

5a

Classes and Objects: A Deeper Look

OBJECTIVES

In this lecture you will learn:

- Encapsulation and data hiding.
- The notions of data abstraction and abstract data types (ADTs).
- To use keyword `this`.
- To use `static` variables and methods.
- To import `static` members of a class.
- To use the `enum` type to create sets of constants with unique identifiers.
- How to declare `enum` constants with parameters.

- 5a.1 Introduction**
- 5a.2 Time Class Case Study**
- 5a.3 Controlling Access to Members**
- 5a.4 Referring to the Current Object's Members with the *this* Reference**
- 5a.5 Time Class Case Study: Overloaded Constructors**
- 5a.6 Default and No-Argument Constructors**
- 5a.7 Notes on *Set* and *Get* Methods**
- 5a.8 Composition**
- 5a.9 Enumerations**
- 5a.10 Garbage Collection and Method *finalize***

- 5a.11** **static Class Members**
- 5a.12** **static Import**
- 5a.13** **final Instance Variables**
- 5a.14** **Software Reusability**
- 5a.15** **Data Abstraction and Encapsulation**
- 5a.16** **Time Class Case Study: Creating Packages**
- 5a.17** **Package Access**
- 5a.18** **(Optional) GUI and Graphics Case Study: Using Objects with Graphics**
- 5a.19** **(Optional) Software Engineering Case Study: Starting to Program the Classes of the ATM System**
- 5a.20** **Wrap-Up**



5a.2 Time Class Case Study

public services (or public interface)

- **public methods available for a client to use**

If a class does not define a constructor the compiler will provide a default constructor

Instance variables

- **Can be initialized when they are declared or in a constructor**
- **Should maintain consistent (valid) values**

Software Engineering Observation

5a.1

Methods that modify the values of private variables should verify that the intended new values are proper. If they are not, the set methods should place the private variables into an appropriate consistent state.

Outline

Time1.java

(1 of 2)

```
1 // Fig. 8.1: Time1.java
2 // Time1 class declaration maintains the time in 24-hour format.
3
4 public class Time1
5 {
6     private int hour;    // 0 - 23
7     private int minute;  // 0 - 59
8     private int second;  // 0 - 59
9
10    // set a new time value using universal time; ensure that
11    // the data remains consistent by setting invalid values to zero
12    public void setTime( int h, int m, int s )
13
14        hour = ( ( h >= 0 && h < 24 ) ? h : 0 );    // validate hour
15        minute = ( ( m >= 0 && m < 60 ) ? m : 0 ); // validate minute
16        second = ( ( s >= 0 && s < 60 ) ? s : 0 ); // validate second
17    } // end method setTime
18
```

private instance variables

Declare **public** method **setTime**

Validate parameter values before setting
instance variables



Outline

Time1.java

(2 of 2)

```
19 // convert to String in universal-time format (HH:MM:SS)
20 public String toUniversalString()
21 {
22     return String.format( "%02d:%02d:%02d", hour, minute, second );
23 } // end method toUniversalString
24
25 // convert to String in standard-time format (H:MM:SS AM or PM)
26 public String toString()
27 {
28     return String.format( "%d:%02d:%02d %s",
29         ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ),
30         minute, second, ( hour < 12 ? "AM" : "PM" ) );
31 } // end method toString
32 } // end class Time1
```

format strings



5a.2 Time Class Case Study (Cont.)

String method format

- Similar to `printf` except it returns a formatted string instead of displaying it in a command window

`new` implicitly invokes `Time1`'s default constructor since `Time1` does not declare any constructors

Software Engineering Observation

5a.2

Classes simplify programming, because the client can use only the `public` methods exposed by the class. Such methods are usually client oriented rather than implementation oriented. Clients are neither aware of, nor involved in, a class's implementation. Clients generally care about *what* the class does but not *how* the class does it.

Software Engineering Observation

5a.3

Interfaces change less frequently than implementations. When an implementation changes, implementation-dependent code must change accordingly. Hiding the implementation reduces the possibility that other program parts will become dependent on class-implementation details.

Outline

Time1Test.java

(1 of 2)

```
1 // Fig. 8.2: Time1Test.java
2 // Time1 object used in an application.
3
4 public class Time1Test
5 {
6     public static void main( String args[] )
7     {
8         // create and initialize a Time1 object
9         Time1 time = new Time1(); // invokes Time1 constructor
10
11        // output string representations of the time
12        System.out.print( "The initial universal time is: " );
13        System.out.println( time.toUniversalString() );
14        System.out.print( "The initial standard time is: " );
15        System.out.println( time.toString() );
16        System.out.println(); // output a blank line
17    }
```

Create a **Time1** object

Call **toUniversalString** method

Call **toString** method



Outline

Time1Test.java

```
18 // change time and output updated time
19 time.setTime( 13, 27, 6 ); ←
20 System.out.print( "Universal time after setTime is: " );
21 System.out.println( time.toUniversalString() );
22 System.out.print( "Standard time after setTime is: " );
23 System.out.println( time.toString() );
24 System.out.println(); // output a blank line
25
26 // set time with invalid values; output updated time
27 time.setTime( 99, 99, 99 ); ←
28 System.out.println( "After attempting invalid settings:" );
29 System.out.print( "Universal time: " );
30 System.out.println( time.toUniversalString() );
31 System.out.print( "Standard time: " );
32 System.out.println( time.toString() );
33 } // end main
34 } // end class Time1Test
```

Call **setTime** method

Call **setTime** method
with invalid values

```
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
```



5a.3 Controlling Access to Members

A class's public interface

- **public** methods a view of the services the class provides to the class's clients

A class's implementation details

- **private** variables and **private** methods are not accessible to the class's clients

Common Programming Error 5a.1

An attempt by a method that is not a member of a class to access a private member of that class is a compilation error.

Outline

MemberAccessTest .java

```
1 // Fig. 8.3: MemberAccessTest.java
2 // Private members of class Time1 are not accessible.
3 public class MemberAccessTest
4 {
5     public static void main( String args[] )
6     {
7         Time1 time = new Time1(); // create and initialize Time1 object
8
9         time.hour = 7; // error: hour has private access in Time1
10        time.minute = 15; // error: minute has private access in Time1
11        time.second = 30; // error: second has private access in Time1
12    } // end main
13 } // end class MemberAccessTest
```

Attempting to access **private** instance variables

```
MemberAccessTest.java:9: hour has private access in Time1
    time.hour = 7; // error: hour has private access in Time1
      ^
MemberAccessTest.java:10: minute has private access in Time1
    time.minute = 15; // error: minute has private access in Time1
      ^
MemberAccessTest.java:11: second has private access in Time1
    time.second = 30; // error: second has private access in Time1
      ^
3 errors
```



5a.4 Referring to the Current Object's Members with the `this` Reference

The `this` reference

- Any object can access a reference to itself with keyword `this`
- Non-`static` methods implicitly use `this` when referring to the object's instance variables and other methods
- Can be used to access instance variables when they are shadowed by local variables or method parameters

A `.java` file can contain more than one class

- But only one class in each `.java` file can be `public`

Outline

ThisTest.java

(1 of 2)

```
1 // Fig. 8.4: ThisTest.java
2 // this used implicitly and explicitly to refer to members of an object.
3
4 public class ThisTest
5 {
6     public static void main( String args[] )
7     {
8         SimpleTime time = new SimpleTime( 15, 30, 19 );
9         System.out.println( time.buildString() );
10    } // end main
11 } // end class ThisTest
12
13 // class SimpleTime demonstrates the "this" reference
14 class SimpleTime
15 {
16     private int hour;    // 0-23
17     private int minute; // 0-59
18     private int second; // 0-59
19
20     // if the constructor uses parameter names identical to
21     // instance variable names the "this" reference is
22     // required to distinguish between names
23     public SimpleTime( int hour, int minute, int second )
24     {
25         this.hour = hour;    // set "this" object's hour
26         this.minute = minute; // set "this" object's minute
27         this.second = second; // set "this" object's second
28     } // end SimpleTime constructor
29
```

Create new **SimpleTime** object

Declare instance variables

Method parameters shadow
instance variables

Using this to access the object's instance variables



Outline

ThisTest.java

Using **this** explicitly and implicitly
to call **toUniversalString**

(2 of 2)

```
30 // use explicit and implicit "this" to call toUniversalString
31 public String buildString()
32 {
33     return String.format( "%24s: %s\n%24s: %s",
34         "this.toUniversalString()", this.toUniversalString(),
35         "toUniversalString()", toUniversalString() );
36 } // end method buildString
37
38 // convert to String in universal-time format (HH:MM:SS)
39 public String toUniversalString()
40 {
41     // "this" is not required here to access instance variables,
42     // because method does not have local variables with same
43     // names as instance variables
44     return String.format( "%02d:%02d:%02d",
45         this.hour, this.minute, this.second );
46 } // end method toUniversalString
47 } // end class SimpleTime
```

Use of **this** not necessary here

```
this.toUniversalString(): 15:30:19
toUniversalString(): 15:30:19
```



Common Programming Error

5a.2

It is often a logic error when a method contains a parameter or local variable that has the same name as a field of the class. In this case, use reference `this` if you wish to access the field of the class—otherwise, the method parameter or local variable will be referenced.

Error-Prevention Tip

5a.1

Avoid method parameter names or local variable names that conflict with field names. This helps prevent subtle, hard-to-locate bugs.

Performance Tip

5a.1

Java conserves storage by maintaining only one copy of each method per class—this method is invoked by every object of the class. Each object, on the other hand, has its own copy of the class's instance variables (i.e., non-static fields). Each method of the class implicitly uses `this` to determine the specific object of the class to manipulate.

5a.5 Time Class Case Study: Overloaded Constructors

Overloaded constructors

- Provide multiple constructor definitions with different signatures

No-argument constructor

- A constructor invoked without arguments

The `this` reference can be used to invoke another constructor

- Allowed only as the first statement in a constructor's body

Outline

Time2.java

(1 of 4)

```
1 // Fig. 8.5: Time2.java
2 // Time2 class declaration with overloaded constructors.
3
4 public class Time2
5 {
6     private int hour;    // 0 - 23
7     private int minute; // 0 - 59
8     private int second; // 0 - 59
9
10    // Time2 no-argument constructor: initializes each instance variable
11    // to zero; ensures that Time2 objects start in a consistent state
12    public Time2()
13    {
14        this( 0, 0, 0 ); // invoke Time2 constructor with three arguments
15    } // end Time2 no-argument constructor
16
17    // Time2 constructor: hour supplied, minute and second defaulted to 0
18    public Time2( int h )
19    {
20        this( h, 0, 0 ); // invoke Time2 constructor with three arguments
21    } // end Time2 one-argument constructor
22
23    // Time2 constructor: hour and minute supplied, second defaulted to 0
24    public Time2( int h, int m )
25    {
26        this( h, m, 0 ); // invoke Time2 constructor with three arguments
27    } // end Time2 two-argument constructor
28
```

No-argument constructor

Invoke three-argument constructor

Outline

Time2.java

(2 of 4)

```
29 // Time2 constructor: hour, minute and second supplied
30 public Time2( int h, int m, int s )
31 {
32     setTime( h, m, s ); // invoke setTime to validate time
33 } // end Time2 three-argument constructor
```

Call **setTime** method

```
34
35 // Time2 constructor: another Time2 object supplied
36 public Time2( Time2 time )
37 {
38     // invoke Time2 three-argument constructor
39     this( time.getHour(), time.getMinute(), time.getSecond() );
40 } // end Time2 constructor with a Time2 object argument
```

Constructor takes a reference to another **Time2** object as a parameter

Could have directly accessed instance variables of object **time** here

```
41
42 // Set Methods
43 // set a new time value using universal time; ensure that
44 // the data remains consistent by setting invalid values to zero
45 public void setTime( int h, int m, int s )
46 {
47     setHour( h ); // set the hour
48     setMinute( m ); // set the minute
49     setSecond( s ); // set the second
50 } // end method setTime
51
```



Outline

Time2.java

(3 of 4)

```
52 // validate and set hour
53 public void setHour( int h )
54 {
55     hour = ( ( h >= 0 && h < 24 ) ? h : 0 );
56 } // end method setHour
57
58 // validate and set minute
59 public void setMinute( int m )
60 {
61     minute = ( ( m >= 0 && m < 60 ) ? m : 0 );
62 } // end method setMinute
63
64 // validate and set second
65 public void setSecond( int s )
66 {
67     second = ( ( s >= 0 && s < 60 ) ? s : 0 );
68 } // end method setSecond
69
70 // Get Methods
71 // get hour value
72 public int getHour()
73 {
74     return hour;
75 } // end method getHour
76
```



Outline

Time2.java

(4 of 4)

```
77 // get minute value
78 public int getMinute()
79 {
80     return minute;
81 } // end method getMinute
82
83 // get second value
84 public int getSecond()
85 {
86     return second;
87 } // end method getSecond
88
89 // convert to String in universal-time format (HH:MM:SS)
90 public String toUniversalString()
91 {
92     return String.format(
93         "%02d:%02d:%02d", getHour(), getMinute(), getSecond() );
94 } // end method toUniversalString
95
96 // convert to String in standard-time format (H:MM:SS AM or PM)
97 public String toString()
98 {
99     return String.format( "%d:%02d:%02d %s",
100         ( (getHour() == 0 || getHour() == 12) ? 12 : getHour() % 12 ),
101         getMinute(), getSecond(), ( getHour() < 12 ? "AM" : "PM" ) );
102 } // end method toString
103 } // end class Time2
```



Common Programming Error 5a.3

It is a syntax error when `this` is used in a constructor's body to call another constructor of the same class if that call is not the first statement in the constructor. It is also a syntax error when a method attempts to invoke a constructor directly via `this`.

Common Programming Error

5a.4

A constructor can call methods of the class. Be aware that the instance variables might not yet be in a consistent state, because the constructor is in the process of initializing the object. Using instance variables before they have been initialized properly is a logic error.

Software Engineering Observation

5a.4

When one object of a class has a reference to another object of the same class, the first object can access all the second object's data and methods (including those that are private).

5a.5 Time Class Case Study: Overloaded Constructors (Cont.)

Using *set* methods

- Having constructors use *set* methods to modify instance variables instead of modifying them directly simplifies implementation changing

Software Engineering Observation

5a.5

When implementing a method of a class, use the class's *set* and *get* methods to access the class's private data. This simplifies code maintenance and reduces the likelihood of errors.

Outline

Call overloaded constructors

Time2Test.java

(1 of 3)

```
1 // Fig. 8.6: Time2Test.java
2 // overloaded constructors used to initialize Time2 objects.
3
4 public class Time2Test
5 {
6     public static void main( String args[] )
7     {
8         Time2 t1 = new Time2();           // 00:00:00
9         Time2 t2 = new Time2( 2 );       // 02:00:00
10        Time2 t3 = new Time2( 21, 34 );  // 21:34:00
11        Time2 t4 = new Time2( 12, 25, 42 ); // 12:25:42
12        Time2 t5 = new Time2( 27, 74, 99 ); // 00:00:00
13        Time2 t6 = new Time2( t4 );      // 12:25:42
14
15        System.out.println( "Constructed with:" );
16        System.out.println( "t1: all arguments defaulted" );
17        System.out.printf( "    %s\n", t1.toUniversalString() );
18        System.out.printf( "    %s\n", t1.toString() );
19    }
```



Outline

Time2Test.java

(2 of 3)

```
20 System.out.println(  
21     "t2: hour specified; minute and second defaulted" );  
22 System.out.printf( "    %s\n", t2.toUniversalString() );  
23 System.out.printf( "    %s\n", t2.toString() );  
24  
25 System.out.println(  
26     "t3: hour and minute specified; second defaulted" );  
27 System.out.printf( "    %s\n", t3.toUniversalString() );  
28 System.out.printf( "    %s\n", t3.toString() );  
29  
30 System.out.println( "t4: hour, minute and second specified" );  
31 System.out.printf( "    %s\n", t4.toUniversalString() );  
32 System.out.printf( "    %s\n", t4.toString() );  
33  
34 System.out.println( "t5: all invalid values specified" );  
35 System.out.printf( "    %s\n", t5.toUniversalString() );  
36 System.out.printf( "    %s\n", t5.toString() );  
37
```



```
38      System.out.println( "t6: Time2 object t4 specified" );
39      System.out.printf( "    %s\n", t6.toUniversalString() );
40      System.out.printf( "    %s\n", t6.toString() );
41  } // end main
42 } // end class Time2Test
```

Outline

Time2Test.java

(3 of 3)

```
t1: all arguments defaulted
    00:00:00
    12:00:00 AM
t2: hour specified; minute and second defaulted
    02:00:00
    2:00:00 AM
t3: hour and minute specified; second defaulted
    21:34:00
    9:34:00 PM
t4: hour, minute and second specified
    12:25:42
    12:25:42 PM
t5: all invalid values specified
    00:00:00
    12:00:00 AM
t6: Time2 object t4 specified
    12:25:42
    12:25:42 PM
```



5a.6 Default and No-Argument Constructors

Every class must have at least one constructor

- **If no constructors are declared, the compiler will create a default constructor**
 - **Takes no arguments and initializes instance variables to their initial values specified in their declaration or to their default values**
 - **Default values are zero for primitive numeric types, `false` for `boolean` values and `null` for references**
- **If constructors are declared, the default initialization for objects of the class will be performed by a no-argument constructor (if one is declared)**

Common Programming Error

5a.5

If a class has constructors, but none of the `public` constructors are no-argument constructors, and a program attempts to call a no-argument constructor to initialize an object of the class, a compilation error occurs. A constructor can be called with no arguments only if the class does not have any constructors (in which case the default constructor is called) or if the class has a `public` no-argument constructor.

Software Engineering Observation 5a.6

Java allows other methods of the class besides its constructors to have the same name as the class and to specify return types. Such methods are not constructors and will not be called when an object of the class is instantiated. Java determines which methods are constructors by locating the methods that have the same name as the class and do not specify a return type.

5a.7 Notes on *Set* and *Get* Methods

Set methods

- Also known as mutator methods
- Assign values to instance variables
- Should validate new values for instance variables
 - Can return a value to indicate invalid data

Get methods

- Also known as accessor methods or query methods
- Obtain the values of instance variables
- Can control the format of the data it returns

Software Engineering Observation

5a.7

When necessary, provide public methods to change and retrieve the values of private instance variables. This architecture helps hide the implementation of a class from its clients, which improves program modifiability.

Software Engineering Observation

5a.8

Class designers need not provide *set* or *get* methods for each private field. These capabilities should be provided only when it makes sense.

5a.7 Notes on *Set* and *Get* Methods (Cont.)

Predicate methods

- Test whether a certain condition on the object is true or false and returns the result
- Example: an `isEmpty` method for a container class (a class capable of holding many objects)

Encapsulating specific tasks into their own methods simplifies debugging efforts



Time3.java

Lines 6-8
private variables
cannot be accessed
directly by objects in
different classes

private variables cannot be
accessed directly by objects in
different classes

```
1 // Fig. 5a.7a: Time3.java
2 // Time3 class declaration with set and get methods.
3 import java.text.DecimalFormat;
4
5 public class Time3 {
6     private int hour;    // 0 - 23
7     private int minute;  // 0 - 59
8     private int second;  // 0 - 59
9
10    // Time3 constructor initializes each
11    // ensures that Time object starts in a consistent state
12    public Time3()
13    {
14        this( 0, 0, 0 ); // invoke Time3 constructor with three arguments
15    }
16
17    // Time3 constructor: hour supplied, minute and second defaulted to 0
18    public Time3( int h )
19    {
20        this( h, 0, 0 ); // invoke Time3 constructor with three arguments
21    }
22
23    // Time3 constructor: hour and minute supplied, second defaulted to 0
24    public Time3( int h, int m )
25    {
26        this( h, m, 0 ); // invoke Time3 constructor with three arguments
27    }
28
```



Time3.java

Lines 45-68

Set methods allows
objects to manipulate
private variables

```
29 // Time3 constructor: hour, minute and second supplied
30 public Time3( int h, int m, int s )
31 {
32     setTime( h, m, s );
33 }
34
35 // Time3 constructor: another Time3 object supplied
36 public Time3( Time3 time )
37 {
38     // invoke Time3 constructor with three arguments
39     this( time.getHour(), time.getMinute(), time.getSecond() );
40 }
41
42 // Set Methods
43 // set a new time value using universal time; perform
44 // validity checks on data; set invalid values to zero
45 public void setTime( int h, int m, int s )
46 {
47     setHour( h ); // set the hour
48     setMinute( m ); // set the minute
49     setSecond( s ); // set the second
50 }
51
52 // validate and set hour
53 public void setHour( int h )
54 {
55     hour = ( ( h >= 0 && h < 24 ) ? h : 0 );
56 }
57
```

Set methods allows objects to
manipulate **private** variables



Time3.java

Lines 72-87

Get methods allow
objects to read
private variables

```
58 // validate and set minute
59 public void setMinute( int m )
60 {
61     minute = ( ( m >= 0 && m < 60 ) ? m : 0 );
62 }
63
64 // validate and set second
65 public void setSecond( int s )
66 {
67     second = ( ( s >= 0 && s < 60 ) ? s : 0 );
68 }
69
70 // Get Methods
71 // get hour value
72 public int getHour()
73 {
74     return hour;
75 }
76
77 // get minute value
78 public int getMinute()
79 {
80     return minute;
81 }
82
```

Get methods allow objects to
read **private** variables



```
83 // get second value
84 public int getSecond()
85 {
86     return second;
87 }
88
89 // convert to String in universal-time format
90 public String toUniversalString()
91 {
92     DecimalFormat twoDigits = new DecimalFormat( "00" );
93
94     return twoDigits.format( getHour() ) + ":" +
95         twoDigits.format( getMinute() ) + ":" +
96         twoDigits.format( getSecond() );
97 }
98
99 // convert to String in standard-time format
100 public String toStandardString()
101 {
102     DecimalFormat twoDigits = new DecimalFormat( "00" );
103
104     return ( ( getHour() == 12 || getHour() == 0 ) ?
105         12 : getHour() % 12 ) + ":" + twoDigits.format( getMinute() ) +
106         ":" + twoDigits.format( getSecond() ) +
107         ( getHour() < 12 ? " AM" : " PM" );
108 }
109
110 } // end class Time3
```



TimeTest4.java

Lines 8 and 17

Declare and instantiate
Time3 object

Lines 25 and 31

JTextFields allow user
to specify hour.

```

1  // Fig. 5a.8a: TimeTest4.java
2  // Demonstrating the Time3 class set and get methods.
3  import java.awt.*;
4  import java.awt.event.*;
5  import javax.swing.*;
6
7  public class TimeTest4 extends JApplet implements ActionListener {
8      private Time3 time;
9
10     private JLabel hourLabel, minuteLabel;
11     private JTextField hourField, minuteField;
12     private JButton tickButton;
13
14     // create Time3 object and set up GUI
15     public void init()
16     {
17         time = new Time3(); // create Time3 object
18
19         // get applet's content pane and change its layout to FlowLayout
20         Container container = getContentPane();
21         container.setLayout( new FlowLayout() );
22
23         // set up hourLabel and hourField
24         hourLabel = new JLabel( "Set Hour" );
25         hourField = new JTextField( 10 );
26         container.add( hourLabel );
27         container.add( hourField );
28

```

Declare and instantiate
Time3 object

JTextFields allow user to
specify hour



TimeTest4.java

Line 31

JTextField allows
user to specify minute

Line 37

JTextField allows
user to specify second

```
29 // set up minuteLabel and minuteField
30 minuteLabel = new JLabel( "Set Minute" );
31 minuteField = new JTextField( 10 );
32 container.add( minuteLabel );
33 container.add( minuteField );
34
35 // set up secondLabel and secondField
36 secondLabel = new JLabel( "Set Second" );
37 secondField = new JTextField( 10 );
38 container.add( secondLabel );
39 container.add( secondField );
40
41 // set up displayField
42 displayField = new JTextField( 30 );
43 displayField.setEditable( false );
44 container.add( displayField );
45
46 // set up tickButton
47 tickButton = new JButton( "Add 1 to Second" );
48 container.add( tickButton );
49
50 // register event handlers; this applet is the ActionListener,
51 // which contains method actionPerformed that will be called to
52 // handle action events generated by hourField, minuteField,
53 // secondField and tickButton
54 hourField.addActionListener( this );
55 minuteField.addActionListener( this );
56 secondField.addActionListener( this );
57 tickButton.addActionListener( this );
```

JTextField allows
user to specify minuteJTextField allows
user to specify second

TimeTest4.java

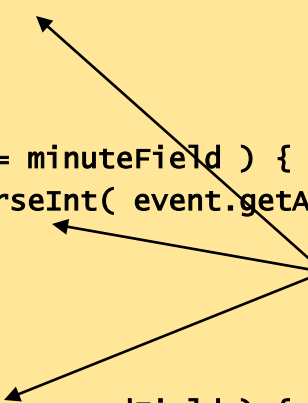
Lines 71-74

Lines 77-80

Lines 83-86

TimeTest5 uses
Time3 set methods to
set Time3 private
variables

```
58      displayTime(); // update text in displayField and status bar
59
60
61  } // end method init
62
63  // event handler for button and textfield events
64  public void actionPerformed( ActionEvent event )
65  {
66      // process tickButton event
67      if ( event.getSource() == tickButton )
68          tick();
69
70      // process hourField event
71      else if ( event.getSource() == hourField ) {
72          time.setHour( Integer.parseInt( event.getActionCommand() ) );
73          hourField.setText( "" );
74      }
75
76      // process minuteField event
77      else if ( event.getSource() == minuteField ) {
78          time.setMinute( Integer.parseInt( event.getActionCommand() ) );
79          minuteField.setText( "" );
80      }
81
82      // process secondField event
83      else if ( event.getSource() == secondField ) {
84          time.setSecond( Integer.parseInt( event.getActionCommand() ) );
85          secondField.setText( "" );
86      }
```



TimeTest5 uses Time3 set methods to
set Time3 private variables



TimeTest4.java

Lines 95-96

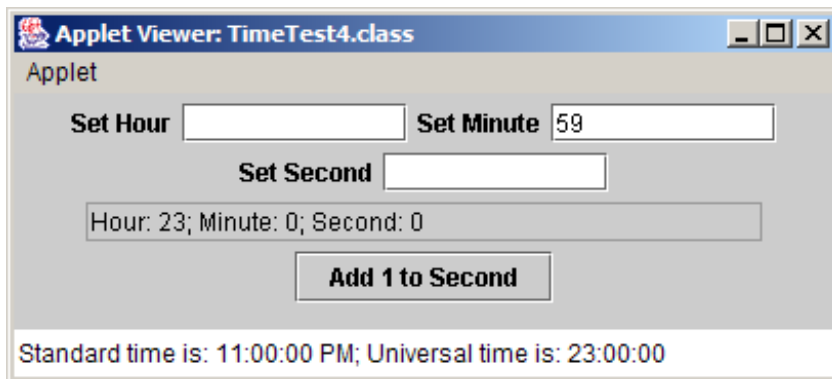
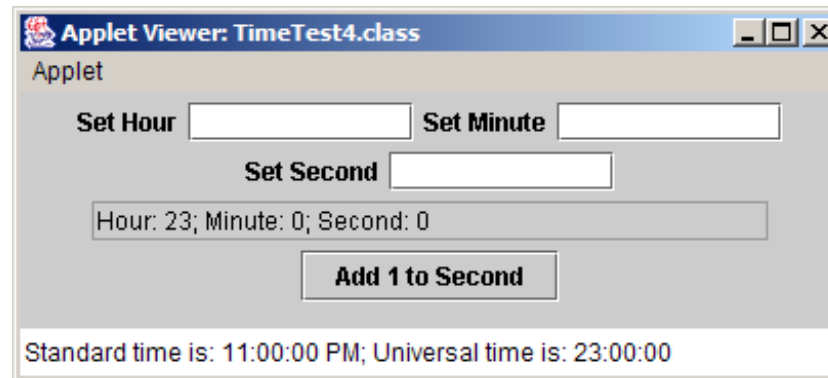
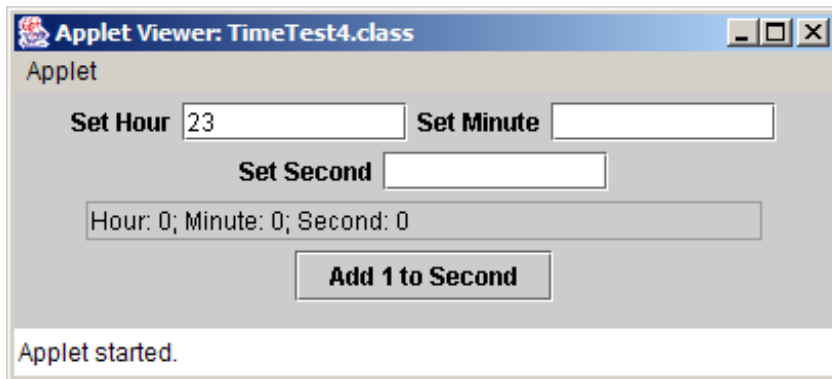
TimeTest5 uses
Time3 get methods to
read Time3
private variables

TimeTest5 uses Time3 get methods
to read Time3 private variables

```
87      displayTime(); // update text in displayField and status bar
88
89  } // end method actionPerformed
90
91  // update displayField and applet container's status bar
92  public void displayTime()
93  {
94      displayField.setText( "Hour: " + time.getHour() + "; Minute: " +
95                          time.getMinute() + "; Second: " + time.getSecond() );
96
97      showStatus( "Standard time is: " + time.toStandardString() +
98                "; Universal time is: " + time.toUniversalString() );
99
100 } // end method updatedDisplay
101
102 // add one to second and update hour/minute if needed
103 public void tick()
104 {
105     time.setSecond( ( time.getSecond() + 1 ) % 60 );
106
107     if ( time.getSecond() == 0 ) {
108         time.setMinute( ( time.getMinute() + 1 ) % 60 );
109
110         if ( time.getMinute() == 0 )
111             time.setHour( ( time.getHour() + 1 ) % 24 );
112     }
113 }
114
115 } // end method tick
116
117 } // end class TimeTest4
```

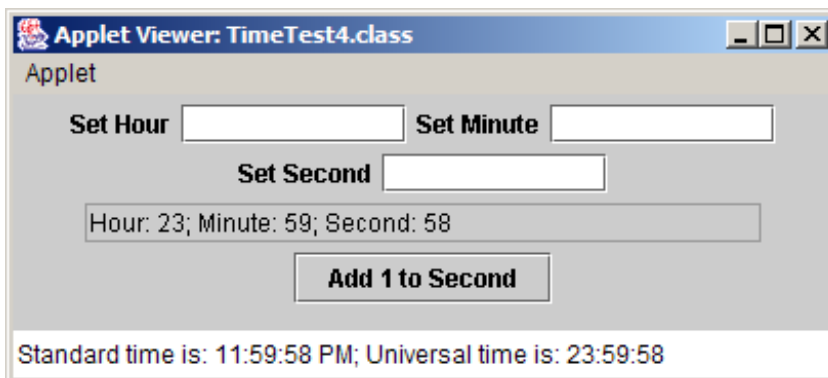
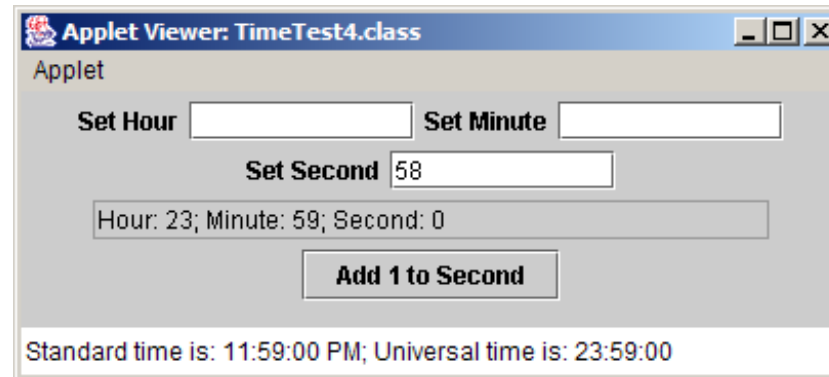
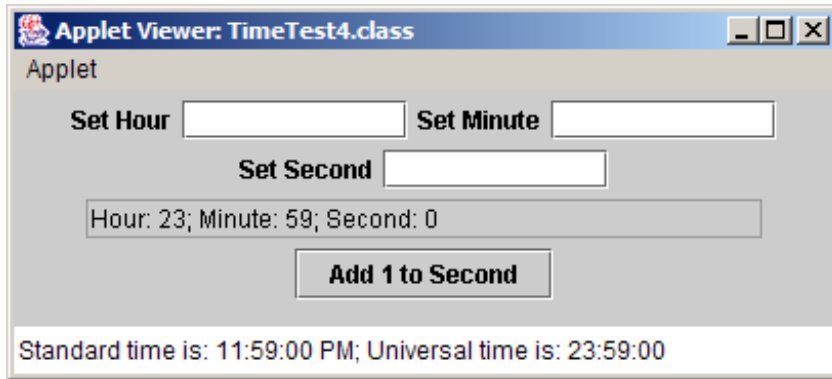
Outline

TimeTest4.java



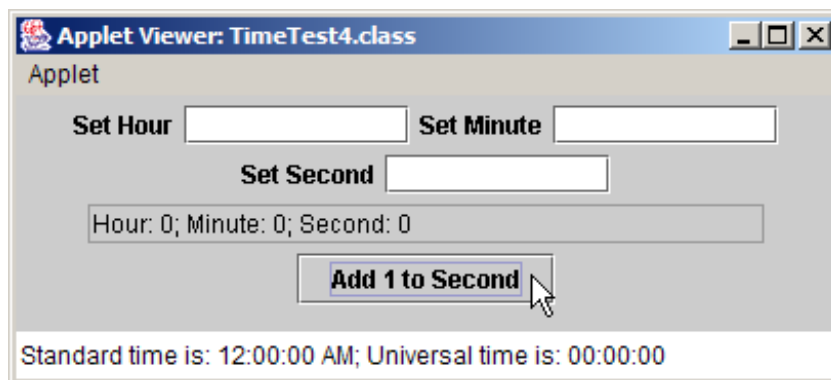
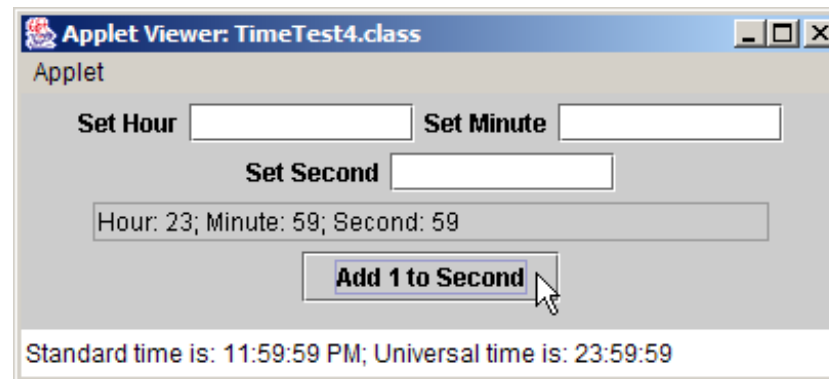
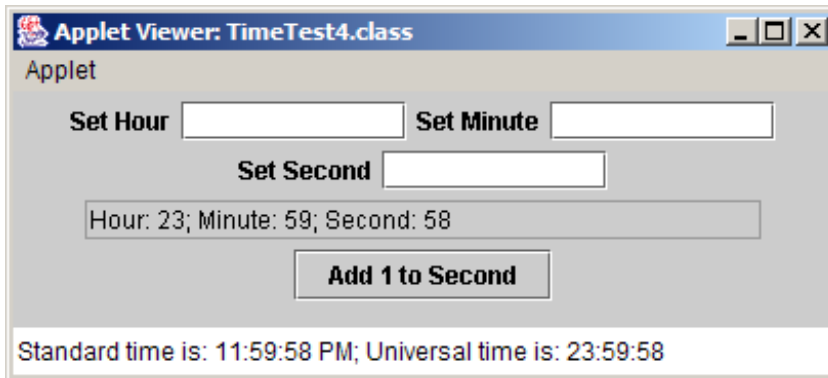
Outline

TimeTest4.java



Outline

TimeTest4.java



5a.8 Composition

The **Single responsibility principle** states that **every context** (class, method, variable) should have a **single responsibility**, and that responsibility should be entirely encapsulated by the context. All its services should be narrowly aligned with that responsibility.

Definition: Responsibility is a *reason to change*,
Hence, a class, method, variable should have one, and only one, reason to change.

5a.8 Composition

Example

Consider a class that compiles and prints a report. It may change for two reasons. First, the content of the report can change. Second, the format of the report can change. The single responsibility principle says that these two aspects of the problem are really two separate responsibilities, and should therefore be in separate classes. It would be a **bad design** to **couple two things that change for different reasons** at different times.

Software Engineering Observation

5a.9

The reason it is important to keep a class focused on a **single concern** is that it **makes the class more robust**. Continuing with the foregoing example, if there is a change to the report compilation process, there is greater danger that the printing code will break, if it is part of the same class.

5a.8 Composition

Composition

- A class can have references to objects of other classes as members
- Sometimes referred to as a *has-a* relationship

Software Engineering Observation

5a.9

One form of software reuse is composition, in which a class has as members references to objects of other classes.

Outline

Date.java

(1 of 3)

```
1 // Fig. 8.7: Date.java
2 // Date class declaration.
3
4 public class Date
5 {
6     private int month; // 1-12
7     private int day;   // 1-31 based on month
8     private int year;  // any year
9
10    // constructor: call checkMonth to confirm proper value for month;
11    // call checkDay to confirm proper value for day
12    public Date( int theMonth, int theDay, int theYear )
13    {
14        month = checkMonth( theMonth ); // validate month
15        year = theYear; // could validate year
16        day = checkDay( theDay ); // validate day
17
18        System.out.printf(
19            "Date object constructor for date %s\n", this );
20    } // end Date constructor
21
```



Outline

Date.java

(2 of 3)

```
22 // utility method to confirm proper month value
23 private int checkMonth( int testMonth ) ← Validates month value
24 {
25     if ( testMonth > 0 && testMonth <= 12 ) // validate month
26         return testMonth;
27     else // month is invalid
28     {
29         System.out.printf(
30             "Invalid month (%d) set to 1.", testMonth );
31         return 1; // maintain object in consistent state
32     } // end else
33 } // end method checkMonth
34
35 // utility method to confirm proper day value based on month and year
36 private int checkDay( int testDay ) ← Validates day value
37 {
38     int daysPerMonth[] =
39         { 0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31 };
40
```



Outline

Date.java

```
41 // check if day in range for month
42 if ( testDay > 0 && testDay <= daysPerMonth[ month ] )
43     return testDay;
44
45 // check for leap year
46 if ( month == 2 && testDay == 29 && ( year % 400 == 0 ||
47     ( year % 4 == 0 && year % 100 != 0 ) ) )
48     return testDay;
49
50 System.out.printf( "Invalid day (%d) set to 1.", testDay );
51 return 1; // maintain object in consistent state
52 } // end method checkDay
53
54 // return a String of the form month/day/year
55 public String toString()
56 {
57     return String.format( "%d/%d/%d", month, day, year );
58 } // end method toString
59 } // end class Date
```

Check if the day is
February 29 on a
leap year



Outline

Employee.java

```
1 // Fig. 8.8: Employee.java
2 // Employee class with references to other objects.
3
4 public class Employee
5 {
6     private String firstName;
7     private String lastName;
8     private Date birthDate;
9     private Date hireDate;
10
11     // constructor to initialize name, birth date and hire date
12     public Employee( String first, String last, Date dateOfBirth,
13         Date dateOfHire )
14     {
15         firstName = first;
16         lastName = last;
17         birthDate = dateOfBirth;
18         hireDate = dateOfHire;
19     } // end Employee constructor
20
21     // convert Employee to String format
22     public String toString()
23     {
24         return String.format( "%s, %s Hired: %s Birthday: %s",
25             lastName, firstName, hireDate, birthDate );
26     } // end method toString
27 } // end class Employee
```

Employee contains references
to two **Date** objects

Implicit calls to **hireDate** and
birthDate's **toString** methods



Outline

EmployeeTest.java

```
1 // Fig. 8.9: EmployeeTest.java
2 // Composition demonstration.
3
4 public class EmployeeTest
5 {
6     public static void main( String args[] )
7     {
8         Date birth = new Date( 7, 24, 1949 );
9         Date hire = new Date( 3, 12, 1988 );
10        Employee employee = new Employee( "Bob", "Blue", birth, hire );
11
12        System.out.println( employee );
13    } // end main
14 } // end class EmployeeTest
```

Create an **Employee** object

Display the **Employee** object

Date object constructor for date 7/24/1949
Date object constructor for date 3/12/1988
Blue, Bob Hired: 3/12/1988 Birthday: 7/24/1949



5a.9 Enumerations

enum types

- Declared with an **enum** declaration
 - A comma-separated list of **enum** constants
 - Declares an **enum** class with the following restrictions:
 - **enum** types are implicitly **final**
 - **enum** constants are implicitly **static**
 - Attempting to create an object of an **enum** type with **new** is a compilation error
- **enum** constants can be used anywhere constants can
- **enum** constructor
 - Like class constructors, can specify parameters and be overloaded

Outline

Book.java

(1 of 2)

```
1 // Fig. 8.10: Book.java
2 // Declaring an enum type with constructor and explicit instance fields
3 // and accessors for these field
4
5 public enum Book
6 {
7     // declare constants of enum type
8     JHTP6( "Java How to Program 6e", "2005" ),
9     CHTP4( "C How to Program 4e", "2004" ),
10    IW3HTP3( "Internet & World wide Web How to Program 3e", "2004" ),
11    CPPHTP4( "C++ How to Program 4e", "2003" ),
12    VBHTP2( "Visual Basic .NET How to Program 2e", "2002" ),
13    CSHARPHTP( "C# How to Program", "2002" );
14
15    // instance fields
16    private final String title; // book title
17    private final String copyrightYear; // copyright year
18
19    // enum constructor
20    Book( String bookTitle, String year )
21    {
22        title = bookTitle;
23        copyrightYear = year;
24    } // end enum Book constructor
25
```

Declare six **enum** constants

Arguments to pass to the
enum constructor

Declare instance variables

Declare **enum** constructor **Book**



Outline

Book.java

(2 of 2)

```
26 // accessor for field title
27 public String getTitle()
28 {
29     return title;
30 } // end method getTitle
31
32 // accessor for field copyrightYear
33 public String getCopyrightYear()
34 {
35     return copyrightYear;
36 } // end method getCopyrightYear
37 } // end enum Book
```



5a.9 Enumerations (Cont.)

static method values

- Generated by the compiler for every `enum`
- Returns an array of the `enum`'s constants in the order in which they were declared

static method ordinal

- Returns the sequential number of an `enum` constant

static method range of class EnumSet

- Takes two parameters, the first and last `enum` constants in the desired range
- Returns an `EnumSet` containing the constants in that range, inclusive
- An enhanced `for` statement can iterate over an `EnumSet` as it can over an array



Outline

EnumTest.java

```
1 // Fig. 8.11: EnumTest.java
2 // Testing enum type Book.
3 import java.util.EnumSet;
4
5 public class EnumTest
6 {
7     public static void main( String args[] )
8     {
9         System.out.println( "All books:\n" );
10
11         // print all books in enum Book
12         for ( Book book : Book.values() )
13             System.out.printf( "%-10s%-45s\n", book,
14                               book.getTitle(), book.getCopyrightYear() );
15
16         System.out.println( "\nDisplay a range of enum constants:\n" );
17
18         // print first four books
19         for ( Book book : EnumSet.range( Book.JHTP6, Book.CPPHTP4 ) )
20             System.out.printf( "%-10s%-45s\n", book,
21                               book.getTitle(), book.getCopyrightYear() );
22     } // end main
23 } // end class EnumTest
```

Enhanced **for** loop iterates for each **enum** constant in the array returned by method **value**

Enhanced **for** loop iterates for each **enum** constant in the **EnumSet** returned by method **range**



Outline

EnumTest.java

(2 of 2)

All books:

JHTP6	Java How to Program 6e	2005
CHTP4	C How to Program 4e	2004
IW3HTP3	Internet & World Wide Web How to Program 3e	2004
CPPHTP4	C++ How to Program 4e	2003
VBHTP2	Visual Basic .NET How to Program 2e	2002
CSHARPHTP	C# How to Program	2002

Display a range of enum constants:

JHTP6	Java How to Program 6e	2005
CHTP4	C How to Program 4e	2004
IW3HTP3	Internet & World Wide Web How to Program 3e	2004
CPPHTP4	C++ How to Program 4e	2003



Common Programming Error

5a.6

In an enum declaration, it is a syntax error to declare enum constants after the enum type's constructors, fields and methods in the enum declaration.

Outline

```
1 public enum ConvertableEnum { // convert int to enum
2     POSITIVE, NEGATIVE, EITHER, UNDEFINED;
3
4     public static ConvertableEnum convertIntToEnum(int i) {
5         return values()[i]; // values() converts enum to an array
6     }
7
8     public static ConvertableEnum convertIntToEnumWithException(int i) {
9         try {
10             return values()[i];
11         } catch (ArrayIndexOutOfBoundsException e) {
12             return UNDEFINED;
13         }
14     }
15
16     public static ConvertableEnum convertIntToEnumWithOrdinal(int i) {
17         for (ConvertableEnum current : values()) {
18             if (current.ordinal() == i) { // Using ordinal()!!
19                 return current;
20             }
21         }
22
23         return UNDEFINED;
24     }
25 }
```

ConvertableEnum.java

`values()` converts `enum` to an array

`ordinal()` returns the sequential
number of an `enum` constant



5a.10 Garbage Collection and Method `finalize`

Garbage collection

- JVM marks an object for garbage collection when there are no more references to that object
- JVM's garbage collector will retrieve those objects memory so it can be used for other objects

`finalize` method

- All classes in Java have the `finalize` method
 - Inherited from the `Object` class
- `finalize` is called by the garbage collector when it performs termination housekeeping
- `finalize` takes no parameters and has return type `void`

Software Engineering Observation

5a.10

A class that uses system resources, such as files on disk, should provide a method to eventually release the resources. Many Java API classes provide `close` or `dispose` methods for this purpose. For example, class `Scanner` (java.sun.com/j2se/5.0/docs/api/java/util/Scanner.html) has a `close` method.

5a.11 `static` Class Members

`static` fields

- Also known as class variables
- Represents class-wide information
- Used when:
 - all objects of the class should share the same copy of this instance variable or
 - this instance variable should be accessible even when no objects of the class exist
- Can be accessed with the class name or an object name and a dot (.)
- Must be initialized in their declarations, or else the compiler will initialize it with a default value (0 for `ints`)

Software Engineering Observation

5a.11

Use a static variable when all objects of a class must use the same copy of the variable.

Software Engineering Observation

5a.12

Static class variables and methods exist, and can be used, even if no objects of that class have been instantiated.

Outline

Employee.java

(1 of 2)

```
1 // Fig. 8.12: Employee.java
2 // Static variable used to maintain a count of the number of
3 // Employee objects in memory.
4
5 public class Employee
6 {
7     private String firstName;
8     private String lastName;
9     private static int count = 0; // number of objects in memory
10
11     // initialize employee, add 1 to static count and
12     // output String indicating that constructor was called
13     public Employee( String first, String last )
14     {
15         firstName = first;
16         lastName = last;
17
18         count++; // increment static count of employees
19         System.out.printf( "Employee constructor: %s %s; count = %d\n",
20             firstName, lastName, count );
21     } // end Employee constructor
22
```

Declare a **static** field

Increment **static** field

Outline

Employee.java

(2 of 2)

```
23 // subtract 1 from static count when garbage
24 // collector calls finalize to clean up object;
25 // confirm that finalize was called
26 protected void finalize() ← Declare method finalize
27 {
28     count--; // decrement static count of employees
29     System.out.printf( "Employee finalizer: %s %s; count = %d\n",
30         firstName, lastName, count );
31 } // end method finalize
32
33 // get first name
34 public String getFirstName()
35 {
36     return firstName;
37 } // end method getFirstName
38
39 // get last name
40 public String getLastName()
41 {
42     return lastName;
43 } // end method getLastName
44
45 // static method to get static count value
46 public static int getCount() ← Declare static method getCount to
47 {                                     get static field count
48     return count;
49 } // end method getCount
50 } // end class Employee
```



Outline

EmployeeTest.java

(1 of 3)

```
1 // Fig. 8.13: EmployeeTest.java
2 // Static member demonstration.
3
4 public class EmployeeTest
5 {
6     public static void main( String args[] )
7     {
8         // show that count is 0 before creating Employees
9         System.out.printf( "Employees before instantiation: %d\n",
10             Employee.getCount() );
11
12         // create two Employees; count should be 2
13         Employee e1 = new Employee( "Susan", "Baker" );
14         Employee e2 = new Employee( "Bob", "Blue" );
15
```

Call **static** method **getCount** using class name **Employee**

Create new **Employee** objects



Outline

EmployeeTest.java

```
16 // show that count is 2 after creating two Employees
17 System.out.println( "\nEmployees after instantiation: " );
18 System.out.printf( "via e1.getCount(): %d\n", e1.getCount() );
19 System.out.printf( "via e2.getCount(): %d\n", e2.getCount() );
20 System.out.printf( "via Employee.getCount(): %d\n",
21     Employee.getCount() );
22
23 // get names of Employees
24 System.out.printf( "\nEmployee 1: %s %s\nEmployee 2: %s %s\n\n",
25     e1.getFirstName(), e1.getLastName(),
26     e2.getFirstName(), e2.getLastName() );
27
28 // in this example, there is only one reference to each Employee,
29 // so the following two statements cause the JVM to mark each
30 // Employee object for garbage collection
31 e1 = null;
32 e2 = null;
33
34 System.gc(); // ask for garbage collection to occur now
35
```

Call **static** method
getCount outside objects

Call **static** method **getCount**
inside objects

(2 of 3)

Remove references to objects, JVM will
mark them for garbage collection

Call **static** method **gc** of class **System** to indicate
that garbage collection should be attempted



Outline

EmployeeTest.java

(3 of 3)

```
36 // show Employee count after calling garbage collector; count
37 // displayed may be 0, 1 or 2 based on whether garbage collector
38 // executes immediately and number of Employee objects collected
39 System.out.printf( "\nEmployees after System.gc(): %d\n",
40     Employee.getCount() );
41 } // end main
42 } // end class EmployeeTest
```

Call **static** method **getCount**

```
Employees before instantiation: 0
Employee constructor: Susan Baker; count = 1
Employee constructor: Bob Blue; count = 2

Employees after instantiation:
via e1.getCount(): 2
via e2.getCount(): 2
via Employee.getCount(): 2

Employee 1: Susan Baker
Employee 2: Bob Blue

Employee finalizer: Bob Blue; count = 1
Employee finalizer: Susan Baker; count = 0

Employees after System.gc(): 0
```



Good Programming Practice

5a.1

Invoke every static method by using the class name and a dot (.) to emphasize that the method being called is a static method.

5a.11 `static` Class Members (Cont.)

String objects are immutable

- **String** concatenation operations actually result in the creation of a new **String** object

static method `gc` of class **System**

- Indicates that the garbage collector should make a best-effort attempt to reclaim objects eligible for garbage collection
- It is possible that no objects or only a subset of eligible objects will be collected

static methods cannot access non-**static** class members

- Also cannot use the `this` reference

Common Programming Error

5a.7

A compilation error occurs if a `static` method calls an instance (`non-static`) method in the same class by using only the method name. Similarly, a compilation error occurs if a `static` method attempts to access an instance variable in the same class by using only the variable name.

Common Programming Error 5a.8

Referring to `this` in a `static` method is a syntax error.

5a.12 `static Import`

`static import` declarations

- Enables programmers to refer to imported `static` members as if they were declared in the class that uses them
- Single `static import`
 - `import static
 packageName.ClassName.staticMemberName;`
- `static import on demand`
 - `import static packageName.ClassName.*;`
 - Imports all static members of the specified class

Outline

StaticImportTest .java

```
1 // Fig. 8.14: StaticImportTest.java
2 // Using static import to import static methods of class Math.
3 import static java.lang.Math.*; ← static import on demand
4
5 public class StaticImportTest
6 {
7     public static void main( String args[] )
8     {
9         System.out.printf( "sqrt( 900.0 ) = %.1f\n", sqrt( 900.0 ) );
10        System.out.printf( "ceil( -9.8 ) = %.1f\n", ceil( -9.8 ) );
11        System.out.printf( "log( E ) = %.1f\n", log( E ) );
12        System.out.printf( "cos( 0.0 ) = %.1f\n", cos( 0.0 ) );
13    } // end main
14 } // end class StaticImportTest
```

Use **Math**'s **static** methods and instance variable without preceding them with **Math**.

```
sqrt( 900.0 ) = 30.0
ceil( -9.8 ) = -9.0
log( E ) = 1.0
cos( 0.0 ) = 1.0
```



Common Programming Error

5a.9

A compilation error occurs if a program attempts to import `static` methods that have the same signature or `static` fields that have the same name from two or more classes.

5a.13 `final` Instance Variables

Principle of least privilege

- Code should have only the privilege and access it needs to accomplish its task, but no more

`final` instance variables

- Keyword `final`
 - Specifies that a variable is not modifiable (is a constant)
- `final` instance variables can be initialized at their declaration
 - If they are not initialized in their declarations, they must be initialized in all constructors

Software Engineering Observation

5a.13

Declaring an instance variable as `final` helps enforce the principle of least privilege. If an instance variable should not be modified, declare it to be `final` to prevent modification.

Outline

Increment.java

```
1 // Fig. 8.15: Increment.java
2 // final instance variable in a class.
3
4 public class Increment
5 {
6     private int total = 0; // total of all increments
7     private final int INCREMENT; // constant variable (uninitialized)
8
9     // constructor initializes final instance variable INCREMENT
10    public Increment( int incrementValue )
11    {
12        INCREMENT = incrementValue; // initialize constant variable (once)
13    } // end Increment constructor
14
15    // add INCREMENT to total
16    public void addIncrementToTotal()
17    {
18        total += INCREMENT;
19    } // end method addIncrementToTotal
20
21    // return String representation of an Increment object's data
22    public String toString()
23    {
24        return String.format( "total = %d", total );
25    } // end method toString
26 } // end class Increment
```

Declare **final**
instance variable

Initialize **final** instance variable
inside a constructor



Outline

IncrementTest.java

```
1 // Fig. 8.16: IncrementTest.java
2 // final variable initialized with a constructor argument.
3
4 public class IncrementTest
5 {
6     public static void main( String args[] )
7     {
8         Increment value = new Increment( 5 );
9
10        System.out.printf( "Before incrementing: %s\n\n", value );
11
12        for ( int i = 1; i <= 3; i++ )
13        {
14            value.addIncrementToTotal();
15            System.out.printf( "After increment %d: %s\n", i, value );
16        } // end for
17    } // end main
18 } // end class IncrementTest
```

Create an **Increment** objectCall method **addIncrementToTotal**

Before incrementing: total = 0

After increment 1: total = 5

After increment 2: total = 10

After increment 3: total = 15



Common Programming Error 5a.10

Attempting to modify a `final` instance variable after it is initialized is a compilation error.

Error-Prevention Tip 5a.2

Attempts to modify a final instance variable are caught at compilation time rather than causing execution-time errors. It is always preferable to get bugs out at compilation time, if possible, rather than allow them to slip through to execution time (where studies have found that the cost of repair is often many times more expensive).

Software Engineering Observation

5a.14

A `final` field should also be declared `static` if it is initialized in its declaration. Once a `final` field is initialized in its declaration, its value can never change. Therefore, it is not necessary to have a separate copy of the field for every object of the class. Making the field `static` enables all objects of the class to share the `final` field.

Common Programming Error 5a.11

Not initializing a `final` instance variable in its declaration or in every constructor of the class yields a compilation error indicating that the variable might not have been initialized. The same error occurs if the class initializes the variable in some, but not all, of the class's constructors.

Outline

Increment.java

```
Increment.java:13: variable INCREMENT might not have been initialized
    } // end Increment constructor
    ^
1 error
```





IncrementTest.j
ava

```
1 // Fig. 5a.14a: IncrementTest.java
2 // Initializing a final variable.
3 import java.awt.*;
4 import java.awt.event.*;
5 import javax.swing.*;
6
7 public class IncrementTest extends JApplet implements ActionListener {
8     private Increment incrementObject;
9     private JButton button;
10
11     // set up GUI
12     public void init()
13     {
14         incrementObject = new Increment( 5 );
15
16         Container container = getContentPane();
17
18         button = new JButton( "Click to increment" );
19         button.addActionListener( this );
20         container.add( button );
21     }
22
23     // add INCREMENT to total when user clicks button
24     public void actionPerformed((ActionEvent actionEvent) )
25     {
26         incrementObject.increment();
27         showStatus( incrementObject.toIncrementString() );
28     }
29
30 } // end class IncrementTest
31
```

Increment.java

final keyword declares
INCREMENT as constant

Line 36

final keyword
declares INCREMENT
as constant

Line 41

final variable
INCREMENT must be
initialized before
using it

final variable INCREMENT
must be initialized before using it

```

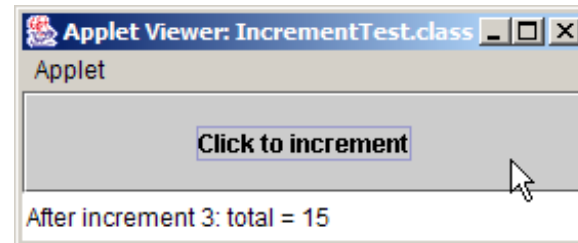
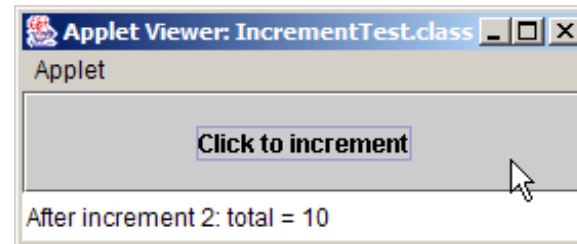
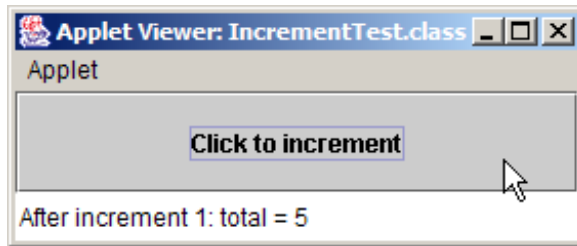
32 // class containing constant variable
33 class Increment {
34     private int count = 0;        // number of increments
35     private int total = 0;        // total of all increments
36     private final int INCREMENT;  // constant variable
37
38     // initialize constant INCREMENT
39     public Increment( int incrementValue )
40     {
41         INCREMENT = incrementValue; // initialize constant variable (once)
42     }
43
44     // add INCREMENT to total and add 1 to count
45     public void increment()
46     {
47         total += INCREMENT;
48         ++count;
49     }
50
51     // return String representation of an Increment object's data
52     public String toIncrementString()
53     {
54         return "After increment " + count + ": total = " + total;
55     }
56
57 } // end class Increment

```

IncrementTest.java:40: variable INCREMENT might not have been initialized

```
{  
^
```

1 error



5a.14 Software Reusability

Rapid application development

- Software reusability speeds the development of powerful, high-quality software

Java's API

- provides an entire framework in which Java developers can work to achieve true reusability and rapid application development
- Documentation:
 - java.sun.com/j2se/5.0/docs/api/index.html
 - Or java.sun.com/j2se/5.0/download.html to download

5a.15 Data Abstraction and Encapsulation

Data abstraction

- Information hiding
 - Classes normally hide the details of their implementation from their clients
- Abstract data types (ADTs)
 - Data representation
 - example: primitive type `int` is an abstract representation of an integer
 - `ints` are only approximations of integers, can produce arithmetic overflow
 - Operations that can be performed on data

Good Programming Practice 5a.2

Avoid reinventing the wheel. Study the capabilities of the Java API. If the API contains a class that meets your program's requirements, use that class rather than create your own.

5a.15 Data Abstraction and Encapsulation (Cont.)

Queues

- **Similar to a “waiting line”**
 - **Clients place items in the queue (enqueue an item)**
 - **Clients get items back from the queue (dequeue an item)**
 - **First-in, first out (FIFO) order**
- **Internal data representation is hidden**
 - **Clients only see the ability to enqueue and dequeue items**

Software Engineering Observation

5a.15

Programmers create types through the class mechanism. New types can be designed to be convenient to use as the built-in types. This marks Java as an extensible language. Although the language is easy to extend via new types, the programmer cannot alter the base language itself.

5a.16 Time Class Case Study: Creating Packages

To declare a reusable class

- Declare a **public** class
- Add a **package** declaration to the source-code file
 - must be the very first executable statement in the file
 - **package** name should consist of your Internet domain name in reverse order followed by other names for the package
 - example: `com.deitel.jhttp6.ch08`
 - **package** name is part of the fully qualified class name
 - Distinguishes between multiple classes with the same name belonging to different packages
 - Prevents name conflict (also called name collision)
 - Class name without **package** name is the simple name

Outline

Time1.java

(1 of 2)

```
1 // Fig. 8.18: Time1.java
2 // Time1 class declaration maintains the time in 24-hour format.
3 package com.deitel.jhtp6.ch08;
4
5 public class Time1
6 {
7     private int hour;    // 0 - 23
8     private int minute;  // 0 - 59
9     private int second;  // 0 - 59
10
11     // set a new time value using universal time; perform
12     // validity checks on the data; set invalid values to zero
13     public void setTime( int h, int m, int s )
14     {
15         hour = ( ( h >= 0 && h < 24 ) ? h : 0 );    // validate hour
16         minute = ( ( m >= 0 && m < 60 ) ? m : 0 ); // validate minute
17         second = ( ( s >= 0 && s < 60 ) ? s : 0 ); // validate second
18     } // end method setTime
19
```

package declaration

Time1 is a **public** class so it can be used by importers of this package



```
20 // convert to String in universal-time format (HH:MM:SS)
21 public String toUniversalString()
22 {
23     return String.format( "%02d:%02d:%02d", hour, minute, second );
24 } // end method toUniversalString
25
26 // convert to String in standard-time format (H:MM:SS AM or PM)
27 public String toString()
28 {
29     return String.format( "%d:%02d:%02d %s",
30         ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ),
31         minute, second, ( hour < 12 ? "AM" : "PM" ) );
32 } // end method toString
33 } // end class Time1
```

Outline

Time1.java

(2 of 2)



5a.16 Time Class Case Study: Creating Packages (Cont.)

- Compile the class so that it is placed in the appropriate package directory structure
 - Example: our package should be in the directory

```
com
└── deitel
    └── jhttp6
        └── ch08
```

- **javac** command-line option **-d**
 - **javac** creates appropriate directories based on the class's **package** declaration
 - A period (.) after **-d** represents the current directory

5a.16 Time Class Case Study: Creating Packages (Cont.)

- **Import the reusable class into a program**
 - **Single-type-import declaration**
 - Imports a single class
 - Example: `import java.util.Random;`
 - **Type-import-on-demand declaration**
 - Imports all classes in a package
 - Example: `import java.util.*;`

Common Programming Error

5a.12

Using the import declaration `import java.*;` causes a compilation error. You must specify the exact name of the package from which you want to import classes.

Outline

```
1 // Fig. 8.19: Time1PackageTest.java
2 // Time1 object used in an application.
3 import com.deitel.jhtp6.ch08.Time1; // import class Time1
4
5 public class Time1PackageTest
6 {
7     public static void main( String args[] )
8     {
9         // create and initialize a Time1 object
10        Time1 time = new Time1(); // calls Time1 constructor
11
12        // output string representations of the time
13        System.out.print( "The initial universal time is: " );
14        System.out.println( time.toUniversalString() );
15        System.out.print( "The initial standard time is: " );
16        System.out.println( time.toString() );
17        System.out.println(); // output a blank line
18
```

Single-type **import** declaration

Time1PackageTest
.java

(1 of 2)

Refer to the **Time1** class
by its simple name



Outline

Time1PackageTest
.java

(2 of 2)

```
19 // change time and output updated time
20 time.setTime( 13, 27, 6 );
21 System.out.print( "Universal time after setTime is: " );
22 System.out.println( time.toUniversalString() );
23 System.out.print( "Standard time after setTime is: " );
24 System.out.println( time.toString() );
25 System.out.println(); // output a blank line
26
27 // set time with invalid values; output updated time
28 time.setTime( 99, 99, 99 );
29 System.out.println( "After attempting invalid settings:" );
30 System.out.print( "Universal time: " );
31 System.out.println( time.toUniversalString() );
32 System.out.print( "Standard time: " );
33 System.out.println( time.toString() );
34 } // end main
35 } // end class Time1PackageTest
```

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



5a.16 Time Class Case Study: Creating Packages (Cont.)

Class loader

- **Locates classes that the compiler needs**
 - **First searches standard Java classes bundled with the JDK**
 - **Then searches for optional packages**
 - **These are enabled by Java's extension mechanism**
 - **Finally searches the classpath**
 - **List of directories or archive files separated by directory separators**
 - **These files normally end with `.jar` or `.zip`**
 - **Standard classes are in the archive file `rt.jar`**

5a.16 Time Class Case Study: Creating Packages (Cont.)

To use a classpath other than the current directory

- `-classpath` option for the `javac` compiler
- Set the `CLASSPATH` environment variable

The JVM must locate classes just as the compiler does

- The `java` command can use other classpaths by using the same techniques that the `javac` command uses

Common Programming Error

5a.13

Specifying an explicit classpath eliminates the current directory from the classpath. This prevents classes in the current directory (including packages in the current directory) from loading properly. If classes must be loaded from the current directory, include a dot (.) in the classpath to specify the current directory.

Software Engineering Observation

5a.16

In general, it is a better practice to use the `-classpath` option of the compiler, rather than the `CLASSPATH` environment variable, to specify the classpath for a program. This enables each application to have its own classpath.

Error-Prevention Tip

5a.3

Specifying the classpath with the CLASSPATH environment variable can cause subtle and difficult-to-locate errors in programs that use different versions of the same package.

5a.17 Package Access

Package access

- **Methods and variables declared without any access modifier are given package access**
- **This has no effect if the program consists of one class**
- **This does have an effect if the program contains multiple classes from the same package**
 - **Package-access members can be directly accessed through the appropriate references to objects in other classes belonging to the same package**

Outline

PackageDataTest
.java

(1 of 2)

```
1 // Fig. 8.20: PackageDataTest.java
2 // Package-access members of a class are accessible by other classes
3 // in the same package.
4
5 public class PackageDataTest
6 {
7     public static void main( String args[] )
8     {
9         PackageData packageData = new PackageData();
10
11         // output String representation of packageData
12         System.out.printf( "After instantiation:\n%s\n", packageData );
13
14         // change package access data in packageData object
15         packageData.number = 77;
16         packageData.string = "Goodbye";
17
18         // output String representation of packageData
19         System.out.printf( "\nAfter changing values:\n%s\n", packageData );
20     } // end main
21 } // end class PackageDataTest
22
```

Can directly access package-access members




Outline

PackageDataTest
.java

(2 of 2)

```
23 // class with package access instance variables
24 class PackageData
25 {
26     int number; // package-access instance variable
27     String string; // package-access instance variable
28
29     // constructor
30     public PackageData()
31     {
32         number = 0;
33         string = "Hello";
34     } // end PackageData constructor
35
36     // return PackageData object String representation
37     public String toString()
38     {
39         return String.format( "number: %d; string: %s", number, string );
40     } // end method toString
41 } // end class PackageData
```



Package-access instance variables

After instantiation:
number: 0; string: Hello

After changing values:
number: 77; string: Goodbye



5a.18 (Optional) GUI and Graphics Case Study: Using Objects with Graphics

To create a consistent drawing that remains the same each time it is drawn

- **Store information about the displayed shapes so that they can be reproduced exactly the same way each time `paintComponent` is called**

Outline

Myline.java

```
1 // Fig. 8.21: MyLine.java
2 // Declaration of class MyLine.
3 import java.awt.Color;
4 import java.awt.Graphics;
5
6 public class MyLine
7 {
8     private int x1; // x coordinate of first endpoint
9     private int y1; // y coordinate of first endpoint
10    private int x2; // x coordinate of second endpoint
11    private int y2; // y coordinate of second endpoint
12    private Color myColor; // color of this shape
13
14    // constructor with input values
15    public MyLine( int x1, int y1, int x2, int y2, Color color )
16    {
17        this.x1 = x1; // set x coordinate of first endpoint
18        this.y1 = y1; // set y coordinate of first endpoint
19        this.x2 = x2; // set x coordinate of second endpoint
20        this.y2 = y2; // set y coordinate of second endpoint
21        myColor = color; // set the color
22    } // end MyLine constructor
23
24    // Draw the line in the specified color
25    public void draw( Graphics g )
26    {
27        g.setColor( myColor );
28        g.drawLine( x1, y1, x2, y2 );
29    } // end method draw
30 } // end class MyLine
```

Instance variables to store coordinates and color for a line

Initialize instance variables

Draw a line in the proper color at the proper coordinates

Outline

DrawPanel.java

(1 of 2)

```
1 // Fig. 8.22: DrawPanel.java
2 // Program that uses class MyLine
3 // to draw random lines.
4 import java.awt.Color;
5 import java.awt.Graphics;
6 import java.util.Random;
7 import javax.swing.JPanel;
8
9 public class DrawPanel extends JPanel
10 {
11     private Random randomNumbers = new Random();
12     private MyLine lines[]; // array of lines
13
14     // constructor, creates a panel with random shapes
15     public DrawPanel()
16     {
17         setBackground( Color.WHITE );
18
19         lines = new MyLine[ 5 + randomNumbers.nextInt( 5 ) ];
20     }
```

Declare a **MyLine** array

Create the **MyLine** array



Outline

DrawPanel.java

(2 of 2)

```

21 // create lines
22 for ( int count = 0; count < lines.length; count++ )
23 {
24     // generate random coordinates
25     int x1 = randomNumbers.nextInt( 300 );
26     int y1 = randomNumbers.nextInt( 300 );
27     int x2 = randomNumbers.nextInt( 300 );
28     int y2 = randomNumbers.nextInt( 300 );
29
30     // generate a random color
31     Color color = new Color( randomNumbers.nextInt( 256 ),
32                             randomNumbers.nextInt( 256 ), randomNumbers.nextInt( 256 ) );
33
34     // add the line to the list of lines to be displayed
35     lines[ count ] = new MyLine( x1, y1, x2, y2, color );
36 } // end for
37 } // end DrawPanel constructor
38
39 // for each shape array, draw the individual shapes
40 public void paintComponent( Graphics g )
41 {
42     super.paintComponent( g );
43
44     // draw the lines
45     for ( MyLine line : lines )
46         line.draw( g );
47 } // end method paintComponent
48 } // end class DrawPanel

```

Generate coordinates for this line

Generate a color for this line

Create the new **MyLine** object with
the generated attributes

Draw each **MyLine**



Outline

TestDraw.java

```
1 // Fig. 8.23: TestDraw.java
2 // Test application to display a DrawPanel.
3 import javax.swing.JFrame;
4
5 public class TestDraw
6 {
7     public static void main( String args[] )
8     {
9         DrawPanel panel = new DrawPanel();
10        JFrame application = new JFrame();
11
12        application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
13        application.add( panel );
14        application.setSize( 300, 300 );
15        application.setVisible( true );
16    } // end main
17 } // end class TestDraw
```

