Chapter 9 - Object-Oriented Programming

- Object-oriented programming
  - Inheritance
    - Software reusability
    - Classes are created from existing ones
      - Absorbing attributes and behaviors
      - Adding new capabilities
      - **`Class Convertible`** inherits from class **`Automobile`**
      - **`Superclass v.s. subclass`**
      - **`Single inheritance v.s. multiple inheritance`**
  - Polymorphism
    - Enables developers to write programs in general fashion
      - Handle a variety of existing and yet-to-be-specified related classes
    - Helps add new capabilities to system

Introduction

- Object-oriented programming
  - Inheritance
    - *Sub-class* inherits from *super-class*
      - Subclass usually adds their characteristics of instance variables and methods
    - Single vs. multiple inheritance
      - Single inheritance → **class subclass extends superclass**
      - Java does not support multiple inheritance
        - Interfaces (discussed later) achieve the same effect

        Ex. **class subclass implements superclass1, superclass2, …**
    - "**Is a**" relationship (an object of a subclass type may be treated as its super-class type)
  - Composition
    - "**Has a**" relationship(an object has one or more objects of other classes)

Superclasses and Subclasses

- "Is a" Relationship
  - Object "is an" object of another class
    - Rectangle "is a" quadrilateral
      - Class **`Rectangle`** inherits from class **`Quadrilateral`**
  - Form tree-like hierarchical structures
- "Has a" Relationship
  - Object "is composed of" objects of another class
    - Car "has a" steering wheel
      - Class **`car`** is composed of class **`wheel`**

Superclass	Subclasses
`Student`	`GraduateStudent` `UndergraduateStudent`

`Shape`	`Circle`
	`Triangle`
	`Rectangle`

`Loan`	`CarLoan`
	`HomeImprovementLoan`
	`MortgageLoan`

`Employee`	`FacultyMember` `StaffMember`
`Account`	`CheckingAccount` `SavingsAccount`

Fig. 9.1 Some simple inheritance examples in which the subclass "is a" superclass.

Fig. 9.2 An inheritance hierarchy for university `CommunityMembers`.

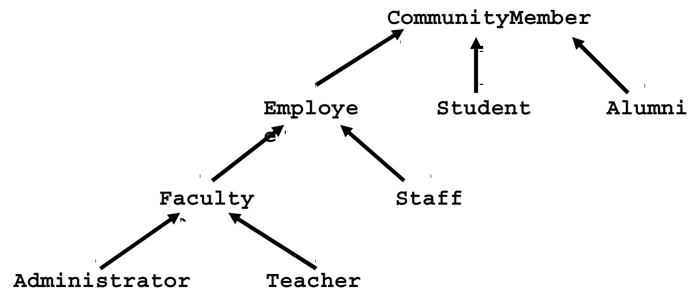
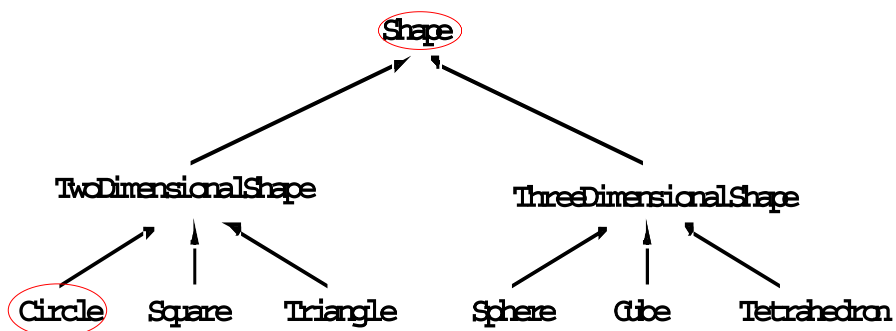


Fig. 9.3 A portion of a `Shape` class hierarchy.



protected Members

- **`protected`** access members
  - Between **`public`** and **`private`** in protection
  - Accessed only by
    - **Superclass methods**
    - **Subclass methods**
    - Methods of classes in same package
      - package access

Relationship between Superclass and Subclass Objects

- Subclass object
  - Can be treated as superclass object
    - Reverse is not true
      - **`Shape`** is not always a **`Circle`**
  - Every class implicitly extends **`java.lang.Object`**
    - Unless specified otherwise in class definition's first line

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```
1   // Fig. 9.4: Point.java
2   // Definition of class Point
3
4   public class Point {
5      protected int x, y; // coordinates of Point
6
7      // No-argument constructor
8      public Point()
9      {
10        // implicit call to superclass constructor occurs here
11        setPoint( 0, 0 );
12     }
13
14     // constructor
15     public Point( int xCoordinate, int yCoordinate )
16     {
17        // implicit call to superclass constructor occurs here
18        setPoint( xCoordinate, yCoordinate );
19     }
20
21     // set x and y coordinates of Point
22     public void setPoint( int xCoordinate, int yCoordinate )
23     {
24        x = xCoordinate;
25        y = yCoordinate;
26     }
27
28     // get x coordinate
29     public int getX()
30     {
31        return x;
32     }
33
```

Outline

`Point.java`

Line 5
`protected` members prevent clients from direct access (unless clients are **`Point`** subclasses or are in same package)

8

```
34    // get y coordinate
35    public int getY()
36    {
37       return y;
38    }
39
40    // convert into a String representation
41    public String toString()
42    {
43       return "[" + x + ", " + y + "]";
44    }
45
46 }  // end class Point
```

Outline

Point.java

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```
1  // Fig. 9.5: Circle.java
2  // Definition of class Circle
3
4  public class Circle extends Point {  // inherits from Point
5     protected double radius;
6
7     // no-argument constructor
8     public Circle()
9     {
10       // implicit call to superclass constructor occurs here
11       setRadius( 0 );
12    }
13
14    // constructor
15    public Circle( double circleRadius, int xCoordinate,
16       int yCoordinate )
17    {
18       // call superclass constructor to set coordinates
19       super( xCoordinate, yCoordinate );
20
21       // set radius
22       setRadius( circleRadius );
23    }
24
25    // set radius of Circle
26    public void setRadius( double circleRadius )
27    {
28       radius = ( circleRadius >= 0.0 ? circleRadius : 0.0 );
29    }
30
```

Outline

Circle.java

Line 4
Circle is a **Point** subclass

Line 4
Circle inherits **Point**'s **protected** variables and **public** methods (except for constuctor)

Line 10
Implicit call to **Point** constructor

Line 19
Explicit call to **Point** constructor using **super**

10

```java
31     // get radius of Circle
32     public double getRadius()
33     {
34        return radius;
35     }
36
37     // calculate area of Circle
38     public double area()
39     {
40        return Math.PI * radius * radius;
41     }
42
43     // convert the Circle to a String
44     public String toString()
45     {
46        return "Center = " + "[" + x + ", " + y + "]" +
47               "; Radius = " + radius;
48     }
49
50  }  // end class Circle
```

Outline

`Circle.java`

Lines 44-48
Override method **`toString`** of class **`Point`** by using same signature


```java
1   // Fig. 9.6: InheritanceTest.java
2   // Demonstrating the "is a" relationship
3
4   // Java core packages
5   import java.text.DecimalFormat;
6
7   // Java extension packages
8   import javax.swing.JOptionPane;
9
10  public class InheritanceTest {
11
12     // test classes Point and Circle
13     public static void main( String args[] )
14     {
15        Point point1, point2;
16        Circle circle1, circle2;
17
18        point1 = new Point( 30, 50 );
19        circle1 = new Circle( 2.7, 120, 89 );
20
21        String output = "Point point1: " + point1.toString() +
22           "\nCircle circle1: " + circle1.toString();
23
24        // use "is a" relationship to refer to a Circle
25        // with a Point reference
26        point2 = circle1;   // assigns Circle to a Point reference
27
28        output += "\n\nCircle circle1 (via point2 reference): " +
29           point2.toString();
30
31        // use downcasting (casting a superclass reference to a
32        // subclass data type) to assign point2 to circle2
33        circle2 = ( Circle ) point2;
34
```

Outline

`InheritanceTest.java`

Lines 18-19
Instantiate objects

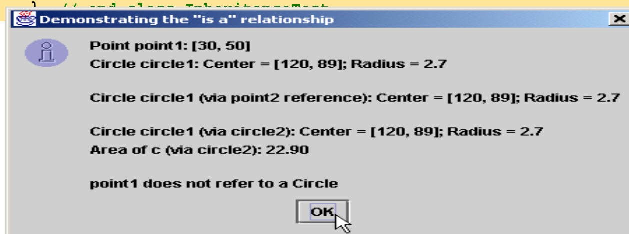
Line 22
`Circle` invokes method **`toString`**

Line 26
Superclass object references subclass

Line 29
`Point` invokes **`Circle`**'s **`toString`** method

Line 33
Downcast **`Point`** to **`Circle`**

```
35          output += "\n\nCircle circle1 (via circle2): " +
36             circle2.toString();
37
38          DecimalFormat precision2 = new DecimalFormat( "0.00" );
39          output += "\nArea of c (via circle2): " +
40             precision2.format( circle2.area() );
41
42          // attempt to refer to Point object with Circle reference
43          if ( point1 instanceof Circle ) {
44             circle2 = ( Circle ) point1;
45             output += "\n\ncast successful";
46          }
47          else
48             output += "\n\npoint1 does not refer to a Circle";
49
50          JOptionPane.showMessageDialog( null, output,
51             "Demonstrating the \"is a\" relationship",
52             JOptionPane.INFORMATION_MESSAGE );
53
54          System.exit( 0 );
55       }
56
57    }
```



Outline

InheritanceTest.java

Line 36
Circle invokes its overridden **toString** method

Line 40
Circle invokes method **area**

Line 43
Use **instanceof** to determine if **Point** refers to **Circle**

Line 44
If **Point** refers to **Circle**, cast **Point** as **Circle**

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Constructors and Finalizers in Subclasses

- Superclass constructor
  - Initializes superclass instance variables of subclass
  - Not inherited by subclass
  - Called by subclass
    - Implicitly or explicitly with **super** reference
- **finalize** method
  - Garbage collection
  - Subclass **finalize** method
    - should invoke superclass **finalize** method

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```java
1   // Fig. 9.7: Point.java
2   // Definition of class Point
3   public class Point extends Object {
4      protected int x, y; // coordinates of the Point
5
6      // no-argument constructor
7      public Point()
8      {
9         x = 0;
10        y = 0;
11        System.out.println( "Point constructor: " + this );
12     }
13
14     // constructor
15     public Point( int xCoordinate, int yCoordinate )
16     {
17        x = xCoordinate;
18        y = yCoordinate;
19        System.out.println( "Point constructor: " + this );
20     }
21
22     // finalizer
23     protected void finalize()
24     {
25        System.out.println( "Point finalizer: " + this );
26     }
27
28     // convert Point into a String representation
29     public String toString()
30     {
31        return "[" + x + ", " + y + "]";
32     }
33
34  }  // end class Point
```

Outline

`Point.java`

Lines 7-20
Superclass constructors

Lines 23-26
Superclass **`finalize`** method uses **`protected`** for subclass access, but not for other clients

15

```java
1   // Fig. 9.8: Circle.java
2   // Definition of class Circle
3   public class Circle extends Point {  // inherits from Point
4      protected double radius;
5
6      // no-argument constructor
7      public Circle()
8      {
9         // implicit call to superclass constructor here
10        radius = 0;
11        System.out.println( "Circle constructor: " + this );
12     }
13
14     // Constructor
15     public Circle( double circleRadius, int xCoordinate,
16        int yCoordinate )
17     {
18        // call superclass constructor
19        super( xCoordinate, yCoordinate );
20
21        radius = circleRadius;
22        System.out.println( "Circle constructor: " + this );
23     }
24
25     // finalizer
26     protected void finalize()
27     {
28        System.out.println( "Circle finalizer: " + this );
29        super.finalize();  // call superclass finalize method
30     }
31
```

Outline

`Circle.java`

Line 9
Implicit call to **`Point`** constructor

Line 19
Explicit call to **`Point`** constructor using **`super`**

Lines 26-30
Override **`Point`**'s method **`finalize`**, but call it using **`super`**

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Outline

Circle.java

```java
32     // convert the Circle to a String
33     public String toString()
34     {
35        return "Center = " + super.toString() +
36               "; Radius = " + radius;
37     }
38
39  }  // end class Circle
```


Outline

Test.java

Lines 10-11
Instantiate **Circle** objects

Line 17
Invoke **Circle**'s method **finalize** by calling **System.gc**

```java
1   // Fig. 9.9: Test.java
2   // Demonstrate when superclass and subclass
3   // constructors and finalizers are called.
4   public class Test {
5
6      // test when constructors and finalizers are called
7      public static void main( String args[] )
8      {
9         Circle circle1, circle2;
10
11        circle1 = new Circle( 4.5, 72, 29 );
12        circle2 = new Circle( 10, 5, 5 );
13
14        circle1 = null;  // mark for garbage collection
15        circle2 = null;  // mark for garbage collection
16
17        System.gc();     // call the garbage collector
18     }
19
20  }  // end class Test
```

```
Point constructor: Center = [72, 29]; Radius = 0.0
Circle constructor: Center = [72, 29]; Radius = 4.5
Point constructor: Center = [5, 5]; Radius = 0.0
Circle constructor: Center = [5, 5]; Radius = 10.0
Circle finalizer: Center = [72, 29]; Radius = 4.5
Point finalizer: Center = [72, 29]; Radius = 4.5
Circle finalizer: Center = [5, 5]; Radius = 10.0
Point finalizer: Center = [5, 5]; Radius = 10.0
```

Implicit Subclass-Object-to-Superclass-Object Conversion

- Superclass reference and subclass reference
  - Implicit conversion
    - Subclass reference to superclass reference
      - Subclass object "is a" superclass object
  - Four ways to mix and match references
    - Refer to superclass object with superclass reference
    - Refer to subclass object with subclass reference
    - Refer to subclass object with superclass reference
      - **Can refer only to superclass members**
      - ➔ **Superclass = subclass**
    - Refer to superclass object with subclass reference
      - **Syntax error**
      - ➔ **Subclass = superclass is error!!!! ➔ should convert the type**

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Software Engineering with Inheritance

- Inheritance
  - Create class (subclass) from existing one (superclass)
    - Subclass creation does not affect superclass
  - New class inherits attributes and behaviors of superclass
  - Add attributes and behaviors or override superclass behavior
  - Software reuse

Composition vs. Inheritance

- Inheritance
  - "Is a" relationship
  - `Teacher` *is an* `Employee`
- Composition
  - "Has a" relationship
  - `Employee` *has a* `TelephoneNumber`

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Case Study: Point, Cylinder, Circle

- Consider point, circle, cylinder hierarchy
  - **`Point`** is superclass
  - **`Circle`** is **`Point`** subclass
  - **`Cylinder`** is **`Circle`** subclass


```
1   // Fig. 9.10: Point.java
2   // Definition of class Point
3   package com.deitel.jhtp4.ch09;
4
5   public class Point {
6      protected int x, y; // coordinates of Point
7
8      // No-argument constructor
9      public Point()
10     {
11        // implicit call to superclass constructor occurs here
12        setPoint( 0, 0 );
13     }
14
15     // constructor
16     public Point( int xCoordinate, int yCoordinate )
17     {
18        // implicit call to superclass constructor occurs here
19        setPoint( xCoordinate, yCoordinate );
20     }
21
22     // set x and y coordinates of Point
23     public void setPoint( int xCoordinate, int yCoordinate )
24     {
25        x = xCoordinate;
26        y = yCoordinate;
27     }
28
29     // get x coordinate
30     public int getX()
31     {
32        return x;
33     }
34
```

Outline

`Point.java`

Line 6
`protected` members prevent clients from direct access (unless clients are **`Point`** subclasses or are in same package)

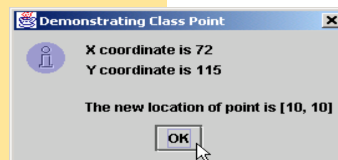
Lines 9-20
Constructor and overloaded constructor

```
35      // get y coordinate
36      public int getY()
37      {
38         return y;
39      }
40
41      // convert into a String representation
42      public String toString()
43      {
44         return "[" + x + ", " + y + "]";
45      }
46
47   }  // end class Point
```

Outline

`Point.java`


```
1    // Fig. 9.11: Test.java
2    // Applet to test class Point
3
4    // Java extension packages
5    import javax.swing.JOptionPane;
6
7    // Deitel packages
8    import com.deitel.jhtp4.ch09.Point;
9
10   public class Test {
11
12      // test class Point
13      public static void main( String args[] )
14      {
15         Point point = new Point( 72, 115 );
16
17         // get coordinates
18         String output = "X coordinate is " + point.getX() +
19                  "\nY coordinate is " + point.getY();
20
21         // set coordinates
22         point.setPoint( 10, 10 );
23
24         // use implicit call to point.toString()
25         output += "\n\nThe new location of point is " + point;
26
27         JOptionPane.showMessageDialog( null, output,
28            "Demonstrating Class Point",
29            JOptionPane.INFORMATION_MESSAGE );
30
31         System.exit( 0 );
32      }
33
34   }  // end class Test
```



Outline

`Test.java`

Line 15
Instantiate **`Point`** object

Lines 18-19
Methods **`getX`** and **`getY`** read **`Point`**'s **`protected`** variables

```
1    // Fig. 9.12: Circle.java
2    // Definition of class Circle
3    package com.deitel.jhtp4.ch09;
4
5    public class Circle extends Point {  // inherits from Point
6       protected double radius;
7
8       // no-argument constructor
9       public Circle()
10      {
11         // implicit call to superclass constructor occurs here
12         setRadius( 0 );
13      }
14
15      // constructor
16      public Circle( double circleRadius, int xCoordinate,
17         int yCoordinate )
18      {
19         // call superclass constructor to set coordinates
20         super( xCoordinate, yCoordinate );
21
22         // set radius
23         setRadius( circleRadius );
24      }
25
26      // set radius of Circle
27      public void setRadius( double circleRadius )
28      {
29         radius = ( circleRadius >= 0.0 ? circleRadius : 0.0 );
30      }
31
```

Outline

Circle.java

Line 5
Circle is a **Point** subclass

Line 5
Circle inherits **Point**'s **protected** variables and **public** methods (except for constuctor)

Line 11
Implicit call to **Point** constructor

Line 20
explicit call to **Point** constructor using **super**


```
32      // get radius of Circle
33      public double getRadius()
34      {
35         return radius;
36      }
37
38      // calculate area of Circle
39      public double area()
40      {
41         return Math.PI * radius * radius;
42      }
43
44      // convert the Circle to a String
45      public String toString()
46      {
47         return "Center = " + "[" + x + ", " + y + "]" +
48                "; Radius = " + radius;
49      }
50
51   }  // end class Circle
```

Outline

Circle.java

```
1    // Fig. 9.13: Test.java
2    // Applet to test class Circle
3
4    // Java core packages
5    import java.text.DecimalFormat;
6
7    // Java extension packages
8    import javax.swing.JOptionPane;
9
10   // Deitel packages
11   import com.deitel.jhtp4.ch09.Circle;
12
13   public class Test {
14
15      // test class Circle
16      public static void main( String args[] )
17      {
18         // create a Circle
19         Circle circle = new Circle( 2.5, 37, 43 );
20         DecimalFormat precision2 = new DecimalFormat( "0.00" );
21
22         // get coordinates and radius
23         String output = "X coordinate is " + circle.getX() +
24                 "\nY coordinate is " + circle.getY() +
25                 "\nRadius is " + circle.getRadius();
26
27         // set coordinates and radius
28         circle.setRadius( 4.25 );
29         circle.setPoint( 2, 2 );
30
31         // get String representation of Circle and calculate area
32         output +=
33            "\n\nThe new location and radius of c are\n" + circle +
34            "\nArea is " + precision2.format( circle.area() );
35
```

Outline

`Test.java`

Line 19
Instantiate **`Circle`** object

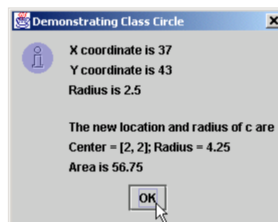
Lines 25 and 28
Calls to methods **`getRadius`** and **`setRadius`** read and manipulate **`Circle`**'s **`protected`** variables

Lines 23-24 and 29
Calls to methods **`getX`**, **`getY`** and **`setPoint`** read and manipulate **`Circle`**'s inherited **`protected`** variables


```
36         JOptionPane.showMessageDialog( null, output,
37            "Demonstrating Class Circle",
38            JOptionPane.INFORMATION_MESSAGE );
39
40         System.exit( 0 );
41      }
42
43   }  // end class Test
```

Outline

`Test.java`



```
1   // Fig. 9.14: Cylinder.java
2   // Definition of class Cylinder
3   package com.deitel.jhtp4.ch09;
4
5   public class Cylinder extends Circle {
6      protected double height;  // height of Cylinder
7
8      // no-argument constructor
9      public Cylinder()
10     {
11        // implicit call to superclass constructor here
12        setHeight( 0 );
13     }
14
15     // constructor
16     public Cylinder( double cylinderHeight, double cylinderRadius,
17        int xCoordinate, int yCoordinate )
18     {
19        // call superclass constructor to set coordinates/radius
20        super( cylinderRadius, xCoordinate, yCoordinate );
21
22        // set cylinder height
23        setHeight( cylinderHeight );
24     }
25
26     // set height of Cylinder
27     public void setHeight( double cylinderHeight )
28     {
29        height = ( cylinderHeight >= 0 ? cylinderHeight : 0 );
30     }
31
```

Outline

`Cylinder.java`

Line 5
`Cylinder` is a **`Circle`** subclass

Line 5
`Cylinder` inherits **`Point`**'s and **`Circle`**'s **`protected`** variables and **`public`** methods (except for constuctors)

Line 11
Implicit call to **`Circle`** constructor

Line 20
Explicit call to **`Circle`** constructor using **`super`**

29

```
32     // get height of Cylinder
33     public double getHeight()
34     {
35        return height;
36     }
37
38     // calculate area of Cylinder (i.e., surface area)
39     public double area()
40     {
41        return 2 * super.area() +
42               2 * Math.PI * radius * height;
43     }
44
45     // calculate volume of Cylinder
46     public double volume()
47     {
48        return super.area() * height;
49     }
50
51     // convert the Cylinder to a String
52     public String toString()
53     {
54        return super.toString() + "; Height = " + height;
55     }
56
57  }  // end class Cylinder
```

Outline

`Cylinder.java`

Lines 39-43
Override method area of class **`Circle`**

30

Outline

`Test.java`

Line 19
Instantiate **`Cylinder`** object

Lines 23-31
Method calls read and manipulate **`Cylinder`**'s **`protected`** variables and inherited **`protected`** variables

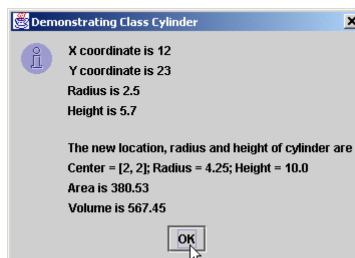
```
1   // Fig. 9.15: Test.java
2   // Application to test class Cylinder
3
4   // Java core packages
5   import java.text.DecimalFormat;
6
7   // Java extension packages
8   import javax.swing.JOptionPane;
9
10  // Deitel packages
11  import com.deitel.jhtp4.ch09.Cylinder;
12
13  public class Test {
14
15     // test class Cylinder
16     public static void main( String args[] )
17     {
18        // create Cylinder
19        Cylinder cylinder = new Cylinder( 5.7, 2.5, 12, 23 );
20        DecimalFormat precision2 = new DecimalFormat( "0.00" );
21
22        // get coordinates, radius and height
23        String output = "X coordinate is " + cylinder.getX() +
24           "\nY coordinate is " + cylinder.getY() +
25           "\nRadius is " + cylinder.getRadius() +
26           "\nHeight is " + cylinder.getHeight();
27
28        // set coordinates, radius and height
29        cylinder.setHeight( 10 );
30        cylinder.setRadius( 4.25 );
31        cylinder.setPoint( 2, 2 );
32
```

31

Outline

`Test.java`

```
33        // get String representation of Cylinder and calculate
34        // area and volume
35        output += "\n\nThe new location, radius " +
36           "and height of cylinder are\n" + cylinder +
37           "\nArea is " + precision2.format( cylinder.area() ) +
38           "\nVolume is " + precision2.format( cylinder.volume() );
39
40        JOptionPane.showMessageDialog( null, output,
41           "Demonstrating Class Cylinder",
42           JOptionPane.INFORMATION_MESSAGE );
43
44        System.exit( 0 );
45     }
46
47  }  // end class Test
```



32

Introduction to Polymorphism

- Polymorphism
  - Helps build extensible systems
  - Programs generically process objects as superclass objects
    - Can add classes to systems easily
      - Classes must be part of generically processed hierarchy

Type Fields and Switch Statements

- **`switch`**-based system
  - Determine appropriate action for object of many different types
    - Based on object's type to take the appropriate action
  - Error prone
    - Programmer can forget to make appropriate type test
    - Programmer may forget to Adding and deleting new case in existing **`switch`** statements

33

Dynamic Method Binding

- Dynamic method binding
  - Implements polymorphic processing of objects
  - Use superclass reference to refer to subclass object
  - Program chooses "correct" method in subclass
- For example,
  - Superclass **`Shape`**
  - Subclasses **`Circle`**, **`Rectangle`** and **`Square`**
  - Each class draws itself according to type of class
    - **`Shape`** has method **`draw`**
    - Each subclass overrides method **`draw`**
    - Call method **`draw`** of superclass **`Shape`**
      - Program determines dynamically which subclass **`draw`** method to invoke

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final Methods and Classes

- `final` method
  - Cannot be overridden in subclass
- `final` class
  - Cannot be superclass (cannot be `extend`ed)
    - Class cannot inherit `final` classes
  - Final method's definition can never change
  - The compiler can optimize the program by removing calls to final method and replace them with the expanded code of their definitions at each method call location ➔ in-lining the code(like assembly's macro instruction)

35

Abstract Superclasses and Concrete Classes

- Abstract classes
  - Objects cannot be instantiated➔ programmer never intends to use to instantiate any objects
  - Too generic to define real objects
    - **TwoDimensionalShape in pp. 451**
  - Provides superclass from which other classes may inherit
    - Normally referred to as ***abstract super-classes***
  - ***Draw the shape ➔ what shape?***
- Concrete classes
  - Classes from which objects are instantiated
  - Provide specifics for instantiating objects
    - **Square**, **Circle** and **Triangle in pp. 451 ➔ derived concrete class**
  - ***Draw the shape ➔ draw the* Square**, **Circle** and **Triangle** ***shape?***

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Polymorphism Examples

- Video game
  - Superclass **`GamePiece`**
    - Contains method **`drawYourself`**
  - Subclasses **`Martian`**, **`Venutian`**, **`LaserBeam`**, etc.
    - Override method **`drawYourself`**
      - **`Martian`** draws itself with antennae
      - **`LaserBeam`** draws itself as bright red beam
      - This is polymorphism
  - Easily extensible
    - Suppose we add class **`Mercurian`**
      - Class **`Mercurian`** inherits superclass **`GamePiece`**
      - Overrides method **`drawYourself`**

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Case Study: A Payroll System Using Polymorphism

- Abstract methods and polymorphism
  - Abstract superclass **Employee**
    - Method **earnings** applies to all employees
    - Person's earnings dependent on type of **Employee**
    - **Earnings is declared abstract in super-class Employee and appropriate implementations of earnings are provided for each of the super-class**
  - Concrete **Abstract superclass Employee** subclasses are
    - **Boss**
    - **CommissionWorker**
    - **PieceWorker**
    - **HourlyWorker**

38

```
1    // Fig. 9.16: Employee.java
2    // Abstract base class Employee.
3
4    public abstract class Employee {
5       private String firstName;
6       private String lastName;
7
8       // constructor
9       public Employee( String first, String last )
10      {
11         firstName = first;
12         lastName = last;
13      }
14
15      // get first name
16      public String getFirstName()
17      {
18         return firstName;
19      }
20
21      // get last name
22      public String getLastName()
23      {
24         return lastName;
25      }
26
27      public String toString()
28      {
29         return firstName + ' ' + lastName;
30      }
32      // Abstract method that must be implemented for each
33      // derived class of Employee from which objects are instantiated.
35      public abstract double earnings();
36   }  // end class Employee
```

Outline

Employee.java

Line 4
abstract class cannot be instantiated

Lines 5-6 and 16-30
abstract class can have instance data and non**abstract** methods for subclasses

Lines 9-13
abstract class can have constructors for subclasses to initialize inherited data


```
1    // Fig. 9.17: Boss.java
2    // Boss class derived from Employee.
3
4    public final class Boss extends Employee {
5       private double weeklySalary;
6
7       // constructor for class Boss
8       public Boss( String first, String last, double salary )
9       {
10         super( first, last );  // call superclass constructor
11         setWeeklySalary( salary );
12      }
13
14      // set Boss's salary
15      public void setWeeklySalary( double salary )
16      {
17         weeklySalary = ( salary > 0 ? salary : 0 );
18      }
19
20      // get Boss's pay
21      public double earnings()
22      {
23         return weeklySalary;
24      }
25
26      // get String representation of Boss's name
27      public String toString()
28      {
29         return "Boss: " + super.toString();
30      }
31
32   }  // end class Boss
```

Outline

Boss.java

Line 4
Boss is an **Employee** subclass

Line 4
Boss inherits **Employee**'s **public** methods (except for constuctor)

Line 10
Explicit call to **Employee** constructor using **super**

Lines 21-24
Required to implement **Employee**'s method **earnings** (polymorphism)

```java
1    // Fig. 9.18: CommissionWorker.java
2    // CommissionWorker class derived from Employee
3
4    public final class CommissionWorker extends Employee {
5       private double salary;      // base salary per week
6       private double commission;  // amount per item sold
7       private int quantity;       // total items sold for week
8
9       // constructor for class CommissionWorker
10      public CommissionWorker( String first, String last,
11         double salary, double commission, int quantity )
12      {
13         super( first, last );  // call superclass constructor
14         setSalary( salary );
15         setCommission( commission );
16         setQuantity( quantity );
17      }
18
19      // set CommissionWorker's weekly base salary
20      public void setSalary( double weeklySalary )
21      {
22         salary = ( weeklySalary > 0 ? weeklySalary : 0 );
23      }
24
25      // set CommissionWorker's commission
26      public void setCommission( double itemCommission )
27      {
28         commission = ( itemCommission > 0 ? itemCommission : 0 );
29      }
30
```

Outline

CommissionWorker.java

Line 4
CommissionWorker is an **Employee** subclass

Line 13
Explicit call to **Employee** constructor using **super**

41

```java
31      // set CommissionWorker's quantity sold
32      public void setQuantity( int totalSold )
33      {
34         quantity = ( totalSold > 0 ? totalSold : 0 );
35      }
36
37      // determine CommissionWorker's earnings
38      public double earnings()
39      {
40         return salary + commission * quantity;
41      }
42
43      // get String representation of CommissionWorker's name
44      public String toString()
45      {
46         return "Commission worker: " + super.toString();
47      }
48
49   }  // end class CommissionWorker
```

Outline

CommissionWorker.java

Lines 38-41
Required to implement **Employee**'s method **earnings**; this implementation differs from that in **Boss**

42

```
1    // Fig. 9.19: PieceWorker.java
2    // PieceWorker class derived from Employee
3
4    public final class PieceWorker extends Employee {
5       private double wagePerPiece; // wage per piece output
6       private int quantity;        // output for week
7
8       // constructor for class PieceWorker
9       public PieceWorker( String first, String last,
10         double wage, int numberOfItems )
11      {
12         super( first, last );  // call superclass constructor
13         setWage( wage );
14         setQuantity( numberOfItems);
15    }
16
17      // set PieceWorker's wage
18      public void setWage( double wage )
19      {
20         wagePerPiece = ( wage > 0 ? wage : 0 );
21      }
22
23      // set number of items output
24      public void setQuantity( int numberOfItems )
25      {
26         quantity = ( numberOfItems > 0 ? numberOfItems : 0 );
27      }
28
29      // determine PieceWorker's earnings
30      public double earnings()
31      {
32         return quantity * wagePerPiece;
33      }
34
```

Outline

PieceWorker.java

Line 4
PieceWorker is an **Employee** subclass

Line 12
Explicit call to **Employee** constructor using **super**

Lines 30-33
Implementation of **Employee**'s method **earnings**; differs from that of **Boss** and **CommissionWorker**

43

```
35      public String toString()
36      {
37         return "Piece worker: " + super.toString();
38      }
39
40   }  // end class PieceWorker
```

Outline

PieceWorker.java

44

Outline

`HourlyWorker.java`

Line 4
`PieceWorker` is an **`Employee`** subclass

Line 12
Explicit call to **`Employee`** constructor using **`super`**

Line 31
Implementation of **`Employee`**'s method **`earnings`**; differs from that of other **`Employee`** subclasses

```
1    // Fig. 9.20: HourlyWorker.java
2    // Definition of class HourlyWorker
3
4    public final class HourlyWorker extends Employee {
5       private double wage;    // wage per hour
6       private double hours;   // hours worked for week
7
8       // constructor for class HourlyWorker
9       public HourlyWorker( String first, String last,
10         double wagePerHour, double hoursWorked )
11      {
12         super( first, last );   // call superclass constructor
13         setWage( wagePerHour );
14         setHours( hoursWorked );
15      }
16
17      // Set the wage
18      public void setWage( double wagePerHour )
19      {
20         wage = ( wagePerHour > 0 ? wagePerHour : 0 );
21      }
22
23      // Set the hours worked
24      public void setHours( double hoursWorked )
25      {
26         hours = ( hoursWorked >= 0 && hoursWorked < 168 ?
27            hoursWorked : 0 );
28      }
29
30      // Get the HourlyWorker's pay
31      public double earnings() { return wage * hours; }
32
```

45

Outline

`HourlyWorker.java`

```
33      public String toString()
34      {
35         return "Hourly worker: " + super.toString();
36      }
37
38   }  // end class HourlyWorker
```

46

```
1     // Fig. 9.21: Test.java
2     // Driver for Employee hierarchy
3
4     // Java core packages
5     import java.text.DecimalFormat;
6
7     // Java extension packages
8     import javax.swing.JOptionPane;
9
10    public class Test {
11
12       // test Employee hierarchy
13       public static void main( String args[] )
14       {
15          Employee employee;  // superclass reference
16          String output = "";
17
18          Boss boss = new Boss( "John", "Smith", 800.0 );
19
20           CommissionWorker commisionWorker =
21             new CommissionWorker(
22             "Sue", "Jones", 400.0, 3.0, 150 );
23
24         PieceWorker pieceWorker =
25           new PieceWorker( "Bob", "Lewis", 2.5, 200 );
26
27         HourlyWorker hourlyWorker =
28            new HourlyWorker( "Karen", "Price", 13.75, 40 );
29
30        DecimalFormat precision2 = new DecimalFormat( "0.00" );
31
```

Outline

Test.java

Line 15
Test cannot instantiate **Employee** but can reference one

Lines 18-28
Instantiate one instance each of **Employee** subclasses


```
32        // Employee reference to a Boss
33        employee = boss;
34
35        output += employee.toString() + " earned $" +
36           precision2.format( employee.earnings() ) + "\n" +
37           boss.toString() + " earned $" +
38           precision2.format( boss.earnings() ) + "\n";
39
40        // Employee reference to a CommissionWorker
41        employee = commissionWorker;
42
43        output += employee.toString() + " earned $" +
44           precision2.format( employee.earnings() ) + "\n" +
45           commissionWorker.toString() + " earned $" +
46           precision2.format(
47              commissionWorker.earnings() ) + "\n";
48
49        // Employee reference to a PieceWorker
50        employee = pieceWorker;
51
52        output += employee.toString() + " earned $" +
53           precision2.format( employee.earnings() ) + "\n" +
54           pieceWorker.toString() + " earned $" +
55           precision2.format( pieceWorker.earnings() ) + "\n";
56
```

Outline

Test.java

Line 33
Use **Employee** to reference **Boss**

Line 36
Method **employee.earnings** dynamically binds to method **boss.earnings**

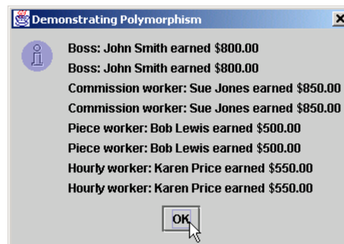
Lines 41-55
Do same for **CommissionWorker** and **PieceWorker**

```
57       // Employee reference to an HourlyWorker
58       employee = hourlyWorker;
59
60       output += employee.toString() + " earned $" +
61       precision2.format( employee.earnings() ) + "\n" +
62            hourlyWorker.toString() + " earned $" +
63            precision2.format( hourlyWorker.earnings() ) + "\n";
64
65         JOptionPane.showMessageDialog( null, output,
66            "Demonstrating Polymorphism",
67            JOptionPane.INFORMATION_MESSAGE );
68
69         System.exit( 0 );
70      }
71
72   }  // end class Test
```

Outline

Test.java

Lines 58-63
Repeat for **HourlyWorker**



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New Classes and Dynamic Binding

- Dynamic binding (late binding)
  - Object's type need not be know at compile time
  - At run time, call is matched with method of called object
- **Point**, **Circle**, **Cylinder** hierarchy
  - Modify by including **abstract** superclass **Shape**
    - Demonstrates polymorphism
    - Contains **abstract** method **getName**
      - Each subclass must implement method **getName**
    - Contains (non**abstract**) methods **area** and **volume**
      - **Return 0 by default**
      - Each subclass **overrides** these methods

50

Outline

Case Study: Inheriting Interface and Implementation

```
1    // Fig. 9.22: Shape.java
2    // Definition of abstract base class Shape
3
4    public abstract class Shape extends Object {
5
6       // return shape's area
7       public double area()
8       {
9          return 0.0;
10      }
11
12      // return shape's volume
13      public double volume()
14      {
15         return 0.0;
16      }
17
18      // abstract method must be defined by concrete subclasses
19      // to return appropriate shape name
20      public abstract String getName();
21
22   }  // end class Shape
```

Shape.java

Line 4
Shape cannot be instantiated

Lines 7-16
abstract class can have non**abstract** methods for subclasses

Line 20
Concrete subclasses must implement method **getName**


```
1    // Fig. 9.23: Point.java
2    // Definition of class Point
3
4    public class Point extends Shape {
5       protected int x, y; // coordinates of the Point
6
7       // no-argument constructor
8       public Point()
9       {
10         setPoint( 0, 0 );
11      }
12
13      // constructor
14      public Point( int xCoordinate, int yCoordinate )
15      {
16         setPoint( xCoordinate, yCoordinate );
17      }
18
19      // set x and y coordinates of Point
20      public void setPoint( int xCoordinate, int yCoordinate )
21      {
22         x = xCoordinate;
23         y = yCoordinate;
24      }
25
26      // get x coordinate
27      public int getX()
28      {
29         return x;
30      }
31
```

Outline

Point.java

Line 4
Point inherits **Shape**'s **public** methods

Line 5
protected members prevent clients from direct access (unless clients are **Point** subclasses or are in same package)

```
32      // get y coordinate
33      public int getY()
34      {
35         return y;
36      }
37
38      // convert point into String representation
39      public String toString()
40      {
41         return "[" + x + ", " + y + "]";
42      }
43
44      // return shape name
45      public String getName()
46      {
47         return "Point";
48      }
49
50   }  // end class Point
```

Outline

Point.java

Lines 45-48
Implementation of **Shape**'s method **getName**

*** **Note** ***


```
1    // Fig. 9.24: Circle.java
2    // Definition of class Circle
3
4    public class Circle extends Point {  // inherits from Point
5       protected double radius;
6
7       // no-argument constructor
8       public Circle()
9       {
10         // implicit call to superclass constructor here
11         setRadius( 0 );
12      }
13
14      // constructor
15      public Circle( double circleRadius, int xCoordinate,
16         int yCoordinate )
17      {
18         // call superclass constructor
19         super( xCoordinate, yCoordinate );
20
21         setRadius( circleRadius );
22      }
23
24      // set radius of Circle
25      public void setRadius( double circleRadius )
26      {
27         radius = ( circleRadius >= 0 ? circleRadius : 0 );
28      }
29
30      // get radius of Circle
31      public double getRadius()
32      {
33         return radius;
34      }
35
```

Outline

Circle.java

Line 4
Circle inherits variables/methods from **Point** and **Shape**

Lines 5 and 24-34
Methods for reading/setting **protected** value

```
36      // calculate area of Circle
37      public double area()
38      {
39         return Math.PI * radius * radius;
40      }
41
42      // convert Circle to a String represention
43      public String toString()
44      {
45         return "Center = " + super.toString() +
46            "; Radius = " + radius;
47      }
48
49      // return shape name
50      public String getName()
51      {
52         return "Circle";
53      }
54
55   }  // end class Circle
```

Outline

Circle.java

Lines 37-40
Override method **area** but not method **volume** (circles do not have volume)

Lines 50-53
Implementation of **Shape**'s method **getName**


```
1    // Fig. 9.25: Cylinder.java
2    // Definition of class Cylinder.
3
4    public class Cylinder extends Circle {
5       protected double height;  // height of Cylinder
6
7       // no-argument constructor
8       public Cylinder()
9       {
10         // implicit call to superclass constructor here
11         setHeight( 0 );
12      }
13
14      // constructor
15      public Cylinder( double cylinderHeight,
16         double cylinderRadius, int xCoordinate,
17         int yCoordinate )
18      {
19         // call superclass constructor
20         super( cylinderRadius, xCoordinate, yCoordinate );
21
22         setHeight( cylinderHeight );
23      }
24
25      // set height of Cylinder
26      public void setHeight( double cylinderHeight )
27      {
28         height = ( cylinderHeight >= 0 ? cylinderHeight : 0 );
29      }
30
```

Outline

Cylinder.java

Line 4
Cylinder inherits variables and methods from **Point**, **Circle** and **Shape**

```java
31    // get height of Cylinder
32    public double getHeight()
33    {
34       return height;
35    }
36
37    // calculate area of Cylinder (i.e., surface area)
38    public double area()
39    {
40       return 2 * super.area() + 2 * Math.PI * radius * height;
41    }
42
43    // calculate volume of Cylinder
44    public double volume()
45    {
46       return super.area() * height;
47    }
48
49    // convert Cylinder to a String representation
50    public String toString()
51    {
52       return super.toString() + "; Height = " + height;
53    }
54
55    // return shape name
56    public String getName()
57    {
58       return "Cylinder";
59    }
60
61 }  // end class Cylinder
```

Outline

Cylinder.java

Lines 38-47
Override methods **area** and **volume**

Lines 56-59
Implementation of **Shape**'s method **getName**


```java
1  // Fig. 9.26: Test.java
2  // Class to test Shape, Point, Circle, Cylinder hierarchy
3
4  // Java core packages
5  import java.text.DecimalFormat;
6
7  // Java extension packages
8  import javax.swing.JOptionPane;
9
10 public class Test {
11
12    // test Shape hierarchy
13    public static void main( String args[] )
14    {
15       // create shapes
16       Point point = new Point( 7, 11 );
17       Circle circle = new Circle( 3.5, 22, 8 );
18       Cylinder cylinder = new Cylinder( 10, 3.3, 10, 10 );
19
20       // create Shape array
21       Shape arrayOfShapes[] = new Shape[ 3 ];
22
23       // aim arrayOfShapes[ 0 ] at subclass Point object
24       arrayOfShapes[ 0 ] = point;
25
26       // aim arrayOfShapes[ 1 ] at subclass Circle object
27       arrayOfShapes[ 1 ] = circle;
28
29       // aim arrayOfShapes[ 2 ] at subclass Cylinder object
30       arrayOfShapes[ 2 ] = cylinder;
31
```

Outline

Test.java

Lines 16-18
Instantiate one instance each of **Shape** subclasses

Lines 21-30
Create three **Shape**s to reference each subclass object

```
32        // get name and String representation of each shape
33        String output =
34           point.getName() + ": " + point.toString() + "\n" +
35           circle.getName() + ": " + circle.toString() + "\n" +
36           cylinder.getName() + ": " + cylinder.toString();
37
38        DecimalFormat precision2 = new DecimalFormat( "0.00" );
39
40        // loop through arrayOfShapes and get name,
41        // area and volume of each shape in arrayOfShapes
42        for ( int i = 0; i < arrayOfShapes.length; i++ ) {
43           output += "\n\n" + arrayOfShapes[ i ].getName() +
44              ": " + arrayOfShapes[ i ].toString() +
45              "\nArea = " +
46              precision2.format( arrayOfShapes[ i ].area() ) +
47              "\nVolume = " +
48              precision2.format( arrayOfShapes[ i ].volume() );
49        }
50
51        JOptionPane.showMessageDialog( null, output,
52           "Demonstrating Polymorphism",
53           JOptionPane.INFORMATION_MESSAGE );
54
55        System.exit( 0 );
56     }
57
58  }  // end class Test
```

Outline

`Test.java`

Line 43
Dynamically bind method **`getName`**

Line 46
Dynamically bind method **`area`** for **`Circle`** and **`Cylinder`** objects

Line 48
Dynamically bind method **`volume`** for **`Cylinder`** object

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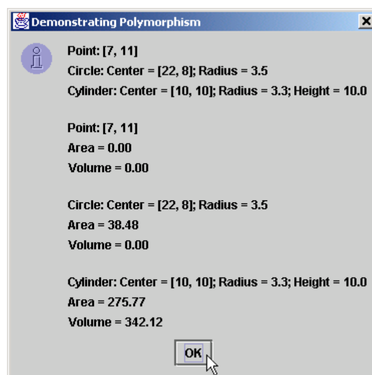
Outline

`Test.java`



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Case Study: Creating and Using Interfaces

- Use **`interface Shape`**
  - Replace **`abstract`** class **`Shape`**
- Interface
  - Definition begins with ***`interface`*** keyword
  - Classes ***`implement`*** an interface (and its methods)
  - Contains ***`public abstract`*** methods
    - Classes (that **`implement`** the interface) must implement these methods


```
1   // Fig. 9.27: Shape.java
2   // Definition of interface Shape
3
4   public interface Shape {
5
6      // calculate area
7      public abstract double area();
8
9      // calculate volume
10     public abstract double volume();
11
12     // return shape name
13     public abstract String getName();
14  }
```

Outline

`Shape.java`

Lines 7-13
Classes that **`implement Shape`** must implement these methods

```
1     // Fig. 9.28: Point.java
2     // Definition of class Point
3
4     public class Point extends Object implements Shape {
5        protected int x, y; // coordinates of the Point
6
7        // no-argument constructor
8        public Point()
9        {
10          setPoint( 0, 0 );
11       }
12
13       // constructor
14       public Point( int xCoordinate, int yCoordinate )
15       {
16          setPoint( xCoordinate, yCoordinate );
17       }
18
19       // Set x and y coordinates of Point
20       public void setPoint( int xCoordinate, int yCoordinate )
21       {
22          x = xCoordinate;
23          y = yCoordinate;
24       }
25
26       // get x coordinate
27       public int getX()
28       {
29          return x;
30       }
31
```

Outline

`Point.java`

Line 4
`Point` implements interface **`Shape`**


```
32       // get y coordinate
33       public int getY()
34       {
35          return y;
36       }
37
38       // convert point into String representation
39       public String toString()
40       {
41          return "[" + x + ", " + y + "]";
42       }
43
44       // calculate area
45       public double area()
46       {
47          return 0.0;
48       }
49
50       // calculate volume
51       public double volume()
52       {
53          return 0.0;
54       }
55
56       // return shape name
57       public String getName()
58       {
59          return "Point";
60       }
61
62    }  // end class Point
```

Outline

`Point.java`

Lines 45-60
Implement methods specified by interface **`Shape`**

```java
1    // Fig. 9.29: Circle.java
2    // Definition of class Circle
3
4    public class Circle extends Point {  // inherits from Point
5       protected double radius;
6
7       // no-argument constructor
8       public Circle()
9       {
10         // implicit call to superclass constructor here
11         setRadius( 0 );
12      }
13
14      // constructor
15      public Circle( double circleRadius, int xCoordinate,
16         int yCoordinate )
17      {
18         // call superclass constructor
19         super( xCoordinate, yCoordinate );
20
21         setRadius( circleRadius );
22      }
23
24      // set radius of Circle
25      public void setRadius( double circleRadius )
26      {
27         radius = ( circleRadius >= 0 ? circleRadius : 0 );
28      }
29
30      // get radius of Circle
31      public double getRadius()
32      {
33         return radius;
34      }
35
```

Outline

`Circle.java`

Line 4
`Circle` inherits variables/methods from **`Point`**, including method implementations of **`Shape`**


```java
36      // calculate area of Circle
37      public double area()
38      {
39         return Math.PI * radius * radius;
40      }
41
42      // convert Circle to a String represention
43      public String toString()
44      {
45         return "Center = " + super.toString() +
46            "; Radius = " + radius;
47      }
48
49      // return shape name
50      public String getName()
51      {
52         return "Circle";
53      }
54
55   }  // end class Circle
```

Outline

`Circle.java`

Lines 43-47
Override method **`toString`**

Lines 37-40 and 50-53
Override methods **`area`** and **`getName`** but not method **`volume`**

Outline

`Cylinder.java`

Line 4
`Circle` inherits variables/methods from **`Point`** and **`Circle`** and method implementations of **`Shape`**

```
1    // Fig. 9.30: Cylinder.java
2    // Definition of class Cylinder.
3
4    public class Cylinder extends Circle {
5       protected double height;  // height of Cylinder
6
7       // no-argument constructor
8       public Cylinder()
9       {
10         // implicit call to superclass constructor here
11         setHeight( 0 );
12      }
13
14      // constructor
15      public Cylinder( double cylinderHeight,
16         double cylinderRadius, int xCoordinate,
17         int yCoordinate )
18      {
19         // call superclass constructor
20         super( cylinderRadius, xCoordinate, yCoordinate );
21
22         setHeight( cylinderHeight );
23      }
24
25      // set height of Cylinder
26      public void setHeight( double cylinderHeight )
27      {
28         height = ( cylinderHeight >= 0 ? cylinderHeight : 0 );
29      }
30
31      // get height of Cylinder
32      public double getHeight()
33      {
34         return height;
35      }
```

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Outline

`Cylinder.java`

Lines 50-53
Override method **`toString`**

Line 38-59
Override methods **`area`**, **`volume`** and **`getName`**

```
36
37      // calculate area of Cylinder (i.e., surface area)
38      public double area()
39      {
40         return 2 * super.area() + 2 * Math.PI * radius * height;
41      }
42
43      // calculate volume of Cylinder
44      public double volume()
45      {
46         return super.area() * height;
47      }
48
49      // convert Cylinder to a String representation
50      public String toString()
51      {
52         return super.toString() + "; Height = " + height;
53      }
54
55      // return shape name
56      public String getName()
57      {
58         return "Cylinder";
59      }
60
61   }  // end class Cylinder
```

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Outline

Test.java

Fig. 9.31 is identical to Fig. 9.26

```
1     // Fig. 9.31: Test.java
2     // Test Point, Circle, Cylinder hierarchy with interface Shape.
3
4     // Java core packages
5     import java.text.DecimalFormat;
6
7     // Java extension packages
8     import javax.swing.JOptionPane;
9
10    public class Test {
11
12       // test Shape hierarchy
13       public static void main( String args[] )
14       {
15          // create shapes
16          Point point = new Point( 7, 11 );
17          Circle circle = new Circle( 3.5, 22, 8 );
18          Cylinder cylinder = new Cylinder( 10, 3.3, 10, 10 );
19
20          // create Shape array
21          Shape arrayOfShapes[] = new Shape[ 3 ];
22
23          // aim arrayOfShapes[ 0 ] at subclass Point object
24          arrayOfShapes[ 0 ] = point;
25
26          // aim arrayOfShapes[ 1 ] at subclass Circle object
27          arrayOfShapes[ 1 ] = circle;
28
29          // aim arrayOfShapes[ 2 ] at subclass Cylinder object
30          arrayOfShapes[ 2 ] = cylinder;
31
```

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Outline

Test.java

```
32          // get name and String representation of each shape
33          String output =
34             point.getName() + ": " + point.toString() + "\n" +
35             circle.getName() + ": " + circle.toString() + "\n" +
36             cylinder.getName() + ": " + cylinder.toString();
37
38          DecimalFormat precision2 = new DecimalFormat( "0.00" );
39
40          // loop through arrayOfShapes and get name,
41          // area and volume of each shape in arrayOfShapes
42          for ( int i = 0; i < arrayOfShapes.length; i++ ) {
43             output += "\n\n" + arrayOfShapes[ i ].getName() +
44                ": " + arrayOfShapes[ i ].toString() +
45                "\nArea = " +
46                precision2.format( arrayOfShapes[ i ].area() ) +
47                "\nVolume = " +
48                precision2.format( arrayOfShapes[ i ].volume() );
49          }
50
51          JOptionPane.showMessageDialog( null, output,
52             "Demonstrating Polymorphism",
53             JOptionPane.INFORMATION_MESSAGE );
54
55          System.exit( 0 );
56       }
57
58    }  // end class Test
```

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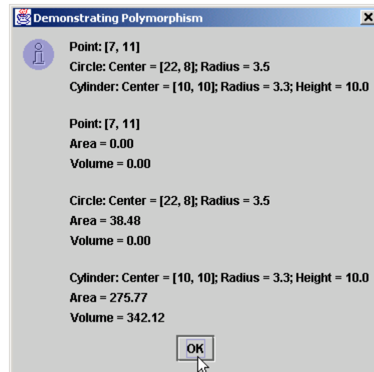
Outline

Test.java

Output is identical to that of Fig. 9.26



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Inner Class Definitions

- Inner classes
  - Class is defined inside another class body
  - Inner class object is allowed to access directly all the instance variable and methods of the outer class object.
  - Frequently used with GUI event handling
    - Declare **`ActionListener`** inner class
    - GUI components can register **`ActionListener`**s for events
      - Button events, key events, etc.

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Inner Class Definitions (cont.)

- Anonymous inner class
  - Inner class without name
  - Created when class is defined in program

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Notes on Inner Class Definitions

- Notes for inner-class definition and use
  - Compiling class that contains inner class
    - Results in separate **.class** file (outercslassname$innerclassname.class)
  - Inner classes with class names
    - **public**, **protected**, **private** or package access
  - Outer class is responsible for creating inner class objects
  - To create an object of another class's inner class, first create an object of the outer class and assign to a reference

  Ex. **OuterClassName.InnerClassName** innerRef=**ref.new InnerClassName();**
  - Inner classes can be declared **static→cannot access to the outer class's non-static members**

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Type-Wrapper Classes for Primitive Types

- Type-wrapper class
  - Each primitive type has one
    - **Character**, **Byte**, **Integer**, **Boolean**, etc.
  - Enable to manipulate primitive types as **Object**
    - Value of primitive data types can be processed polymorphically
  - Declared as **final(Byte, Short, …)**→ inherit from **Number**
  - Many methods are declared final **static➔cannot be overriden**
- (Optional Case Study) Thinking About Objects: Incorporating Inheritance into the Elevator Simulation
- Our design can benefit from inheritance
  - Examine sets of classes
  - Look for commonality between/among sets ➔ Fig. 9.37
    - Extract commonality into superclass(UML's generalization)→ Location
      - Subclasses inherits this commonality(UML's specialization)→Elevator, Floor

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Thinking About Objects (cont.)

- **`ElevatorButton`** and **`FloorButton`**
  - Treated as separate classes
  - Both have *attribute* **`pressed`**
  - Both have *behaviors* **`pressButton`** and **`resetButton`**
  - Move attribute and behaviors into superclass **`Button`**?
    - We must examine whether these **objects have distinct behavior**
      - If **same behavior**
        - They are objects of class **`Button`**
      - If different behavior
        - They are objects of distinct **`Button`** subclasses

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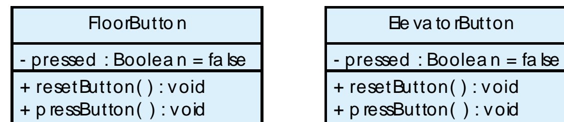
Fig. 9.35 Attributes and operations of classes **FloorButton** and **ElevatorButton.**



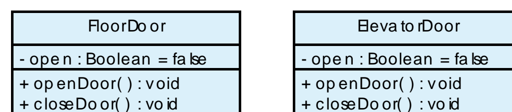
9.23 Thinking About Objects (cont.)

- **ElevatorButton** and **FloorButton**
  - **FloorButton** requests **Elevator** to **Floor** of request
    - **Elevator** will sometimes respond
  - **ElevatorButton** signals **Elevator** to move
    - **Elevator** will always respond
  - Neither button *decides* for the **Elevator** to move
    - **Elevator** decides itself
  - Both buttons signal **Elevator** to move
    - Therefore, **both buttons exhibit identical behavior**
      - They are objects of class **Button**
      - Combine (not inherit) **ElevatorButton** and **FloorButton** into class **Button**

9.23 Thinking About Objects (cont.)

- **`ElevatorDoor`** and **`FloorDoor`**
  - Treated as separate classes
  - Both have *attribute* **`open`**
  - Both have *behaviors* **`openDoor`** and **`closeDoor`**
  - Both door "inform" a **`Person`** that a door has opened
    - **Both doors exhibit identical behavior**
      - They are objects of class **`Door`**
      - Combine (not inherit) **`ElevatorDoor`** and **`FloorDoor`** into class **`Door`**

Fig. 9.36 Attributes and operations of classes FloorDoor and ElevatorDoor



Thinking About Objects (cont.)

- Representing location of **`Person`**
  - On what **`Floor`** is **`Person`** when riding **`Elevator`**?
  - Both **`Floor`** and **`Elevator`** are types of locations
    - Share **`int`** attribute **`capacity`**
    - Inherit from **`abstract`** superclass **`Location`**
      - Contains **`String locationName`** representing location
        - **`"firstFloor"`**
        - **`"secondFloor"`**
        - **`"elevator"`**
  - **`Person`** now contains <u>**`Location`** reference</u>
    - References **`Elevator`** when person is <u>in elevator</u>
    - References **`Floor`** when person is <u>on floor</u>

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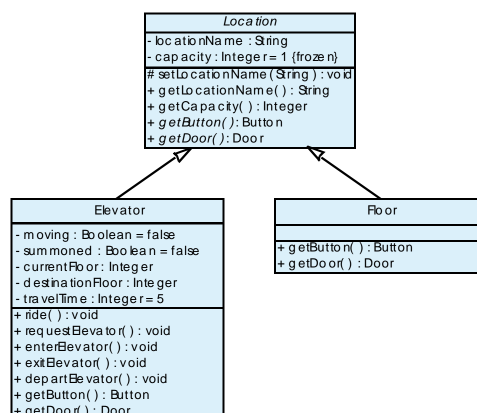
Fig. 9.37 Class diagram modeling generalization of superclass **`Location`** and subclasses **`Elevator`** and **`Floor`**.



Outline

Italics indicate abstract class or method

Pound sign (**#**) indicates **`protected`** member

`{frozen}` indicates constant (final in Java)

Concrete classes implement abstract methods

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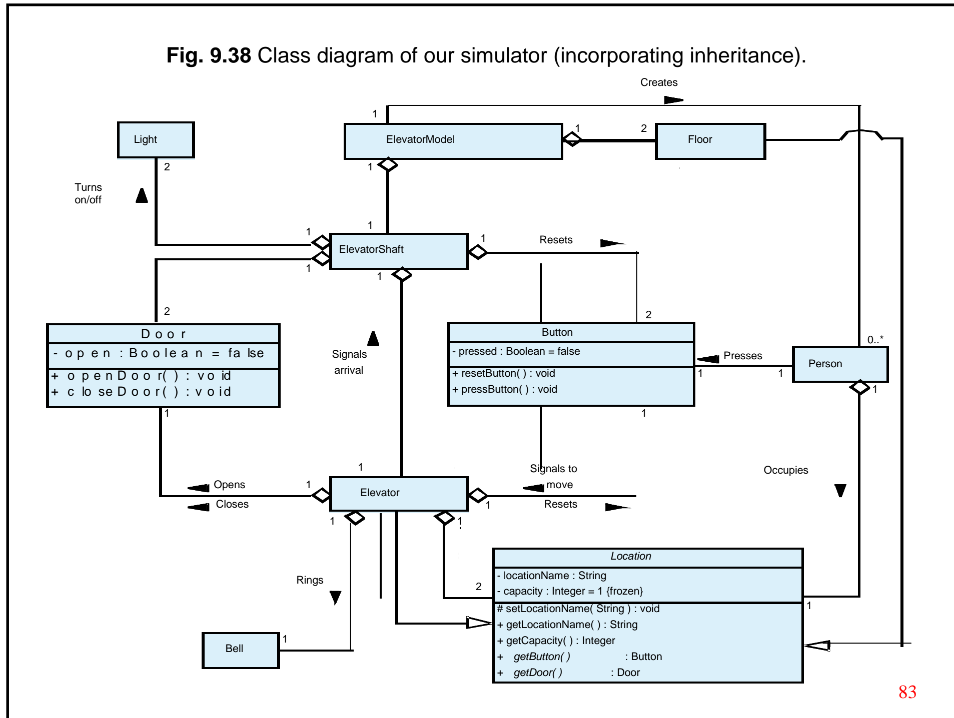

Fig. 9.38 Class diagram of our simulator (incorporating inheritance).

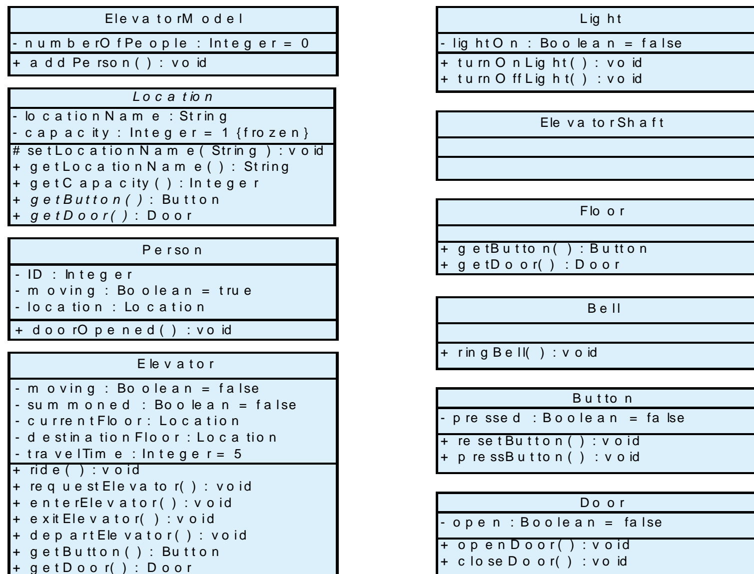

Fig. 9.39 Class diagram with attributes and operations (incorporating inheritance).

Thinking About Objects (cont.)

- Continue implementation
  - Transform design (i.e., class diagram) to code
  - Generate "skeleton code" with our design
    - Use class `Elevator` as example
    - Two steps (incorporating inheritance)

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Thinking About Objects (cont.) Step 1

```
public class Elevator extends Location {

   // class constructor
   public Elevator() {}
}
```

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```java
1   // Elevator.java
2   // Generated using class diagrams 9.38 and 9.39
3   public class Elevator extends Location {
4
5      // class attributes
6      private boolean moving;
7      private boolean summoned;
8      private Location currentFloor;
9      private Location destinationFloor;
10     private int travelTime = 5;
11     private Button elevatorButton;
12     private Door elevatorDoor;
13     private Bell bell;
14
15     // class constructor
16     public Elevator() {}
17
18     // class methods
19     public void ride() {}
20     public void requestElevator() {}
21     public void enterElevator() {}
22     public void exitElevator() {}
23     public void departElevator() {}
24
25     // method overriding getButton
26     public Button getButton()
27     {
29        return elevatorButton;
29     }
30
31     // method overriding getDoor
32     public Door getDoor()
33     {
34        return elevatorDoor;
35     }
36  }
```

Outline

Step 2

Implement abstract classes

(Optional) Discovering Design Patterns: Introducing Creational, Structural and Behavioral Design Patterns

- Design-patterns discussion
  - Discuss each type
    - Creational – related to the creation of objects
    - Structural -- describe common ways to organize classes and objects
    - Behavioral-- Model how objects collaborate with one another
  - Discuss importance
  - Discuss how we can use each pattern in Java
- We also introduce
  - *Concurrent* design patterns
    - Used in multithreaded systems
    - Chapter 15
  - *Architectural* patterns
    - Specify how subsystems interact with each other
    - Chapter 17

Discovering Design Patterns (cont.)

- Creational design patterns
  - Address issues related to object creation
    - e.g., prevent from creating more than one object of class
    - e.g., defer until run time what type of objects to be created
  - Consider 3D drawing program
    - User can create cylinders, spheres, cubes, etc.
    - At compile time, program does not know what shapes the user will draw
    - Based on user input, program should determine this at run time

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Discovering Design Patterns (cont.)

- 5 creational design patterns
  - Abstract Factory (Chapter 17)
  - Builder (not discussed)
  - Factory Method (Chapter 13)
  - Prototype (Chapter 21)
  - Singleton (Chapter 9)
- Singleton
  - Used when system should contain *exactly* one object of class

    Ex. one object manages database connections➔ensure that other objects cannot utilize unnecessary connections that would slow the system
  - Ensures system instantiates *maximum* of one class object

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```
1   // Singleton.java
2   // Demonstrates Singleton design pattern
3   package com.deitel.jhtp4.designpatterns;
4
5   public final class Singleton {
6
7      // Singleton object returned by method getSingletonInstance
8      private static Singleton singleton;
9
10     // constructor prevents instantiation from other objects
11     private Singleton()
12     {
13        System.err.println( "Singleton object created." );
14     }
15
16     // create Singleton and ensure only one Singleton instance
17     public static Singleton getSingletonInstance()
18     {
19        // instantiate Singleton if null
20        if ( singleton == null )
21           singleton = new Singleton();
22
23        return singleton;
24     }
25  }
```

Outline

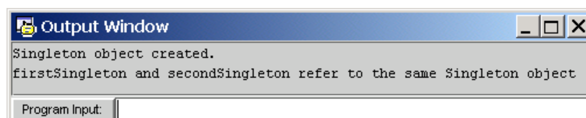
Singleton.java

Line 11
private constructor ensures only class **Singleton** can instantiate **Singleton** object

Lines 20-23
Instantiate **Singleton** object only once, but return same reference

91

```
1   // SingletonExample.java
2   // Attempt to create two Singleton objects
3   package com.deitel.jhtp4.designpatterns;
4
5   public class SingletonExample {
6
7      // run SingletonExample
8      public static void main( String args[] )
9      {
10        Singleton firstSingleton;
11        Singleton secondSingleton;
12
13        // create Singleton objects
14        firstSingleton = Singleton.getSingletonInstance();
15        secondSingleton = Singleton.getSingletonInstance();
16
17        // the "two" Singletons should refer to same Singleton
18        if ( firstSingleton == secondSingleton )
19           System.out.println( "firstSingleton and " +
20              "secondSingleton refer to the same Singleton " +
21              "object" );
22     }
23  }
```



Outline

SingletonExample.java

Line 14
Create **Singleton** instance

Line 15
Get same **Singleton** instance

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Discovering Design Patterns (cont.)

- Structural design patterns
  - Describe common ways to organize classes and objects

  - Adapter (Chapter 13)
  - Bridge (Chapter 13)
  - Composite (Chapter 13)
  - Decorator (Chapter 17)
  - Facade (Chapter 17)
  - Flyweight (not discussed)
  - Proxy (Chapter 9)

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Discovering Design Patterns (cont.)

- Proxy
  - Allows system to use one object instead of another
    - If original object cannot be used (for whatever reason)
  - Consider loading several large images in Java applet
    - Ideally, we want to see these image instantaneously
    - Loading these images can take time to complete
    - Applet can use gauge object that informs use of load status(what percentage of a large image has been loaded)
      - Gauge object is called the *proxy object*
    - Remove proxy object when images have finished loading→ the applet can display an image instead of the proxy object

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Discovering Design Patterns (cont.)

- Behavioral design patterns
  - Model how objects collaborate with one another
  - Assign responsibilities to algorithms→offer special behavior appropriate for a wide variety of application

Discovering Design Patterns (cont.)

- Behavioral design patterns
  - Chain-of-Responsibility (Chapter 13)
  - Command (Chapter 13)
  - Interpreter (not discussed)
  - Iterator (Chapter 21)
  - Mediator (not discussed)
  - Memento (Chapter 9)
  - Observer (Chapter 13)
  - State (Chapter 9)
  - Strategy (Chapter 13)
  - Template Method (Chapter 13)
  - Visitor (not discussed)

Discovering Design Patterns (cont.)

- Memento
  - Allows object to save its *state* (set of attribute values)
  - Consider painting program for creating graphics
    - Offer "undo" feature if user makes mistake
      - Returns program to previous state (before error)
    - *History* lists previous program states(store several states in a list)
  - *Originator object* occupies state
    - e.g., drawing area
  - *Memento object* stores copy of originator object's attributes
    - e.g., memento saves state of drawing area
  - *Caretaker object* (history) contains references to all mementos(include originator object)
    - e.g., history lists mementos from which user can select

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Discovering Design Patterns (cont.)

- State
  - Convey an object's state or represent the various states that an object can occupy
  - Consider optional elevator-simulation case study
    - Person walks across a floor and rides the elevator to the other floor
      - Use integer to represent floor on which person walks
    - Person rides elevator to other floor
    - On what floor is the person when riding elevator?

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Discovering Design Patterns (cont.)

- State
  - We implement a solution:
    - Abstract superclass **`Location`**
    - Classes **`Floor`** and **`Elevator`** extend **`Location`**
    - Encapsulates information about person location
      - Each location has reference to **`Button`** and **`Door`**
    - Class **`Person`** contains **`Location`** reference
      - Reference **`Floor`** when on floor
      - Reference **`Elevator`** when in elevator