member functions

```
ReturnType ClassName::MemberFunctionName( ){
   …
}
```

  - Does not change whether function **`public`** or **`private`**
- Member functions defined inside class
  - Do not need scope resolution operator, class name
  - Compiler attempts **`inline`**
    - Outside class, inline explicitly with keyword **`inline`**

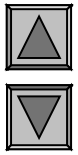


Outline

fig06_03.cpp
(1 of 5)

```
1   // Fig. 6.3: fig06_03.cpp
2   // Time class.
3   #include <iostream>
4
5   using std::cout;
6   using std::endl;
7
8   #include <iomanip>
9
10  using std::setfill;
11  using std::setw;
12
13  // Time abstract data type (ADT) definition
14  class Time {
15
16  public:
17     Time();                          // constructor
18     void setTime( int, int, int );   // set hour, minute, second
19     void printUniversal();           // print universal-time format
20     void printStandard();            // print standard-time format
21
```

Define class **Time**.



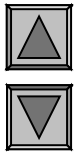
Outline

fig06_03.cpp
(2 of 5)

```
22  private:
23     int hour;     // 0 - 23 (24-hour clock format)
24     int minute;   // 0 - 59
25     int second;   // 0 - 59
26
27  }; // end class Time
28
29  // Time constructor initializes each data m
30  // ensures all Time objects start in a cons
31  Time::Time()
32  {
33     hour = minute = second = 0;
34
35  } // end Time constructor
36
37  // set new Time value using universal time, perform validity
38  // checks on the data values and set invalid values to zero
39  void Time::setTime( int h, int m, int s )
40  {
41     hour = ( h >= 0 && h < 24 ) ? h : 0;
42     minute = ( m >= 0 && m < 60 ) ? m : 0;
43     second = ( s >= 0 && s < 60 ) ? s : 0;
44
45  } // end function setTime
46
```

Constructor initializes **`private`** data members to **`0`**.

`public` member function checks parameter values for validity before setting **`private`** data members.



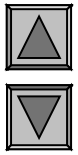
Outline

fig06_03.cpp (3 of 5)

```
47  // print Time in universal format
48  void Time::printUniversal()
49  {
50     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
51          << setw( 2 ) << minute << ":"
52          << setw( 2 ) << second;
53
54  } // end function printUniversal
55
56  // print Time in standard format
57  void Time::printStandard()
58  {
59     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
60          << ":" << setfill( '0' ) << setw( 2 ) << minute
61          << ":" << setw( 2 ) << second
62          << ( hour < 12 ? " AM" : " PM" );
63
64  } // end function prin
65
66  int main()
67  {
68     Time t;  // instantiate object t of class Time
69
```

No arguments (implicitly "know" purpose is to print data members); member function calls more concise.

Declare variable **t** to be object of class **Time**.



Outline

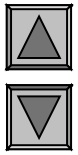
fig06_03.cpp (4 of 5)

```
70     // output Time object t's initial values
71     cout << "The initial universal time is ";
72     t.printUniversal();    // 00:00:00
73
74     cout << "\nThe initial standard time i
75     t.printStandard();     // 12:00:00 AM
76
77     t.setTime( 13, 27, 6 );   // change time
78
79     // output Time object t's new va
80     cout << "\n\nUniversal time afte
81     t.printUniversal();   // 13:27:06
82
83     cout << "\nStandard time after s
84     t.printStandard();    // 1:27:06
85
86     t.setTime( 99, 99, 99 );  // attempt invalid settings
87
88     // output t's values after specifying invalid values
89     cout << "\n\nAfter attempting invalid settings:"
90          << "\nUniversal time: ";
91     t.printUniversal();   // 00:00:00
92
```

Invoke **public** member functions to print time.

Set data members using **public** member function.

Attempt to set data members to invalid values using **public** member function.



Outline

```
93     cout << "\nStandard time: ";
94     t.printStandard();    // 12:00:00 AM
95     cout << endl;
96
97     return 0;
98
99  } // end main
```

```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM

After attempting invalid settings:
Universal time: 00:00:00
Standard time: 12:00:00 AM
```

Data members set to **0** after attempting invalid settings.

fig06_03.cpp (5 of 5)

fig06_03.cpp output (1 of 1)

9.2 Implementing a `Time` Abstract Data Type with a `class`

- Destructors
  - Same name as class
    - Preceded with tilde (**~**)
  - No arguments
  - Cannot be overloaded
  - Performs “termination housekeeping”

9.2 Implementing a `Time` Abstract Data Type with a `class`

- Advantages of using classes
  - Simplify programming
  - Interfaces
    - Hide implementation
  - Software reuse
    - Composition (aggregation)
      - Class objects included as members of other classes
    - Inheritance
      - New classes derived from old

9.3 Class Scope and Accessing Class Members

- Class scope
  - Data members, member functions
  - Within class scope
    - Class members
      - Immediately accessible by all member functions
      - Referenced by name
  - Outside class scope
    - Public members referenced through handles
      - Object name, reference to object, pointer to object
- File scope
  - Nonmember functions

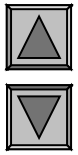
9.3 Class Scope and Accessing Class Members

- Function scope
  - Variables declared in member function
  - Only known to function
  - Variables with same name as class-scope variables
    - Class-scope variable “hidden”
      - Access with scope resolution operator (`::`)

        `ClassName::classVariableName`
  - Variables only known to function they are defined in
  - Variables are destroyed after function completion

9.3 Class Scope and Accessing Class Members

- Operators to access class members
  - Identical to those for **`struct`**s
  - Dot member selection operator (`.`)
    - Object
    - Reference to object
  - Arrow member selection operator (`->`)
    - Pointers

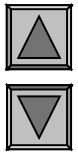


Outline

fig06_04.cpp
(1 of 2)

```
1   // Fig. 6.4: fig06_04.cpp
2   // Demonstrating the class member access operators . and ->
3   //
4   // CAUTION: IN FUTURE EXAMPLES WE AVOID PUBLIC DATA!
5   #include <iostream>
6
7   using std::cout;
8   using std::endl;
9
10  // class Count definition
11  class Count {
12
13  public:
14     int x;
15
16     void print()
17     {
18        cout << x << endl;
19     }
20
21  }; // end class Count
22
```

Data member **`x public`** to illustrate class member access operators; typically data members **`private`**.



Outline

fig06_04.cpp (2 of 2)

fig06_04.cpp output (1 of 1)

```
23  int main()
24  {
25     Count counter;                // create counter object
26     Count *counterPtr = &counter; // create pointer to counter
27     Count &counterRef = counter;  // create reference to counter
28
29     cout << "Assign 1 to x and print using the object's name: ";
30     counter.x = 1;          // assign 1 to data member x
31     counter.print();        // call member print
32
33     cout << "Assign 2 to x and print using a reference: ";
34     counterRef.x = 2;       // assign 2 to data member x
35     counterRef.print();     // call member print
36
37     cout << "Assign 3 to x and print using a pointer: ";
38     counterPtr->x = 3;      // assign 3 to data member x
39     counterPtr->print(); // call member function print
40
41     return 0;
42
43  } // end main
```

Use dot member selection operator for **counter** object.

Use dot member selection operator for **counterRef** reference to object.

Use arrow member selection operator for **counterPtr** pointer to object.

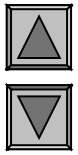
```
Assign 1 to x and print using the object's name: 1
Assign 2 to x and print using a reference: 2
Assign 3 to x and print using a pointer: 3
```

9.4 Separating Interface from Implementation

- Separating interface from implementation
  - Advantage
    - Easier to modify programs
  - Disadvantage
    - Header files
      - Portions of implementation
        - Inline member functions
      - Hints about other implementation
        - private members
    - Can hide more with proxy class (discussed later)

9.4 Separating Interface from Implementation

- Header files
  - Class definitions and function prototypes
  - Included in each file using class
    - `#include`
  - File extension `.h`
- Source-code files
  - Member function definitions
  - Same base name
    - Convention
  - Compiled and linked



Outline

time1.h (1 of 1)

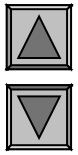
```
1   // Fig. 6.5: time1.h
2   // Declaration of class Time.
3   // Member functions are defined in
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME1_H
7   #define TIME1_H
8
9   // Time abstract
10  class Time {
11
12  public:
13     Time();                          // constructor
14     void setTime( int, int, int ); // set hour, minute, second
15     void printUniversal();           // print universal-time format
16     void printStandard();            // print standard-time format
17
18  private:
19     int hour;     // 0 - 23 (24-hour clock format)
20     int minute;   // 0 - 59
21     int second;   // 0 - 59
22
23  }; // end class Time
24
25  #endif
```

Preprocessor code to prevent multiple inclusions.

Code between these directives

"If not de ines

Naming convention: header file name with underscore replacing period.



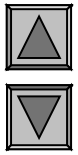
Outline

time1.cpp (1 of 3)

```
1   // Fig. 6.6: time1.cpp
2   // Member-function definitions for class Time.
3   #include <iostream>
4
5   using std::cout;
6
7   #include <iomanip>
8
9   using std::setfill;
10  using std::setw;
11
12  // include definition of class Time from time1.h
13  #include "time1.h"
14
15  // Time constructor initializes each data member to zero.
16  // Ensures all Time object
17  Time::Time()
18  {
19     hour = minute = second
20
21  } // end Time constructor
22
```

Include header file **`time1.h`**.

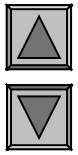
Name of header file enclosed in quotes; angle brackets cause preprocessor to assume header part of C++ Standard Library.



Outline

time1.cpp (2 of 3)

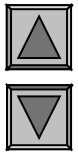
```
23  // Set new Time value using universal time. Perform validity
24  // checks on the data values. Set invalid values to zero.
25  void Time::setTime( int h, int m, int s )
26  {
27     hour = ( h >= 0 && h < 24 ) ? h : 0;
28     minute = ( m >= 0 && m < 60 ) ? m : 0;
29     second = ( s >= 0 && s < 60 ) ? s : 0;
30
31  } // end function setTime
32
33  // print Time in universal format
34  void Time::printUniversal()
35  {
36     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
37          << setw( 2 ) << minute << ":"
38          << setw( 2 ) << second;
39
40  } // end function printUniversal
41
```



Outline

time1.cpp (3 of 3)

```
42  // print Time in standard format
43  void Time::printStandard()
44  {
45     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
46          << ":" << setfill( '0' ) << setw( 2 ) << minute
47          << ":" << setw( 2 ) << second
48          << ( hour < 12 ? " AM" : " PM" );
49
50  } // end function printStandard
```

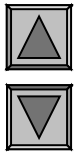


Outline

fig06_07.cpp (1 of 2)

```
1   // Fig. 6.7: useTime1.cpp
2   // Program to test class Time.
3   // NOTE: This file must be compiled with time1.cpp.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // include definition of class Time
10  #include "time1.h"
11
12  int main()
13  {
14     Time t;  // instantiate object t of class Time
15
16     // output Time object t's initial values
17     cout << "The initial universal time is ";
18     t.printUniversal();   // 00:00:00
19     cout << "\nThe initial standard time is ";
20     t.printStandard();    // 12:00:00 AM
21
22     t.setTime( 13, 27, 6 );   // change time
23
```

Include header file **`time1.h`** to ensure correct creation/manipulation and determine size of **`Time`** class object.



Outline

```
24     // output Time object t's new values
25     cout << "\n\nUniversal time after setTime is ";
26     t.printUniversal();   // 13:27:06
27     cout << "\nStandard time after setTime is ";
28     t.printStandard();    // 1:27:06 PM
29
30     t.setTime( 99, 99, 99 );  // attempt invalid settings
31
32     // output t's values after specifying invalid values
33     cout << "\n\nAfter attempting invalid settings:"
34          << "\nUniversal time: ";
35     t.printUniversal();   // 00:00:00
36     cout << "\nStandard time: ";
37     t.printStandard();    // 12:00:00 AM
38     cout << endl;
39
40     return 0;
41
42  } // end main
```

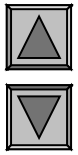
```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM
```

fig06_07.cpp (2 of 2)

fig06_07.cpp output (1 of 1)

9.5 Controlling Access to Members

- Access modes
  - **`private`**
    - Default access mode
    - Accessible to member functions and **`friend`**s
  - **`public`**
    - Accessible to any function in program with handle to class object
  - **`protected`**
    - Discussed later



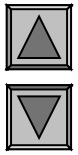
Outline

fig06_08.cpp
(1 of 1)

```
1  // Fig. 6.8: fig06_08.cpp
2  // Demonstrate errors resulting from attempts
3  // to access private class members.
4  #include <iostream>
5
6  using std::cout;
7
8  // include definition of class Time from time1.h
9  #include "time1.h"
10
11 int main()
12 {
13    Time t;  // create Time obj
14
15
16    t.hour = 7;  // error: 'Tim
17
18    // error: 'Time::minute' is not accessible
19    cout << "minute = " << t.minute;
20
21    return 0;
22
23 } // end main
```

Recall data member **hour** is **private**; attempts to access **private** members results in error.

Data member **minute** also **private**; attempts to access **private** members produces error.



Outline

```
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(16) : error C2248:
   'hour' : cannot access private member declared in class 'Time'
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(19) : error C2248:
   'minute' : cannot access private member declared in class 'Time'
```

fig06_08.cpp output (1 of 1)

Errors produced by attempting to access **`private`** members.

9.5 Controlling Access to Members

- Class member access
  - Default **`private`**
  - Explicitly set to **`private`**, **`public`**, **`protected`**
- **`struct`** member access
  - Default **`public`**
  - Explicitly set to **`private`**, **`public`**, **`protected`**
- Access to class's **`private`** data
  - Controlled with access functions (accessor methods)
    - Get function
      - Read **`private`** data
    - Set function
      - Modify **`private`** data

9.5 Access Functions and Utility Functions

- Access functions
  - **`public`**
  - Read/display data
  - Predicate functions
    - Check conditions
- Utility functions (helper functions)
  - **`private`**
  - Support operation of **`public`** member functions
  - Not intended for direct client use

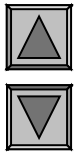
9.6 Initializing Class Objects: Constructors

- Constructors
  - Initialize data member
  - Same name as class
  - No return type

9.6 Using Default Arguments with Constructors

- Constructors
  - Can specify default arguments
  - Default constructors
    - Defaults all arguments

      OR
    - Explicitly requires no arguments
    - Can be invoked with no arguments
    - Only one per class



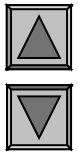
Outline

time2.h (1 of 1)

```
1   // Fig. 6.12: time2.h
2   // Declaration of class Time.
3   // Member functions defined in time2.cpp.
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME2_H
7   #define TIME2_H
8
9   // Time abstract data type definition
10  class Time {
11
12  public:
13     Time( int = 0, int = 0, int = 0); // default constructor
14     void setTime( int, int, int ); // set hour, minute, second
15     void printUniversal();         // print universal-time format
16     void printStandard();          // print standard-time format
17
18  private:
19     int hour;     // 0 - 23 (24-hour clock format)
20     int minute;   // 0 - 59
21     int second;   // 0 - 59
22
23  }; // end class Time
24
25  #endif
```

Default constructor specifying all arguments.

Set time to set the time

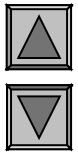


Outline

time2.cpp (1 of 3)

```
1   // Fig. 6.13: time2.cpp
2   // Member-function definitions for class Time.
3   #include <iostream>
4
5   using std::cout;
6
7   #include <iomanip>
8
9   using std::setfill;
10  using std::setw;
11
12  // include definition of class Time from time2.h
13  #include "time2.h"
14
15  // Time constructor initializes each data member to zero;
16  // ensures all Time objects start in a consistent state
17  Time::Time( int hr, int min, int sec )
18  {
19     setTime( hr, min, sec );  // validate and set time
20
21  } // end Time constructor
22
```

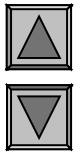
Constructor calls **`setTime`** to validate passed (or default) values.



Outline

time2.cpp (2 of 3)

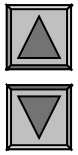
```
23  // set new Time value using universal time, perform validity
24  // checks on the data values and set invalid values to zero
25  void Time::setTime( int h, int m, int s )
26  {
27     hour = ( h >= 0 && h < 24 ) ? h : 0;
28     minute = ( m >= 0 && m < 60 ) ? m : 0;
29     second = ( s >= 0 && s < 60 ) ? s : 0;
30
31  } // end function setTime
32
33  // print Time in universal format
34  void Time::printUniversal()
35  {
36     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
37          << setw( 2 ) << minute << ":"
38          << setw( 2 ) << second;
39
40  } // end function printUniversal
41
```



Outline

time2.cpp (3 of 3)

```
42  // print Time in standard format
43  void Time::printStandard()
44  {
45     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
46          << ":" << setfill( '0' ) << setw( 2 ) << minute
47          << ":" << setw( 2 ) << second
48          << ( hour < 12 ? " AM" : " PM" );
49
50  } // end function printStandard
```



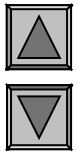
Outline

fig06_14.cpp
(1 of 2)

```
1   // Fig. 6.14: fig06_14.cpp
2   // Demonstrating a default constructor for class Time.
3   #include <iostream>
4
5   using std::cout;
6   using std::endl;
7
8   // include definition of class Time from time2.h
9   #include "time2.h"
10
11  int main()
12  {
13     Time t1;               // all arguments defaulted
14     Time t2( 2 );          // minute and second defaulted
15     Time t3( 21, 34 );     // second defaulted
16     Time t4( 12, 25, 42 ); // all values specified
17     Time t5( 27, 74, 99 ); // all bad values specified
18
19     cout << "Constructed with:\n\n"
20          << "all default arguments:\n  ";
21     t1.printUniversal();  // 00:00:00
22     cout << "\n  ";
23     t1.printStandard();   // 12:00:00 AM
24
```

Initialize **`Time`** objects using default arguments.

Initialize **`Time`** object with invalid values; validity checking will set values to **`0`**.

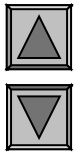


Outline

fig06_14.cpp
(2 of 2)

```
25     cout << "\n\nhour specified; default minute and second:\n  ";
26     t2.printUniversal();  // 02:00:00
27     cout << "\n  ";
28     t2.printStandard();   // 2:00:00 AM
29
30     cout << "\n\nhour and minute specified; default second:\n  ";
31     t3.printUniversal();  // 21:34:00
32     cout << "\n  ";
33     t3.printStandard();   // 9:34:00 PM
34
35     cout << "\n\nhour, minute, and second specified:\n  ";
36     t4.printUniversal();  // 12:25:42
37     cout << "\n  ";
38     t4.printStandard();   // 12:25:42 PM
39
40     cout << "\n\nall invalid values specified:\n  ";
41     t5.printUniversal();  // 00:00:00
42     cout << "\n  ";
43     t5.printStandard();   // 12:00:00 AM
44     cout << endl;
45
46     return 0;
47
48  } // end main
```

t5 constructed with invalid arguments; values set to **0**.



Outline

```
Constructed with:

all default arguments:
  00:00:00
  12:00:00 AM

hour specified; default minute and second:
  02:00:00
  2:00:00 AM

hour and minute specified; default second:
  21:34:00
  9:34:00 PM

hour, minute, and second specified:
  12:25:42
  12:25:42 PM

all invalid values specified:
  00:00:00
  12:00:00 AM
```

fig06_14.cpp
output (1 of 1)

9.7 Destructors

- Destructors
  - Special member function
  - Same name as class
    - Preceded with tilde (~)
  - No arguments
  - No return value
  - Cannot be overloaded
  - Performs “termination housekeeping”
    - Before system reclaims object’s memory
      - Reuse memory for new objects
  - No explicit destructor
    - Compiler creates “empty” destructor”

9.8 When Constructors and Destructors Are Called

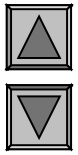
- Constructors and destructors
  - Called implicitly by compiler
- Order of function calls
  - Depends on order of execution
    - When execution enters and exits scope of objects
  - Generally, destructor calls reverse order of constructor calls

9.8 When Constructors and Destructors Are Called

- Order of constructor, destructor function calls
  - Global scope objects
    - Constructors
      - Before any other function (including **`main`**)
    - Destructors
      - When **`main`** terminates (or **`exit`** function called)
      - Not called if program terminates with **`abort`**
  - Automatic local objects
    - Constructors
      - When objects defined
        - Each time execution enters scope
    - Destructors
      - When objects leave scope
        - Execution exits block in which object defined
      - Not called if program ends with **`exit`** or **`abort`**

9.8 When Constructors and Destructors Are Called

- Order of constructor, destructor function calls
  - **`static`** local objects
    - Constructors
      - Exactly once
      - When execution reaches point where object defined
    - Destructors
      - When **`main`** terminates or **`exit`** function called
      - Not called if program ends with **`abort`**



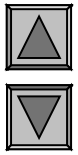
Outline

create.h (1 of 1)

```
1   // Fig. 9.11: create.h
2   // Definition of class CreateAndDestroy.
3   // Member functions defined in create.cpp.
4   #ifndef CREATE_H
5   #define CREATE_H
6
7   class CreateAndDestroy {
8
9   public:
10     CreateAndDestroy( int, char * ); // constructor
11     ~CreateAndDestroy();
12
13  private:
14     int objectID;
15     char *message;
16
17  }; // end class CreateAndDestroy
18
19  #endif
```

Constructor and destructor member functions.

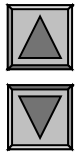
`private` members to show order of constructor, destructor function calls.



Outline

create.cpp (1 of 2)

```
1   // Fig. 9.11: create.cpp
2   // Member-function definitions for class CreateAndDestroy
3   #include <iostream>
5   using std::cout;
6using std::endl;

8   // include CreateAndDestroy class definition from create.h
9   #include "create.h"
10
11  // constructor
12  CreateAndDestroy::CreateAndDestroy(
13     int objectNumber, char *messagePtr ){

15     objectID = objectNumber;
16     message = messagePtr;
17
18     cout << "Object " << objectID << "   constructor runs   "
19          << message << endl;
20


23  // destructor
24  CreateAndDestroy::~CreateAndDestroy()
25  {
26     // the following line is for pedagogic purposes only
27     cout << ( objectID == 1 || objectID == 6 ? "\n" : "" );
28
29     cout << "Object " << objectID << "   destructor runs    "
30          << message << endl;
31
32  } // end ~CreateAndDestroy destructor
```



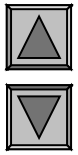
Outline

```
1   // Fig. 6.17: fig06_17.cpp
2   // Demonstrating the order in which constructors and
3   // destructors are called.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // include CreateAndDestroy class definition from create.h
10  #include "create.h"
11
12  void create( void );   // prototype
13
14  // global object
15  CreateAndDestroy first( 1, "(global before main)" );
16
17  int main()
18  {
19     cout << "\nMAIN FUNCTION: EXECUTIO
20
21     CreateAndDestroy second( 2, "(local automatic in
main)" );
22
23     static CreateAndDestroy third(
24        3, "(local static in main)" );
25
```

Create variable with global scope.

Create local automatic object.

Create **`static`** local object.



Outline

fig06_17.cpp (2 of 3)

```
26    create();  // call function to create objects
27
28    cout << "\nMAIN FUNCTION: EXECUTION RESUMES" << endl;
29
30    CreateAndDestroy fourth(
31
32    cout << "\nMAIN FUNCTION: EXECUTION ENDS" << endl;
33
34    return 0;
35
36 } // end main
37
38 // function to create objects
39 void create( void )
40 {
41    cout << "\nCREATE FUNCTI
42
43    CreateAndDestroy fifth(
44
45    static CreateAndDestroy
46       6, "(local static in
47
48    CreateAndDestroy seventh(
49       7, "(local automatic in create)" );
50    cout << "\nCREATE FUNCTION: EXECUTION ENDS\" << endl;
52
53 } // end function create
```

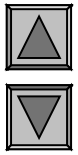
Create local automatic objects.

Create local automatic object.

Create local automatic object in function.

Create **static** local object in function.

Create local automatic object in function.



Outline

fig06_17.cpp
output (1 of 1)

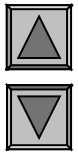
```
Object 1   constructor runs   (global before main)

MAIN FUNCTION: EXECUTION BEGINS
Object 2   constructor runs   (local automatic in main)
Object 3   constructor runs   (local static in main)

CREATE FUNCTION: EXECUTION BEGINS
Object 5   constructor runs   (local automatic in create)
Object 6   constructor runs   (local static in create)
Object 7   constructor runs   (local automatic in create)

CREATE FUNCTION: EXECUTION ENDS
Object 7   destructor runs    (local automatic in create)
Object 5   destructor runs    (local automatic in create)

MAIN FUNCTION: EXECUTION RESUMES
Object 4   constructor runs   (local automatic in main)

MAIN FUNCTION: EXECUTION ENDS
Object 4   destructor runs    (local automatic in main)
Object 2   destructor runs    (local automatic in main)
Object 6   destructor runs    (local static in create)
Object 3   destructor runs    (local static in main)

Object 1   destructor runs    (global before main)
```

Global object constructed

Local **`static`** object constructed on first function call and destroyed after **`main`** execution ends.

3.5 Using *Set* and *Get* Functions

- Set functions
  - Perform validity checks before modifying **`private`** data
  - Notify if invalid values
  - Indicate with return values
- Get functions
  - “Query” functions
  - Control format of data returned



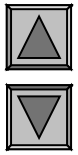
Outline

time3.h (1 of 2)

```
1   // Fig. 6.18: time3.h
2   // Declaration of class Time.
3   // Member functions defined in time3.cpp
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME3_H
7   #define TIME3_H
8
9   class Time {
10
11  public:
12     Time( int = 0, int = 0, int = 0 );  // default constructor
13
14     // set functions
15     void setTime( int, int, int );  // set hour, minute, second
16     void setHour( int );   // set hour
17     void setMinute( int ); // set minute
18     void setSecond( int ); // set second
19
20     // get functions
21     int getHour();         // return hour
22     int getMinute();       // return minute
23     int getSecond();       // return second
24
```

Set functions.

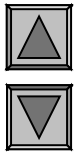
Get functions.



Outline

time3.h (2 of 2)

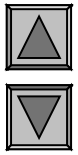
```
25    void printUniversal(); // output universal-time format
26    void printStandard();  // output standard-time format
27
28 private:
29    int hour;              // 0 - 23 (24-hour clock format)
30    int minute;            // 0 - 59
31    int second;            // 0 - 59
32
33 }; // end clas Time
34
35 #endif
```



Outline

time3.cpp (1 of 4)

```
1   // Fig. 6.19: time3.cpp
2   // Member-function definitions for Time class.
3   #include <iostream>
4
5   using std::cout;
6
7   #include <iomanip>
8
9   using std::setfill;
10  using std::setw;
11
12  // include definition of class Time from time3.h
13  #include "time3.h"
14
15  // constructor function to initialize private data;
16  // calls member function setTime to set variables;
17  // default values are 0 (see class definition)
18  Time::Time( int hr, int min, int sec )
19  {
20     setTime( hr, min, sec );
21
22  } // end Time constructor
23
```



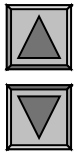
Outline

time3.cpp (2 of 4)

```
24  // set hour, minute and second values
25  void Time::setTime( int h, int m, int s )
26  {
27     setHour( h );
28     setMinute( m );
29     setSecond( s );
30
31  } // end function setTime
32
33  // set hour value
34  void Time::setHour( int h )
35  {
36     hour = ( h >= 0 && h < 24 ) ? h : 0;
37
38  } // end function setHour
39
40  // set minute value
41  void Time::setMinute( int m )
42  {
43     minute = ( m >= 0 && m < 60 ) ? m : 0;
44
45  } // end function setMinute
46
```

Call set functions to perform validity checking.

Set functions perform validity checks before modifying data.



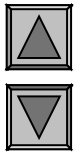
Outline

time3.cpp (3 of 4)

```
47  // set second value
48  void Time::setSecond( int s )
49  {
50     second = ( s >= 0 && s < 60 ) ? s : 0;
51
52  } // end function setSecond
53
54  // return hour value
55  int Time::getHour()
56  {
57     return hour;
58
59  } // end function getHour
60
61  // return minute value
62  int Time::getMinute()
63  {
64     return minute;
65
66  } // end function getMinute
67
```

Set function performs validity checks before modifying data.

Get functions allow client to read data.



Outline

time3.cpp (4 of 4)

```
68  // return second value
69  int Time::getSecond()
70  {
71     return second;
72
73  } // end function getSecond
74
75  // print Time in universal format
76  void Time::printUniversal()
77  {
78     cout << setfill( '0' ) << setw( 2 ) << hour << ":"
79          << setw( 2 ) << minute << ":"
80          << setw( 2 ) << second;
81
82  } // end function printUniversal
83
84  // print Time in standard format
85  void Time::printStandard()
86  {
87     cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
88          << ":" << setfill( '0' ) << setw( 2 ) << minute
89          << ":" << setw( 2 ) << second
90          << ( hour < 12 ? " AM" : " PM" );
91
92  } // end function printStandard
```

Get function allows client to read data.

In-class Assignment: Increment Time Program

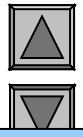
- Create a destructor that prints a message before exiting.
- Create a new function called

```
void incrementMinutes (Time &, const int );
```

That increments the minutes by count.

```
1   // Fig. 6.20: fig06_20.cpp
2   // Demonstrating the Time class set and get functions
3   #include <iostream>
4
5   using std::cout;
6   using std::endl;
7
8   // include definition of class Time from time3.h
9   #include "time3.h"
10
11  void incrementMinutes( Time &, const int );  // prototype
12
13  int main()
14  {
15     Time t;              // create Time object
16
17     // set time using individual set functions
18     t.setHour( 17 );     // set hour to valid value
19     t.setMinute( 34 );   // set minute to valid value
20     t.setSecond( 25 );   // set second to valid value
21
```

Invoke set functions to set valid values.



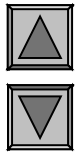
Outline

```
22     // use get functions to obtain hour, minute and second
23     cout << "Result of setting all valid values:\n"
24          << "  Hour: " << t.getHour()
25          << "  Minute: " << t.getMinute()
26          << "  Second: " << t.getSecond();
27
28     // set time using individual set functions
29     t.setHour( 234 );    // invalid hour set to 0
30     t.setMinute( 43 );   // set minute to valid value
31     t.setSecond( 6373 ); // invalid second set to 0
32
33     // display hour, minute and second after setting
34     // invalid hour and second values
35     cout << "\n\nResult of attempting to set invalid hour and"
36          << " second:\n  Hour: " << t.getHour()
37          << "  Minute: " << t.getMinute()
38          << "  Second: " << t.getSecond() << "\n\n";
39
40     t.setTime( 11, 58, 0 );    // set time
41     incrementMinutes( t, 3 );  // increment t's minute by 3
42
43     return 0;
44
45  } // end main
46
```

Attempt to set invalid values using set functions.

Invalid values result in setting data members to **0**.

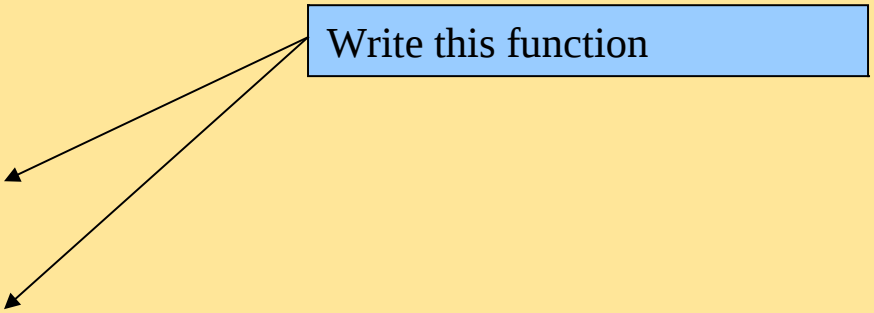
Modify data members using function **setTime**.



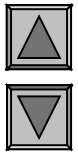
Outline

fig06_20.cpp
(3 of 3)

```
47  // add specified number of minutes to a Time object
48  void incrementMinutes( Time &tt, const int count )
49 {
```




```
50     66
67  } // end function incrementMinutes
```



Outline

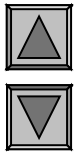
fig06_20.cpp
output (1 of 1)

```
Result of setting all valid values:
  Hour: 17  Minute: 34  Second: 25

Result of attempting to set invalid hour and second:
  Hour: 0  Minute: 43  Second: 0

Incrementing minute 3 times:
Start time: 11:58:00 AM
minute + 1: 11:59:00 AM
minute + 1: 12:00:00 PM
minute + 1: 12:01:00 PM
```

Attempting to set data members with invalid values results in error message and members set to **0**.

9.9 Subtle Trap: Returning a Reference to a `private` Data Member

- Reference to object
  - Alias for name of object
  - Lvalue
    - Can receive value in assignment statement
      - Changes original object
- Returning references
  - **`public`** member functions can return non-**`const`** references to **`private`** data members
    - Client able to modify **`private`** data members

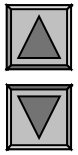


Outline

time4.h (1 of 1)

```
1   // Fig. 6.21: time4.h
2   // Declaration of class Time.
3   // Member functions defined in time4.cpp
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME4_H
7   #define TIME4_H
8
9   class Time {
10
11  public:
12     Time( int = 0, int = 0, int = 0 );
13     void setTime( int, int, int );
14     int getHour();
15
16     int &badSetHour( int );  // DANGEROUS reference return
17
18  private:
19     int hour;
20     int minute;
21     int second;
22
23  }; // end class Time
24
25  #endif
```

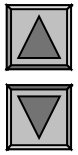
Function to demonstrate effects of returning reference to **`private`** data member.



Outline

time4.cpp (1 of 2)

```
1   // Fig. 6.22: time4.cpp
2   // Member-function definitions for Time class.
3
4   // include definition of class Time from time4.h
5   #include "time4.h"
6
7   // constructor function to initialize private data;
8   // calls member function setTime to set variables;
9   // default values are 0 (see class definition)
10  Time::Time( int hr, int min, int sec )
11  {
12     setTime( hr, min, sec );
13
14  } // end Time constructor
15
16  // set values of hour, minute and second
17  void Time::setTime( int h, int m, int s )
18  {
19     hour = ( h >= 0 && h < 24 ) ? h : 0;
20     minute = ( m >= 0 && m < 60 ) ? m : 0;
21     second = ( s >= 0 && s < 60 ) ? s : 0;
22
23  } // end function setTime
24
```

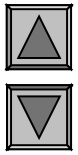


Outline

time4.cpp (2 of 2)

```
25  // return hour value
26  int Time::getHour()
27  {
28     return hour;
29
30  } // end function getHour
31
32  // POOR PROGRAMMING PRACTICE:
33  // Returning a reference to a private data member.
34  int &Time::badSetHour( int hh )
35  {
36     hour = ( hh >= 0 && hh < 24 ) ? hh : 0;
37
38     return hour;  // DANGEROUS reference return
39
40  } // end function badSetHour
```

Return reference to **`private`** data member **`hour`**.



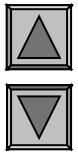
Outline

fig06_23.cpp
(1 of 2)

```
1   // Fig. 6.23: fig06_23.cpp
2   // Demonstrating a public member function that
3   // returns a reference to a private data member.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // include definition of class Time from time4.h
10  #include "time4.h"
11
12  int main()
13  {
14     Time t;
15
16     // store in hourRef the reference returned by badSe
17     int &hourRef = t.badSetHour( 20 );
18
19     cout << "Hour before modificat
20
21     // use hourRef to set invalid
22     hourRef = 30;
23
24     cout << "\nHour after modification: " << t.getHour();
25
```

badSetHour returns reference to **private** data member **hour**.

Reference allows setting of **private** data member **hour**.



Outline

fig06_23.cpp (2 of 2)

fig06_23.cpp output (1 of 1)

```
26     // Dangerous: Function call that returns
27     // a reference can be used as an lvalue!
28     t.badSetHour( 12 ) = 74;
29
30     cout << "\n\n*********************************" <<
31          << "POOR PROGRAMMING PRACTI
32          << "badSetHour as an lvalue
33          << t.getHour()
34          << "\n*********************************" << endl;
35
36     return 0;
37
38  } // end main
```

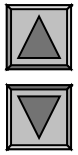
Can use function call as lvalue to set invalid value.

```
Hour before modification: 20
Hour after modification: 30

*********************************
POOR PROGRAMMING PRACTICE!!!!!!!
badSetHour as an lvalue, Hour: 74
*********************************
```

Returning reference allowed invalid setting of **`private`** data member **`hour`**.

9.10 Default Member-wise Assignment

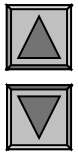
- Assigning objects
  - Assignment operator (=)
    - Can assign one object to another of same type
    - Default: memberwise assignment
      - Each right member assigned individually to left member
- Passing, returning objects
  - Objects passed as function arguments
  - Objects returned from functions
  - Default: pass-by-value
    - Copy of object passed, returned
      - Copy constructor
        - Copy original values into new object



Outline

fig06_24.cpp
(1 of 3)

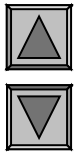
```
1   // Fig. 6.24: fig06_24.cpp
2   // Demonstrating that class objects can be assigned
3   // to each other using default memberwise assignment.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // class Date definition
10  class Date {
11
12  public:
13     Date( int = 1, int = 1, int = 1990 ); // default constructor
14     void print();
15
16  private:
17     int month;
18     int day;
19     int year;
20
21  }; // end class Date
22
```



Outline

fig06_24.cpp
(2 of 3)

```
23  // Date constructor with no range checking
24  Date::Date( int m, int d, int y )
25  {
26     month = m;
27     day = d;
28     year = y;
29
30  } // end Date constructor
31
32  // print Date in the format mm-dd-yyyy
33  void Date::print()
34  {
35     cout << month << '-' << day << '-' << year;
36
37  } // end function print
38
39  int main()
40  {
41     Date date1( 7, 4, 2002 );
42     Date date2;  // date2 defaults to 1/1/1990
43
```



Outline

```
44     cout << "date1 = ";
45     date1.print();
46     cout << "\ndate2 = ";
47     date2.print();
48
49     date2 = date1;   // default me
50
51     cout << "\n\nAfter default memberwise assignment, date2 = ";
52     date2.print();
53     cout << endl;
54
55     return 0;
56
57  } // end main
```

Default memberwise assignment assigns each member of **date1** individually to each member of **date2**.

```
date1 = 7-4-2002
date2 = 1-1-1990

After default memberwise assignment, date2 = 7-4-2002
```

fig06_24.cpp (3 of 3)

fig06_24.cpp output (1 of 1)