Java Classes, Objects, Inheritance, Abstract and Interfaces Recap

CSE260, Computer Science B: Honors
Stony Brook University

http://www.cs.stonybrook.edu/~cse260
Objectives

- To recap classes, objects, inheritance, abstract classes and interfaces
An object represents an entity in the real world that can be distinctly identified.

An object has a unique state and behaviors

- the state of an object consists of a set of data fields (properties) with their current values
- the behavior of an object is defined by a set of methods

Class Name: Circle
Data Fields:
- radius is _______
Methods:
- getArea()

Circle Object 1
Data Fields:
- radius is 1

Circle Object 2
Data Fields:
- radius is 25

Circle Object 3
Data Fields:
- radius is 125

A class template
Three objects of the Circle class
Classes

- Classes are templates that define objects of the same type.

- A Java class uses:
  - variables to define data fields and
  - methods to define behaviors

- A class provides a special type of methods called **constructors** which are invoked to construct objects from the class
class Circle {
    /** The radius of this circle */
    private double radius = 1.0;

    /** Construct a circle object */
    public Circle() {
    }

    /** Construct a circle object */
    public Circle(double newRadius) {
        radius = newRadius;
    }

    /** Return the area of this circle */
    public double getArea() {
        return radius * radius * 3.14159;
    }
}
public class TestCircle {

    public static void main(String[] args) {
        Circle circle1 = new Circle();
        Circle circle2 = new Circle(25);
        Circle circle3 = new Circle(125);

        System.out.println( circle1.getArea() );
        System.out.println( circle2.getArea() );
        System.out.println( circle3.getArea() );

        //System.out.println( circle1.radius );
        //System.out.println( circle2.radius );
        //System.out.println( circle3.radius );
    }
}

UML Class Diagram

**Class name**: Circle

**Data fields**:
- radius: double

**Constructors and methods**:
- Circle()
- Circle(newRadius: double)
- getArea(): double

**Objects**:
- `circle1: Circle`
  - radius = 1.0
- `circle2: Circle`
  - radius = 25
- `circle3: Circle`
  - radius = 125

UML notation for objects
Constructors

- Constructors must have the same name as the class itself.
- Constructors do not have a return type—not even void.
- Constructors are invoked using the new operator when an object is created— they initialize objects to reference variables:

  ```java
  ClassName o = new ClassName();
  ```

- Example:

  ```java
  Circle myCircle = new Circle(5.0);
  ```

- A class may be declared without constructors: a no-arg default constructor with an empty body is implicitly declared in the class
Accessing Objects

• Referencing the object’s data:
  \texttt{objectRefVar.data}
  
  • Example: \texttt{myCircle.radius}

• Invoking the object’s method:
  \texttt{objectRefVar.methodName(arguments)}
  
  • Example: \texttt{myCircle.getArea()}
Default values

Java assigns no default value to a local variable inside a method.

```
public class Test {
    public static void main(String[] args) {
        int x; // x has no default value
        String y; // y has no default value
        System.out.println("x is " + x);
        System.out.println("y is " + y);
    }
}
```

Compilation error: the variables are not initialized

BUT it assigns default values to data fields!
Reference Data Fields

• The data fields can also be of reference types

• Example:

```java
public class Student {
    String name; // name has default value null
    int age; // age has default value 0
    boolean isScienceMajor; // isScienceMajor has default value false
    char gender; // c has default value '\u0000'
}
```

• If a data field of a reference type does not reference any object, the data field holds a special literal value: `null`.

```java
public class Test {
    public static void main(String[] args) {
        Student student = new Student();
        System.out.println("name? " + student.name); // null
        System.out.println("age? " + student.age); // 0
        System.out.println("isScienceMajor? " + student.isScienceMajor); // false
        System.out.println("gender? " + student.gender); // 
    }
}
```
Differences between Variables of Primitive Data Types and Object Types

**Primitive type**

```
int i = 1
```

```
i
1
```

**Object type**

```
Circle c
```

```
c
reference
```

```
c: Circle
radius = 1
```

Created using `new Circle()`
Copying Variables of Primitive Data Types and Object Types

**Primitive type assignment** \( i = j \)

Before:

\[
\begin{array}{c}
  i \\
  j
\end{array}
\]

\[
\begin{array}{c}
  1 \\
  2
\end{array}
\]

After:

\[
\begin{array}{c}
  i \\
  j
\end{array}
\]

\[
\begin{array}{c}
  2 \\
  2
\end{array}
\]

**Object type assignment** \( c1 = c2 \)

Before:

\[
\begin{array}{c}
  c1 \\
  c2
\end{array}
\]

\[
\begin{array}{c}
  c1: \text{Circle} \\
  \text{radius} = 5
\end{array}
\]

\[
\begin{array}{c}
  c2: \text{Circle} \\
  \text{radius} = 9
\end{array}
\]

After:

\[
\begin{array}{c}
  c1 \\
  c2
\end{array}
\]

\[
\begin{array}{c}
  c1: \text{Circle} \\
  \text{radius} = 5
\end{array}
\]

\[
\begin{array}{c}
  c2: \text{Circle} \\
  \text{radius} = 9
\end{array}
\]

- The object previously referenced by \( c1 \) is no longer referenced – it is called *garbage*.
- Garbage is automatically collected by JVM = *garbage collection*.
Static Variables, Constants and Methods

Circle

- radius: double
- numberOfObjects: int

+ getNumberOfObjects(): int
+ getArea(): double

UML Notation:
+-: public variables or methods
underline: static variables or methods

After two Circle objects were created, numberOfObjects is 2.
Visibility Modifiers and Accessor/Mutator Methods

- By default, the class, variable, or method can be accessed by any class in the same package.

  public
  
  The class, data, or method is visible to any class in any package.

private

  The data or methods can be accessed only by the declaring class - To protect data!

The get and set methods are used to read and modify private properties.
Array of Objects

`Circle[] circleArray = new Circle[10];`

- An array of objects is an array of reference variables (like the multi-dimensional arrays seen before)
Immutable Objects and Classes

- Immutable object: the contents of an object cannot be changed once the object is created - its class is called an immutable class

- Example immutable class: no set method in the Circle class

```java
public class Circle{
    private double radius;

    public Circle() { }
    public Circle(double radius) {
        this.radius = radius;
    }
    public double getRadius() {
        return radius;
    }
}
```

- radius is private and cannot be changed without a set method

- A class with all private data fields and without mutators is not necessarily immutable!
What Class is Immutable?

1. It must mark all data fields private!
2. Provide no mutator methods!
3. Provide no accessor methods that would return a reference to a mutable data field object!
public class Student {
    private int id;
    private BirthDate birthDate;
    public Student(int ssn, int year, int month, int day) {
        id = ssn;
        birthDate = new BirthDate(year, month, day);
    }
    public int getId() {
        return id;
    }
    public BirthDate getBirthDate() {
        return birthDate;
    }
}

public class BirthDate {
    private int year;
    private int month;
    private int day;
    public BirthDate(int newYear, int newMonth, int newDay) {
        year = newYear;
        month = newMonth;
        day = newDay;
    }
    public void setYear(int newYear) {
        year = newYear;
    }
    public int getYear() {
        return year;
    }
}

public class Test {
    public static void main(String[] args) {
        Student student = new Student(111223333, 1998, 1, 1);
        BirthDate date = student.getBirthDate();
        date.setYear(2050);
        // Now the student birth year is changed:
        System.out.println(student.getBirthDate().getYear()); // 2050
    }
}
The **this** Keyword

- The **this** keyword is the name of a reference that refers to an object itself.
- Common uses of the **this** keyword:
  1. Reference a class’s “hidden” data fields
  2. To enable a constructor to invoke another constructor of the same class as the first statement in the constructor.
public class Foo {
  private int i = 5;
  private static double k = 0;

  void setI(int i) {
    this.i = i;
  }

  static void setK(double k) {
    Foo.k = k;
  }
}

Suppose that f1 and f2 are two objects of Foo.
Invoking f1.setI(10) is to execute
  this.i = 10, where this refers f1
Invoking f2.setI(45) is to execute
  this.i = 45, where this refers f2
public class Circle {
    private double radius;

    public Circle(double radius) {
        this.radius = radius;
    }

    public Circle() {
        this(1.0);
    }

    public double getArea() {
        return this.radius * this.radius * Math.PI;
    }
}

Every instance variable belongs to an instance represented by this, which is normally omitted.
The Date Class

Java provides a system-independent encapsulation of date and time in the `java.util.Date` class.

The `toString` method returns the date and time as a string.

```java
java.util.Date date = new java.util.Date();
System.out.println(date.toString());
```

January 1, 1970, GMT is called the Unix time (or Unix epoch time).
Constructing Strings

• Pattern:

```java
String newString = new String(stringLiteral);
```

• Example:

```java
String message = new String("Welcome to Java");
```

• Since strings are used frequently, Java provides a shorthand initializer for creating a string:

```java
String message = "Welcome to Java";
```
Strings Are Immutable

- A String object is immutable; its contents cannot be changed

\[
\text{String } s = "Java"; \\
s = "HTML";
\]

- After executing \( s = "Java"; \)
  - String object for "Java"
  - Contents cannot be changed

- After executing \( s = "HTML"; \)
  - This string object is now unreferenced
  - String object for "Java"
  - String object for "HTML"
Interned Strings

String s1 = "Welcome to Java";
String s2 = new String("Welcome to Java");
String s3 = "Welcome to Java";

System.out.println("s1 == s2 is " + (s1 == s2));
System.out.println("s1 == s3 is " + (s1 == s3));

- A new object is created if you use the new operator.
- If you use the string initializer, no new object is created if the interned object is already created.
Matching, Replacing and Splitting by Patterns

- You can match, replace, or split a string by specifying a pattern = regular expressions

"Java is fun".matches("Java.*");
"Java is cool".matches("Java.*");

Social security numbers is \texttt{xxx-xx-xxxx}, where \texttt{x} is a digit:

\[
\texttt{[
\backslash d\right\{3\}-[
\backslash d\right\{2\}-[
\backslash d\right\{4\}
\]
\]
\]

An even number ends with digits \texttt{0, 2, 4, 6, or 8}:

\[
\texttt{[
\backslash d\]*[02468]}
\]

Telephone numbers (\texttt{xxx}) \texttt{xxx-xxxx}, where \texttt{x} is a digit and the first digit cannot be zero:

\[
\texttt{[\backslash ([1-9][\backslash d\right\{2\}\) \] [\backslash d\right\{3\}-[\backslash d\right\{4\}\]
\]
\]
## Regular Expressions

<table>
<thead>
<tr>
<th>Regular Expression</th>
<th>Matches</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>a specified character x</td>
<td>Java matches Java</td>
</tr>
<tr>
<td>.</td>
<td>any single character</td>
<td>Java matches J..a</td>
</tr>
<tr>
<td>(ab</td>
<td>cd)</td>
<td>ab or cd</td>
</tr>
<tr>
<td>[abc]</td>
<td>a, b, or c</td>
<td>Java matches Ja[uvw]a</td>
</tr>
<tr>
<td>[^abc]</td>
<td>any character except a, b, or c</td>
<td>Java matches Ja[^ars]a</td>
</tr>
<tr>
<td>[a-z]</td>
<td>a through z</td>
<td>Java matches [A-M]av[a-d]</td>
</tr>
<tr>
<td>[^a-z]</td>
<td>a through z</td>
<td>Java matches Jav[^b-d]</td>
</tr>
<tr>
<td>[a-e[m-p]]</td>
<td>a through e or m through p</td>
<td>[A-G[I-M]]av[a-d]</td>
</tr>
<tr>
<td>[a-e&amp;&amp;[c-p]]</td>
<td>intersection of a-e with c-p</td>
<td>[A-P&amp;&amp;[I-M]]av[a-d]</td>
</tr>
<tr>
<td>\d</td>
<td>a digit, same as [1-9]</td>
<td>Java2 matches &quot;Java[\d]&quot;</td>
</tr>
<tr>
<td>\D</td>
<td>a non-digit</td>
<td>$Java matches &quot;[\D][\D]ava&quot;</td>
</tr>
<tr>
<td>\w</td>
<td>a word character</td>
<td>Java matches &quot;[\w]ava&quot;</td>
</tr>
<tr>
<td>\W</td>
<td>a non-word character</td>
<td>$Java matches &quot;[\W][\w]ava&quot;</td>
</tr>
<tr>
<td>\s</td>
<td>a whitespace character</td>
<td>&quot;Java 2&quot; matches &quot;Java\s2&quot;</td>
</tr>
<tr>
<td>\S</td>
<td>a non-whitespace char</td>
<td>Java matches &quot;[\S]ava&quot;</td>
</tr>
<tr>
<td>p*</td>
<td>zero or more occurrences of pattern p</td>
<td>Java matches &quot;[\w]*&quot;</td>
</tr>
<tr>
<td>p+</td>
<td>one or more occurrences of pattern p</td>
<td>Java matches &quot;[\w]+&quot;</td>
</tr>
<tr>
<td>p?</td>
<td>zero or one occurrence of pattern p</td>
<td>Java matches &quot;[\w]?Java&quot;</td>
</tr>
<tr>
<td>p{n}</td>
<td>exactly n occurrences of pattern p</td>
<td>Java matches &quot;[\w]{4}&quot;</td>
</tr>
<tr>
<td>p{n,}</td>
<td>at least n occurrences of pattern p</td>
<td>Java matches &quot;[\w]{3,}&quot;</td>
</tr>
<tr>
<td>p{n,m}</td>
<td>between n and m occurrences (inclusive)</td>
<td>Java matches &quot;[\w]{1,9}&quot;</td>
</tr>
</tbody>
</table>
Command-Line Parameters

class TestMain {
    public static void main(String[] args) {
        ...
    }
}

- Run with:
  java TestMain arg0 arg1 arg2 ... argn
or EclipseIDE arguments
StringBuilder and StringBuffer

• The **StringBuilder/StringBuffer** class is an alternative to the **String** class:
  • **StringBuilder/StringBuffer** can be used wherever a string is used
  • **StringBuilder/StringBuffer** is more flexible than **String**
  • You can **add**, **insert**, or **append** new contents into a string buffer, whereas the value of a **String** object is fixed once the string is created
### Superclasses and Subclasses

#### GeometricObject

| -color: String | The color of the object (default: white). |
| -filled: boolean | Indicates whether the object is filled with a color (default: false). |
| -dateCreated: java.util.Date | The date when the object was created. |

| +GeometricObject() | Creates a GeometricObject. |
| +GeometricObject(color: String, filled: boolean) | Creates a GeometricObject with the specified color and filled values. |
| +getColor(): String | Returns the color. |
| +setColor(color: String): void | Sets a new color. |
| +isFilled(): boolean | Returns the filled property. |
| +setFilled(filled: boolean): void | Sets a new filled property. |
| +getDateCreated(): java.util.Date | Returns the dateCreated. |
| +toString(): String | Returns a string representation of this object. |

#### Circle

| -radius: double |  |
| +Circle() |  |
| +Circle(radius: double) |  |
| +Circle(radius: double, color: String, filled: boolean) |  |
| +getRadius(): double |  |
| +setRadius(radius: double): void |  |
| +getArea(): double |  |
| +getPerimeter(): double |  |
| +getDiameter(): double |  |
| +printCircle(): void |  |

#### Rectangle

| -width: double |  |
| -height: double |  |
| +Rectangle() |  |
| +Rectangle(width: double, height: double) |  |
| +Rectangle(width: double, height: double, color: String, filled: boolean) |  |
| +getWidth(): double |  |
| +setWidth(width: double): void |  |
| +getHeight(): double |  |
| +setHeight(height: double): void |  |
| +getArea(): double |  |
| +getPerimeter(): double |  |
public abstract class GeometricObject {
    private String color = "white";
    private boolean filled;
    private java.util.Date dateCreated;
    protected GeometricObject() {
        dateCreated = new java.util.Date();
    }
    protected GeometricObject(String color, boolean filled) {
        dateCreated = new java.util.Date();
        this.color = color;
        this.filled = filled;
    }
    public String getColor() {   return color;  }
    public void setColor(String color) {  this.color = color;  }
    public boolean isFilled() {   return filled;  }
    public void setFilled(boolean filled) {  this.filled = filled;  }
    public java.util.Date getDateCreated() {   return dateCreated;  }
    public String toString() {
        return "created on " + dateCreated + "\ncolor: " + color + " and filled: " + filled;
    }
    /** Abstract method getArea */
    public abstract double getArea();
    /** Abstract method getPerimeter */
    public abstract double getPerimeter();}
public class Circle extends GeometricObject {
    private double radius;
    public Circle() {
    }
    public Circle(double radius) {
        this.radius = radius;
    }
    public double getRadius() {
        return radius;
    }
    public void setRadius(double radius) {
        this.radius = radius;
    }
    public double getArea() {
        return radius * radius * Math.PI;
    }
    public double getDiameter() {
        return 2 * radius;
    }
    public double getPerimeter() {
        return 2 * radius * Math.PI;
    }
    /* Print the circle info */
    public void printCircle() {
        System.out.println("The circle is created " + getDateCreated() + " and the radius is " + radius);
    }
}
public class Rectangle extends GeometricObject {
    private double width;
    private double height;
    public Rectangle() {  }
    public Rectangle(double width, double height, String color,
                     boolean filled) {
        super(color,filled);
        this.width = width;
        this.height = height;
    }
    public double getWidth() {    return width;  }
    public void setWidth(double width) {    this.width = width;  }
    public double getHeight() {    return height;  }
    public void setHeight(double height) {    this.height = height;  }
    public double getArea() {
        return width * height;
    }
    public double getPerimeter() {
        return 2 * (width + height);
    }
}
Are superclass’s Constructor Inherited?

- No. They are not inherited.
- They are invoked explicitly or implicitly:
  - Explicitly using the `super` keyword
  - If the keyword `super` is not explicitly used, the superclass's no-arg constructor is automatically invoked as the first statement in the constructor, unless another constructor is invoked (when the last constructor in the chain will invoke the superclass constructor)
Using the Keyword `super`

- The keyword `super` refers to the superclass of the class in which `super` appears. This keyword can be used in two ways:
  - To call a superclass constructor: Java requires that the statement that uses the keyword `super` appear first in the constructor (unless another constructor is called or the superclass constructor is called implicitly)
  - To call a superclass method
Constructor Chaining

• *Constructor chaining*: constructing an instance of a class invokes all the superclasses’ constructors along the inheritance chain.

```java
public class Faculty extends Employee {
    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
    public static void main(String[] args) {
        new Faculty();
    }
}
class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee’s overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }
    public Employee(String s) {
        System.out.println(s);
    }
}
class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee’s overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}

3. Invoke Employee’s no-arg constructor
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}

4. Invoke Employee(String) constructor
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }
}

public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee’s overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}

5. Invoke Person() constructor
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee’s overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }
}

public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public class Faculty extends Employee {
    public static void main(String[] args) {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }
    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
public void printCircle() {
    System.out.println(
        "The circle is created " + 
        super.getDateCreated() + 
        " and the radius is " + 
        radius);
}
Declaring a Subclass

- A subclass extends properties and methods from the superclass.
- You can also:
  - Add new properties
  - Add new methods
  - Override the methods of the superclass
Method overriding: modify in the subclass the implementation of a method defined in the superclass:

```java
public class Circle extends GeometricObject {
    /** Override the toString method defined in GeometricObject */
    public String toString() {
        return super.toString() + "\nradius is " + radius;
    }
    // Other methods are omitted
    ...
}
```
Overriding Methods in the Superclass

- An instance method can be overridden only if it is accessible
- A private method cannot be overridden, because it is not accessible outside its own class
- If a method defined in a subclass is private in its superclass, the two methods are completely unrelated
- A static method can be inherited
  - A static method cannot be overridden
  - If a static method defined in the superclass is redefined in a subclass, the method defined in the superclass is hidden
public class Test {
    public static void main(String[] args) {
        A a = new A();
        a.p(10);
        a.p(10.0);
        a.p(10.0);
    }
}

class B {
    public void p(double i) {
        System.out.println(i * 2);
    }
}

class A extends B {
    // This method overrides the method in B
    public void p(double i) {
        System.out.println(i);
    }
}

public class Test {
    public static void main(String[] args) {
        A a = new A();
        a.p(10);
        a.p(10.0);
        a.p(10.0);
    }
}

class B {
    public void p(double i) {
        System.out.println(i * 2);
    }
}

class A extends B {
    // This method overloads the method in B
    public void p(double i) {
        System.out.println(i);
    }
    public void p(int i) {
        System.out.println(i);
    }
}
The **Object** Class and Its Methods

- Every class in Java is descended from the `java.lang.Object` class
- If no inheritance is specified when a class is defined, the superclass of the class is `java.lang.Object`

```java
public class Circle {
  ...
}
```

Equivalent:
```
public class Circle extends Object {
  ...
}
```
The `toString()` method in `Object`

- The `toString()` method returns a string representation of the object.
- The default `Object` implementation returns a string consisting of a class name of which the object is an instance, the at sign (`@`), and a number representing this object.

```java
Loan loan = new Loan();
System.out.println(loan.toString());
```

- The code displays something like `Loan@12345e6`
- You should override the `toString()` method so that it returns an informative string representation of the object.
public class PolymorphismDemo {
    public static void main(String[] args) {
        m(new GraduateStudent());
        m(new Student());
        m(new Person());
        m(new Object());
    }
    public static void m(Object x) {
        System.out.println(x.toString());
    }
}

class GraduateStudent extends Student {
}

class Student extends Person {
    public String toString() {
        return "Student";
    }
}

class Person extends Object {
    public String toString() {
        return "Person";
    }
}

Method m takes a parameter of the Object type – can be invoked with any object

**Polymorphism**: an object of a subtype can be used wherever its supertype value is required

**Dynamic binding**: the Java Virtual Machine determines dynamically at runtime which implementation is used by the method

When the method m(Object x) is executed, the argument x’s toString method is invoked.

**Output**:

Student
Student
Person
java.lang.Object@12345678
Dynamic Binding

- Suppose an object $o$ is an instance of classes $C_1, C_2, \ldots, C_{n-1}$, and $C_n$
- $C_1$ is a subclass of $C_2$, $C_2$ is a subclass of $C_3$, $\ldots$, and $C_{n-1}$ is a subclass of $C_n$
- $C_n$ is the most general class, and $C_1$ is the most specific class
- If $o$ invokes a method $p$, the JVM searches the implementation for the method $p$ in $C_1, C_2, \ldots, C_{n-1}$ and $C_n$, in this order, until it is found, the search stops and the first-found implementation is invoked

Since $o$ is an instance of $C_1$, $o$ is also an instance of $C_2, C_3, \ldots, C_{n-1}$, and $C_n$
public class PolymorphismDemo {
    public static void main(String[] args) {
        m(new GraduateStudent());
        m(new Student());
        m(new Person());
        m(new Object());
    }
    public static void m(Object x) {
        System.out.println(x.toString());
    }
}
class GraduateStudent extends Student {
}
class Student extends Person {
    public String toString() {
        return "Student";
    }
}
class Person extends Object {
    public String toString() {
        return "Person";
    }
}
Method Matching vs. Binding

• The compiler finds a matching method according to parameter type, number of parameters, and order of the parameters at compilation time.

• The Java Virtual Machine dynamically binds the implementation of the method at runtime.
Casting Objects

- Casting can be used to convert an object of one class type to another within an inheritance hierarchy

```java
m(new Student());
```

is equivalent to:

```java
Object o = new Student();  // Implicit casting
m(o);
```

*Legal* because an instance of Student is automatically an instance of Object
Why Casting Is Necessary?

```java
Student b = o;
```

- A compilation error would occur because an Object `o` is not necessarily an instance of `Student`.

- We use `explicit casting` to tell the compiler that `o` is a `Student` object - syntax is similar to the one used for casting among primitive data types.

```java
Student b = (Student)o;
```

- This type of casting may not always succeed (check this with `instanceof` operator).
The `instanceof` Operator

- Use the `instanceof` operator to test whether an object is an instance of a class:

```java
Object myObject = new Circle();
...
if (myObject instanceof Circle) {
    System.out.println("The circle diameter is " + ((Circle)myObject).getDiameter());
    ...
}
```
public class CastingDemo{
    public static void main(String[] args){
        Object object1 = new Circle(1);
        Object object2 = new Rectangle(1, 1);
        displayObject(object1);
        displayObject(object2);
    }
    public static void displayObject(Object object) {
        if (object instanceof Circle) {
            System.out.println("The circle area is " + ((Circle)object).getArea());
            System.out.println("The circle diameter is " + ((Circle)object).getDiameter());
        } else if (object instanceof Rectangle) {
            System.out.println("The rectangle area is " + ((Rectangle)object).getArea());
        }
    }
}
The **equals** Method

- The **equals()** method compares the **contents** of two objects - the default implementation of the **equals** method in the Object class is as follows:

  ```java
  public boolean equals(Object obj) {
      return (this == obj);
  }
  ```

- Override the **equals()** method in other classes:

  ```java
  public boolean equals(Object o) {
      if (o instanceof Circle) {
          return radius == ((Circle)o).radius;
      }
      else  return false;
  }
  ```
The **ArrayList** Class

You can create arrays to store objects - but the array’s size is fixed once the array is created. **Java provides the java.util.ArrayList** class that can be used to store an unlimited number of objects:

<table>
<thead>
<tr>
<th>java.util.ArrayList</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ArrayList()</td>
</tr>
<tr>
<td>+add(o: Object) : void</td>
</tr>
<tr>
<td>+add(index: int, o: Object) : void</td>
</tr>
<tr>
<td>+clear(): void</td>
</tr>
<tr>
<td>+contains(o: Object): boolean</td>
</tr>
<tr>
<td>+get(index: int) : Object</td>
</tr>
<tr>
<td>+indexOf(o: Object) : int</td>
</tr>
<tr>
<td>+isEmpty(): boolean</td>
</tr>
<tr>
<td>+lastIndexOf(o: Object) : int</td>
</tr>
<tr>
<td>+remove(o: Object): boolean</td>
</tr>
<tr>
<td>+size(): int</td>
</tr>
<tr>
<td>+remove(index: int) : Object</td>
</tr>
<tr>
<td>+set(index: int, o: Object) : Object</td>
</tr>
</tbody>
</table>
public class TestArrayList {
    public static void main(String[] args) {
        java.util.ArrayList cityList = new java.util.ArrayList();
        cityList.add("London"); cityList.add("New York"); cityList.add("Paris");
        cityList.add("Toronto"); cityList.add("Hong Kong");
        System.out.println("List size? " + cityList.size());
        System.out.println("Is Toronto in the list? " +
            cityList.contains("Toronto");
        System.out.println("The location of New York in the list? " +
            cityList.indexOf("New York");
        System.out.println("Is the list empty? " + cityList.isEmpty()); // false
        cityList.add(2, "Beijing");
        cityList.remove("Toronto");
        for (int i = 0; i < cityList.size(); i++)
            System.out.print(cityList.get(i) + " ");
        System.out.println();
        // Create a list to store two circles
        java.util.ArrayList list = new java.util.ArrayList();
        list.add(new Circle(2));
        list.add(new Circle(3));
        System.out.println(((Circle)(list.get(0))).getArea());
    }
}
public class TestArrayList {
    public static void main(String[] args) { // Generics: eliminates warnings
        java.util.ArrayList<String> cityList = new java.util.ArrayList<String>();
        cityList.add("London");
        cityList.add("New York");
        cityList.add("Paris");
        cityList.add("Toronto");
        cityList.add("Hong Kong");
        System.out.println("List size? " + cityList.size());
        System.out.println("Is Toronto in the list? " +
                cityList.contains("Toronto"));
        System.out.println("The location of New York in the list? " +
                cityList.indexOf("New York"));
        System.out.println("Is the list empty? " + cityList.isEmpty()); // false
        cityList.add(2, "Beijing");
        cityList.remove("Toronto");
        for (int i = 0; i < cityList.size(); i++)
            System.out.print(cityList.get(i) + " ");
        System.out.println();
        // Create a list to store two circles
        java.util.ArrayList<Circle> list = new java.util.ArrayList<Circle>();
        list.add(new Circle(2));
        list.add(new Circle(3));
        System.out.println( list.get(0).getArea() );
    }
}
The protected Modifier

- A protected data or a protected method in a public class can be accessed by any class in the same package or its subclasses, even if the subclasses are in a different package.

Visibility increases:

private, default (if no modifier is used), protected, public
## Accessibility Summary

<table>
<thead>
<tr>
<th>Modifier on members in a class</th>
<th>Accessed from the same class</th>
<th>Accessed from the same package</th>
<th>Accessed from a subclass</th>
<th>Accessed from a different package</th>
</tr>
</thead>
<tbody>
<tr>
<td>public</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>protected</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
</tr>
<tr>
<td>default</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>private</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Visibility Modifiers

```java
class C1 {
  public int x;
  protected int y;
  int z;
  private int u;

  protected void m() {
  }
}

class C2 {
  C1 o = new C1();
  can access o.x;
  can access o.y;
  can access o.z;
  cannot access o.u;

  can invoke o.m();
}

class C3 extends C1 {
  can access x;
  can access y;
  can access z;
  cannot access u;

  can invoke m();
}

class C4 extends C1 {
  can access x;
  can access y;
  cannot access z;
  cannot access u;

  can invoke m();
}

class C5 {
  C1 o = new C1();
  cannot access o.x;
  cannot access o.y;
  cannot access o.z;
  cannot access o.u;

  cannot invoke o.m();
}
```
The **final** Modifier

- A **final** variable is a constant:
  ```java
  final static double PI = 3.14159;
  ```

- A **final** method cannot be overridden by its subclasses

- A **final** class cannot be extended:
  ```java
  final class Math {
    ...
  }
  ```
Exceptions

Exception describes errors caused by your program and external circumstances. These errors can be caught and handled by your program.
Runtime Exceptions

- RuntimeException
- LinkageError
- ClassNotFoundException
- VirtualMachineError
- IOException
- Exception
- ArithmeticException
- NullPointerException
- IndexOutOfBoundsException
- IllegalArgumentException

Object
Throwables

RuntimeException is caused by programming errors, such as bad casting, accessing an out-of-bounds array, and numeric errors.
Checked Exceptions vs. Unchecked Exceptions

`RuntimeException`, `Error` and their subclasses are known as *unchecked exceptions*.

All other exceptions are known as *checked exceptions*, meaning that the compiler forces the programmer to check and deal with the exceptions.
Unchecked Exceptions

- In most cases, unchecked exceptions reflect programming logic errors that are not recoverable.
  - For example, a `NullPointerException` is thrown if you access an object through a reference variable before an object is assigned to it; an `IndexOutOfBoundsException` is thrown if you access an element in an array outside the bounds of the array.
- These are the logic errors that should be corrected in the program.
- Unchecked exceptions can occur anywhere in the program.
- To avoid cumbersome overuse of try-catch blocks, Java does not mandate you to write code to catch unchecked exceptions.
Declaring, Throwing, and Catching Exceptions

```java
method1() {
    try {
        invoke method2;
    } catch (Exception ex) {
        Process exception;
    }
}

method2() throws Exception {
    if (an error occurs) {
        throw new Exception();
    }
}
```

- `catch exception throw exception` 
- `declare exception` 
- `throw exception`
Catch or Declare Checked Exceptions

- Java forces you to deal with **checked exceptions**:
  - If a method declares a checked exception (i.e., an exception other than `Error` or `RuntimeException`), you must invoke it in a `try-catch` block or declare to throw the exception in the calling method
  - For example, suppose that method `p1` invokes method `p2` and `p2` may throw a checked exception (e.g., `IOException`), you have to write the code: (a) or (b):

```java
void p1() {
    try {
        p2();
    }
    catch (IOException ex) {
        ...
    }
}
```

```java
void p1() throws IOException {
    p2();
}
```

(a)                       (b)

(c) Paul Fodor (CS Stony Brook) & Pearson
public class CircleWithException {
  private double radius; /** The radius of the circle */
  private static int numberOfObjects = 0; /** The number of the objects created */

  public CircleWithException() {this(1.0); } /* Construct a circle with radius 1 */
  public CircleWithException(double newRadius) throws IllegalArgumentException {
    setRadius(newRadius);
    numberOfObjects++;
  }
  public double getRadius() { return radius; }
  public void setRadius(double newRadius) throws IllegalArgumentException {
    if (newRadius >= 0)
      radius = newRadius;
    else
      throw new IllegalArgumentException("Radius cannot be negative");
  }

  public static int getNumberOfObjects() {/** Return numberOfObjects */
    return numberOfObjects;
  }

  public double findArea() {/** Return the area of this circle */
    return radius * radius * 3.14159;
  }
}
public static void main(String[] args) {
    try {
        CircleWithException c1 = new CircleWithException(5);
        CircleWithException c2 = new CircleWithException(-5);
        CircleWithException c3 = new CircleWithException(10);
    } catch (IllegalArgumentException ex) {
        System.out.println(ex);
    }
    System.out.println("Number of objects created: "+
                       CircleWithException.getNumberOfObjects());
}

Output:
Radius cannot be negative
Number of objects created: 1
The finally Clause

```java
try {
    statements;
} catch (TheException ex) {
    handling ex;
} finally {
    finalStatements;
}

The finally block always executes when the try block exits
Useful for cleanup code:

```
Custom Exception Class Example

```java
public class InvalidRadiusException extends Exception {
    private double radius;

    /** Construct an exception */
    public InvalidRadiusException(double radius) {
        super("Invalid radius " + radius);
        this.radius = radius;
    }

    /** Return the radius */
    public double getRadius() {
        return radius;
    }
}
```
Text I/O: The **File** Class

- The **File** class is intended to provide an abstraction that deals with most of the machine-dependent complexities of files and path names in a machine-independent fashion.
  - The filename is a string
  - The **File** class is a wrapper class for the filename and its directory path
## Obtaining file properties and manipulating files

<table>
<thead>
<tr>
<th>java.io.File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+File(pathname: String)</td>
<td>Creates a File object for the specified pathname. The pathname may be a directory or a file.</td>
</tr>
<tr>
<td>+File(parent: String, child: String)</td>
<td>Creates a File object for the child under the directory parent. child may be a filename or a subdirectory.</td>
</tr>
<tr>
<td>+File(parent: File, child: String)</td>
<td>Creates a File object for the child under the directory parent. parent is a File object. In the preceding constructor, the parent is a string.</td>
</tr>
<tr>
<td>+exists(): boolean</td>
<td>Returns true if the file or the directory represented by the File object exists.</td>
</tr>
<tr>
<td>+canRead(): boolean</td>
<td>Returns true if the file represented by the File object exists and can be read.</td>
</tr>
<tr>
<td>+canWrite(): boolean</td>
<td>Returns true if the file represented by the File object exists and can be written.</td>
</tr>
<tr>
<td>+isDirectory(): boolean</td>
<td>Returns true if the File object represents a directory.</td>
</tr>
<tr>
<td>+isFile(): boolean</td>
<td>Returns true if the File object represents a file.</td>
</tr>
<tr>
<td>+isAbsolute(): boolean</td>
<td>Returns true if the File object is created using an absolute path name.</td>
</tr>
<tr>
<td>+isHidden(): boolean</td>
<td>Returns true if the file represented in the File object is hidden. The exact definition of hidden is system-dependent. On Windows, you can mark a file hidden in the File Properties dialog box. On Unix systems, a file is hidden if its name begins with a period character '.'.</td>
</tr>
<tr>
<td>+getAbsolutePath(): String</td>
<td>Returns the complete absolute file or directory name represented by the File object.</td>
</tr>
<tr>
<td>+getCanonicalPath(): String</td>
<td>Returns the same as getAbsolutePath() except that it removes redundant names, such as &quot;.&quot; and &quot;..&quot;, from the pathname, resolves symbolic links (on Unix platforms), and converts drive letters to standard uppercase (on Win32 platforms).</td>
</tr>
<tr>
<td>+getName(): String</td>
<td>Returns the last name of the complete directory and file name represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getName() returns test.dat.</td>
</tr>
<tr>
<td>+getPath(): String</td>
<td>Returns the complete directory and file name represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getPath() returns c:\book\test.dat.</td>
</tr>
<tr>
<td>+getParent(): String</td>
<td>Returns the complete parent directory of the current directory or the file represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getParent() returns c:\book.</td>
</tr>
<tr>
<td>+lastModified(): long</td>
<td>Returns the time that the file was last modified.</td>
</tr>
<tr>
<td>+delete(): boolean</td>
<td>Deletes this file. The method returns true if the deletion succeeds.</td>
</tr>
<tr>
<td>+renameTo(dest: File): boolean</td>
<td>Renames this file. The method returns true if the operation succeeds.</td>
</tr>
</tbody>
</table>
Text I/O

- A **File** object encapsulates the properties of a file or a path, but *does not contain the methods for reading/writing data* from/to a file.

- In order to perform I/O, you need to create objects using appropriate Java I/O classes: **Scanner** and **PrintWriter**
## Reading Data Using **Scanner**

<table>
<thead>
<tr>
<th>java.util.Scanner</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Scanner(source: File)</td>
</tr>
<tr>
<td>+Scanner(source: String)</td>
</tr>
<tr>
<td>+close()</td>
</tr>
<tr>
<td>+hasNext(): boolean</td>
</tr>
<tr>
<td>+next(): String</td>
</tr>
<tr>
<td>+nextByte(): byte</td>
</tr>
<tr>
<td>+nextShort(): short</td>
</tr>
<tr>
<td>+nextInt(): int</td>
</tr>
<tr>
<td>+nextLong(): long</td>
</tr>
<tr>
<td>+nextFloat(): float</td>
</tr>
<tr>
<td>+nextDouble(): double</td>
</tr>
<tr>
<td>+useDelimiter(pattern: String): Scanner</td>
</tr>
</tbody>
</table>

**java.util.Scanner**

Creates a Scanner that produces values scanned from the specified file.

Creates a Scanner that produces values scanned from the specified string.

Closes this scanner.

Returns true if this scanner has another token in its input.

Returns next token as a string.

Returns next token as a byte.

Returns next token as a short.

Returns next token as an int.

Returns next token as a long.

Returns next token as a float.

Returns next token as a double.

Sets this scanner’s delimiting pattern.
import java.util.Scanner;

public class ReadData {
    public static void main(String[] args) throws Exception {
        // Create a File instance
        java.io.File file = new java.io.File("scores.txt");
        // Create a Scanner for the file
        Scanner input = new Scanner(file);
        // Read data from a file
        while (input.hasNext()) {
            String firstName = input.next();
            int score = input.nextInt();
            System.out.println(firstName + " " + score);
        }
        // Close the file
        input.close();
    }
}
### Writing Data Using PrintWriter

<table>
<thead>
<tr>
<th>java.io.PrintWriter</th>
<th>Creates a PrintWriter for the specified file.</th>
</tr>
</thead>
<tbody>
<tr>
<td>+PrintWriter(file: File)</td>
<td>Writes a string.</td>
</tr>
<tr>
<td>+print(s: String): void</td>
<td>Writes a character.</td>
</tr>
<tr>
<td>+print(c: char): void</td>
<td>Writes an array of character.</td>
</tr>
<tr>
<td>+print(cArray: char[]): void</td>
<td>Writes an int value.</td>
</tr>
<tr>
<td>+print(i: int): void</td>
<td>Writes a long value.</td>
</tr>
<tr>
<td>+print(l: long): void</td>
<td>Writes a float value.</td>
</tr>
<tr>
<td>+print(f: float): void</td>
<td>Writes a double value.</td>
</tr>
<tr>
<td>+print(d: double): void</td>
<td>Writes a boolean value.</td>
</tr>
<tr>
<td>+print(b: boolean): void</td>
<td>A println method acts like a print method; additionally it prints a line separator. The line separator string is defined by the system. It is \r\n on Windows and \n on Unix.</td>
</tr>
<tr>
<td>Also contains the overloaded println methods.</td>
<td>The printf method was introduced in §3.6, “Formatting Console Output and Strings.”</td>
</tr>
<tr>
<td>Also contains the overloaded printf methods.</td>
<td></td>
</tr>
</tbody>
</table>
public class WriteData {
    public static void main(String[] args)
        throws Exception {
        java.io.File file = new java.io.File("scores.txt");
        if (file.exists()) {
            System.out.println("File already exists");
            System.exit(0);
        }
        // Create the file
        java.io.PrintWriter output = new
        java.io.PrintWriter(file);
        // Write output to the file
        output.print("John T Smith ");
        // Close the file
        output.close();
    }
}
Abstract Classes and Abstract Methods

Abstract classes are italicized or have the annotation `<abstract>`. The # sign indicates protected modifier. Abstract methods are italicized or have the annotation `<abstract>`. Methods `getArea` and `getPerimeter` are overridden in `Circle` and `Rectangle`. Superclass abstract methods are generally omitted in the UML diagram for subclasses.
public abstract class GeometricObject {
    private String color = "white";
    private boolean filled;
    private java.util.Date dateCreated;
    protected GeometricObject() {
        dateCreated = new java.util.Date();
    }
    protected GeometricObject(String color, boolean filled) {
        dateCreated = new java.util.Date();
        this.color = color;
        this.filled = filled;
    }
    public String getColor() { return color; }
    public void setColor(String color) { this.color = color; }
    public boolean isFilled() { return filled; }
    public void setFilled(boolean filled) { this.filled = filled; }
    public java.util.Date getDateCreated() { return dateCreated; }
    public String toString() {
        return "created on " + dateCreated + 
          "
color: " + color + 
          " and filled: " + filled;
    }
    /** Abstract method getArea */
    public abstract double getArea();
    /** Abstract method getPerimeter */
    public abstract double getPerimeter();
}
public class Circle extends GeometricObject {
    private double radius;
    public Circle() {
    }
    public Circle(double radius) {
        this.radius = radius;
    }
    public double getRadius() {
        return radius;
    }
    public void setRadius(double radius) {
        this.radius = radius;
    }
    public double getArea() {
        return radius * radius * Math.PI;
    }
    public double getDiameter() {
        return 2 * radius;
    }
    public double getPerimeter() {
        return 2 * radius * Math.PI;
    }
    /* Print the circle info */
    public void printCircle() {
        System.out.println("The circle is created " + getDateCreated() + ", and the radius is " + radius);
    }
}
public class Rectangle extends GeometricObject {
    private double width;
    private double height;
    public Rectangle() {
    }
    public Rectangle(double width, double height) {
        this.width = width;
        this.height = height;
    }
    public double getWidth() {
        return width;
    }
    public void setWidth(double width) {
        this.width = width;
    }
    public double getHeight() {
        return height;
    }
    public void setHeight(double height) {
        this.height = height;
    }
    public double getArea() {
        return width * height;
    }
    public double getPerimeter() {
        return 2 * (width + height);
    }
}
public class TestGeometricObject {
    public static void main(String[] args) {
        // Declare and initialize two geometric objects
        GeometricObject geoObject1 = new Circle(5);
        GeometricObject geoObject2 = new Rectangle(5, 3);
        System.out.println("The two objects have the same area? " +
            equalArea(geoObject1, geoObject2));
        // Display circle
        displayGeometricObject(geoObject1);
        // Display rectangle
        displayGeometricObject(geoObject2);
    }

    /** A method for comparing the areas of two geometric objects */
    public static boolean equalArea(GeometricObject object1,
            GeometricObject object2) {
        return object1.getArea() == object2.getArea();
    }

    /** A method for displaying a geometric object */
    public static void displayGeometricObject(GeometricObject object) {
        System.out.println();
        System.out.println("The area is " + object.getArea());
        System.out.println("The perimeter is " + object.getPerimeter());
    }
}
**abstract method in abstract class**

- An abstract method cannot be contained in a nonabstract class.
- In a nonabstract subclass extended from an abstract class, all the abstract methods must be implemented, even if they are not used in the subclass.
- If a subclass of an abstract superclass does not implement all the abstract methods, the subclass must be defined abstract.
abstract classes

• An object cannot be created from abstract class
• An abstract class cannot be instantiated using the `new` operator
• We can still define its constructors, which are invoked in the constructors of its subclasses.
  • For instance, the constructors of `GeometricObject` are invoked in the `Circle` class and the `Rectangle` class.
abstract classes

• A class that contains abstract methods must be abstract
• An abstract class without abstract method:
  • It is possible to define an abstract class that contains no abstract methods.
  • We cannot create instances of the class using the new operator.
• This class is used as a base class for defining new subclasses
abstract classes

• A subclass can be abstract even if its superclass is concrete.
• For example, the Object class is concrete, but a subclass, GeometricObject, is abstract
abstract classes

- A subclass can override a method from its superclass to define it **abstract**
- rare, but useful when the implementation of the method in the superclass becomes invalid in the subclass.
- the subclass must be defined **abstract**
abstract classes as types

- You cannot create an instance from an abstract class using the `new` operator, but an abstract class can be used as a data type:

  ```java
  GeometricObject c = new Circle(2);
  ```

- The following statement, which creates an array whose elements are of `GeometricObject` type, is correct:

  ```java
  GeometricObject[] geo=new GeometricObject[10];
  ```

- There are only `null` elements in the array!!!
The abstract Calendar class and its GregorianCalendar subclass

• An instance of `java.util.Date` represents a specific instant in time with millisecond precision

• `java.util.Calendar` is an abstract base class for extracting detailed information such as year, month, date, hour, minute and second from a `Date` object for a specific calendar

  • Subclasses of `Calendar` can implement specific calendar systems such as Gregorian calendar, Lunar Calendar and Jewish calendar.

    • `java.util.GregorianCalendar` is for the Gregorian calendar
The GregorianCalendar Class

- Java API for the GregorianCalendar class: http://docs.oracle.com/javase/8/docs/api/java/util/GregorianCalendar.html

  - `new GregorianCalendar()` constructs a default GregorianCalendar with the current time
  - `new GregorianCalendar(year, month, date)` constructs a GregorianCalendar with the specified year, month, and date
    - The month parameter is 0-based, i.e., 0 is for January.
The abstract Calendar class and its GregorianCalendar subclass

###java.util.Calendar

- `#Calendar()`: Constructs a default calendar.
- `+get(field: int): int`:
  - Returns the value of the given calendar field.
- `+set(field: int, value: int): void`:
  - Sets the given calendar to the specified value.
- `+set(year: int, month: int, dayOfMonth: int): void`:
  - Sets the calendar with the specified year, month, and date. The month parameter is 0-based, that is, 0 is for January.
- `+getActualMaximum(field: int): int`:
  - Returns the maximum value that the specified calendar field could have.
- `+add(field: int, amount: int): void`:
  - Adds or subtracts the specified amount of time to the given calendar field.
- `+getTime(): java.util.Date`:
  - Returns a Date object representing this calendar’s time value (million second offset from the Unix epoch).
- `+setTime(date: java.util.Date): void`:
  - Sets this calendar’s time with the given Date object.

###java.util.GregorianCalendar

- `+GregorianCalendar()`: Constructs a GregorianCalendar for the current time.
- `+GregorianCalendar(year: int, month: int, dayOfMonth: int)`: Constructs a GregorianCalendar for the specified year, month, and day of month.
- `+GregorianCalendar(year: int, month: int, dayOfMonth: int, hour: int, minute: int, second: int)`: Constructs a GregorianCalendar for the specified year, month, day of month, hour, minute, and second. The month parameter is 0-based, that is, 0 is for January.
The get Method in Calendar Class

- The `get(int field)` method defined in the `Calendar` class is useful to extract the date and time information from a `Calendar` object.
- The fields are defined as constants, as shown in the following.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR</td>
<td>The year of the calendar.</td>
</tr>
<tr>
<td>MONTH</td>
<td>The month of the calendar with 0 for January.</td>
</tr>
<tr>
<td>DATE</td>
<td>The day of the calendar.</td>
</tr>
<tr>
<td>HOUR</td>
<td>The hour of the calendar (12-hour notation).</td>
</tr>
<tr>
<td>HOUR_OF_DAY</td>
<td>The hour of the calendar (24-hour notation).</td>
</tr>
<tr>
<td>MINUTE</td>
<td>The minute of the calendar.</td>
</tr>
<tr>
<td>SECOND</td>
<td>The second of the calendar.</td>
</tr>
<tr>
<td>DAY_OF_WEEK</td>
<td>The day number within the week with 1 for Sunday.</td>
</tr>
<tr>
<td>DAY_OF_MONTH</td>
<td>Same as DATE.</td>
</tr>
<tr>
<td>DAY_OF_YEAR</td>
<td>The day number in the year with 1 for the first day of the year.</td>
</tr>
<tr>
<td>WEEK_OF_MONTH</td>
<td>The week number within the month.</td>
</tr>
<tr>
<td>WEEK_OF_YEAR</td>
<td>The week number within the year.</td>
</tr>
<tr>
<td>AM_PM</td>
<td>Indicator for AM or PM (0 for AM and 1 for PM).</td>
</tr>
</tbody>
</table>
import java.util.*;
public class TestCalendar {
    public static void main(String[] args) {
        // Construct a Gregorian calendar for the current date and time
        Calendar calendar = new GregorianCalendar();
        System.out.println("Current time is " + new Date());
        System.out.println("YEAR:	" + calendar.get(Calendar.YEAR));
        System.out.println("MONTH:	" + calendar.get(Calendar.MONTH));
        System.out.println("DATE:	" + calendar.get(Calendar.DATE));
        System.out.println("HOUR:	" + calendar.get(Calendar.HOUR));
        System.out.println("HOUR_OF_DAY:	" + calendar.get(Calendar.HOUR_OF_DAY));
        System.out.println("MINUTE:	" + calendar.get(Calendar.MINUTE));
        System.out.println("SECOND:	" + calendar.get(Calendar.SECOND));
        System.out.println("DAY_OF_WEEK:	" + calendar.get(Calendar.DAY_OF_WEEK));
        System.out.println("DAY_OF_MONTH:	" + calendar.get(Calendar.DAY_OF_MONTH));
        System.out.println("DAY_OF_YEAR: 	" + calendar.get(Calendar.DAY_OF_YEAR));
        System.out.println("WEEK_OF_MONTH: 	" + calendar.get(Calendar.WEEK_OF_MONTH));
        System.out.println("WEEK_OF_YEAR: 	" + calendar.get(Calendar.WEEK_OF_YEAR));
        System.out.println("AM_PM: 	" + calendar.get(Calendar.AM_PM));
        // Construct a calendar for January 1, 2020
        Calendar calendar1 = new GregorianCalendar(2020, 0, 1);
        System.out.println("January 1, 2020 is a " +
                           dayNameOfWeek(calendar1.get(Calendar.DAY_OF_WEEK)) );
    }
    public static String dayNameOfWeek(int dayOfWeek) {
        switch (dayOfWeek) {
            case 1: return "Sunday"; case 2: return "Monday"; case 3: return "Tuesday";
            ... case 7: return "Saturday";
            default: return null;
        }
    }
}
Interfaces

• What is an interface?
  • An interface is a class-like construct that contains only constants and abstract methods.

• Why is an interface useful?
  • An interface is similar to an abstract class, but the intent of an interface is to specify behavior for objects.
    • For example: specify that the objects are comparable, edible, cloneable, …
  • Allows multiple inheritance.
Define an Interface

- Declaration:

```java
public interface InterfaceName {
    // constant declarations;
    // method signatures;
}
```

- Example:

```java
public interface Edible {
    /** Describe how to eat */
    public abstract String howToEat();
}
```
An interface is treated like a special class in Java:

- Each interface is compiled into a separate bytecode file, just like a regular class.
- Like an abstract class, you cannot create an instance from an interface using the `new` operator.

Uses:
- as a data type for a variable
- as the result of casting
Interface Example

- The `Edible` interface specifies whether an object is edible:

  ```java
  public interface Edible {
      public abstract String howToEat();
  }
  ```

- The class `Chicken` implements the `Edible` interface:

  ```java
  class Chicken extends Animal implements Edible {
      public String howToEat() {
          return "Chicken: Fry it";
      }
  }
  ```
interface Edible {
    public abstract String howToEat(); /** Describe how to eat */
}
class Animal { }

class Chicken extends Animal implements Edible {
    public String howToEat() {
        return "Chicken: Fry it";
    }
}

class Tiger extends Animal { /** Does not implement Edible */
}

abstract class Fruit implements Edible { }

class Apple extends Fruit {
    public String howToEat() {
        return "Apple: Make apple cider";
    }
}

class Orange extends Fruit {
    public String howToEat() {
        return "Orange: Make orange juice";
    }
}

public class TestEdible {
    public static void main(String[] args) {
        Object[] objects = {new Tiger(), new Chicken(), new Apple()};
        for (int i = 0; i < objects.length; i++)
            if (objects[i] instanceof Edible)
                System.out.println(((Edible)objects[i]).howToEat());
    }
}
Omitting Modifiers in Interfaces

- All data fields are `public static final` in an interface
- All methods are `public abstract` in an interface
- These modifiers can be omitted:

```java
public interface T1 {
  public static final int K = 1;
  public abstract void p();
}
```

Equivalent
```java
public interface T1 {
  int K = 1;
  void p();
}
```

- A constant defined in an interface can be accessed using `InterfaceName.CONSTANT_NAME`, for example: `T1.K`
Example: The **Comparable** Interface

```java
// This interface is defined in
// the java.lang package

package java.lang;
public interface Comparable {
    int compareTo(Object o);
}
```
String and Date Classes

- Many classes (e.g., String and Date) in the Java library implement Comparable to define a natural order for the objects

```java
public class String extends Object implements Comparable {
    // class body omitted
}

public class Date extends Object implements Comparable {
    // class body omitted
}
```

```java
new String() instanceof String       true
new String() instanceof Comparable  true
new java.util.Date() instanceof java.util.Date true
new java.util.Date() instanceof Comparable true
```
In UML, the interface and the methods are italicized.

Dashed lines and triangles are used to point to the interface.
The return value from the max method is of the Comparable type. So, we need to cast it to String or Date explicitly.
Defining Classes to Implement Comparable

- We cannot use the `max` method to find the larger of two instances of `Rectangle`, because `Rectangle` does not implement `Comparable`.
- We can define a new rectangle class `ComparableRectangle` that implements `Comparable`: the instances of this new class are comparable.

```
GeometricObject
  ↓
Rectangle
  ↓
ComparableRectangle
```

```
«interface»
java.lang.Comparable

+compareTo(o: Object): int
```
public class ComparableRectangle extends Rectangle
    implements Comparable {
    /** Construct a ComparableRectangle with specified properties */
    public ComparableRectangle(double width, double height) {
        super(width, height);
    }

    /** Implement the compareTo method defined in Comparable */
    public int compareTo(Object o) {
        if (getArea() > ((ComparableRectangle)o).getArea())
            return 1;
        else if (getArea() < ((ComparableRectangle)o).getArea())
            return -1;
        else
            return 0;
    }

    public static void main(String[] args) {
        ComparableRectangle rectangle1 = new ComparableRectangle(4, 5);
        ComparableRectangle rectangle2 = new ComparableRectangle(3, 6);
        System.out.println(Max.max(rectangle1, rectangle2));
    }
}
The Cloneable Interface

• Marker Interface: an empty interface
• Does not contain constants or methods
• It is used to denote that a class possesses certain desirable properties
• A class that implements the Cloneable interface is marked cloneable: its objects can be cloned using the clone() method defined in the Object class

```java
package java.lang;
public interface Cloneable {
}
```
The Cloneable Interface

- Calendar (in the Java library) implements Cloneable:

```java
Calendar calendar = new GregorianCalendar(2020, 1, 1);
Calendar calendarCopy = (Calendar)(calendar.clone());
System.out.println("calendar == calendarCopy is " + (calendar == calendarCopy));
```

Displays:

```
calendar == calendarCopy is false
```

```java
System.out.println("calendar.equals(calendarCopy) is " + calendar.equals(calendarCopy));
```

Displays:

```
calendar.equals(calendarCopy) is true
```
Implementing the **Cloneable** Interface

- If we try to create a clone of an object instance of a class that does not implement the **Cloneable** interface, it throws **CloneNotSupportedException**
- We can override the `clone()` method from the **Object** class to create custom clones
  - The `clone` method in the **Object** class creates a new instance of the class of this object and initializes all its fields with exactly the contents of the corresponding fields of this object, as if by assignment; the contents of the fields are not themselves cloned.
  - The `clone()` method returns an **Object** that needs to be casted
public class House implements Cloneable, Comparable {
    private int id;
    private double area;
    private java.util.Date whenBuilt;
    public House(int id, double area) {this.id = id; this.area = area;
        whenBuilt = new java.util.Date();
    }
    public double getId() { return id;}
    public double getArea() { return area;}
    public java.util.Date getWhenBuilt() { return whenBuilt;}
    /** Override the protected clone method defined in the Object
     * class, and strengthen its accessibility */
    public Object clone() {
        try {
            return super.clone();
        } catch (CloneNotSupportedException ex) {
            return null;
        }
    }
    /** Implement the compareTo method defined in Comparable */
    public int compareTo(Object o) {
        if (area > ((House)o).area)
            return 1;
        else if (area < ((House)o).area)
            return -1;
        else
            return 0;
    }
}
Shallow vs. Deep Copy

- House house1 = new House(1, 1750.50);

- House house2 = (House)(house1.clone());

shallow copy: if the field is of reference type, the object’s reference is copied rather than its content
For deep copying, we can override the clone method with custom object creation

```java
public class House implements Cloneable {
    ...

    public Object clone() { // deep copy
        try {
            House h = (House)(super.clone());
            h.whenBuilt = (Date)(whenBuilt.clone());
            return h;
        } catch (CloneNotSupportedException ex) {
            return null;
        }
    }

    ...
}
```
## Interfaces vs. Abstract Classes

- In an interface, the data must be constants; an abstract class can have all types of data
- Each method in an interface has only a signature without implementation; an abstract class can have concrete methods

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constructors</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract class</td>
<td>No restrictions</td>
<td>Constructors are invoked by subclasses through constructor chaining. An abstract class cannot be instantiated using the new operator.</td>
</tr>
<tr>
<td>Interface</td>
<td>All variables must be <code>public static final</code></td>
<td>No constructors. An interface cannot be instantiated using the new operator.</td>
</tr>
</tbody>
</table>
Interfaces vs. Abstract Classes

- A class can implement any number of interfaces
- An interface can extend another interface
- There is no root for interfaces
Caution: conflicting interfaces

- Errors detected by the compiler:
  - If a class implements two interfaces with conflict information:
    - two same constants with different values, or
    - two methods with same signature but different return type
Whether to use an interface or a class?

- **Strong is-a**: a relationship that clearly describes a parent-child relationship - *should be modeled using classes and class inheritance*
  - For example: a staff member is a person

- **Weak is-a (is-kind-of)**: indicates that an object possesses a certain property - *should be modeled using interfaces*
  - For example: all strings are comparable, so the String class implements the Comparable interface

- You can also use interfaces to circumvent single inheritance restriction if multiple inheritance is desired
Wrapper Classes

- Primitive data types in Java ➔ Better performance
- Each primitive has a wrapper class: Boolean, Character, Short, Byte, Integer, Long, Float, Double
  - The wrapper classes do not have no-arg constructors
  - The instances of all wrapper classes are immutable: their internal values cannot be changed once the objects are created
Each wrapper class overrides the `toString`, `equals`, and `hashCode` methods defined in the `Object` class.

Since these classes implement the `Comparable` interface, the `compareTo` method is implemented in these classes.
The **Number Class**

- Each numeric wrapper class extends the abstract Number class:
  - The abstract Number class contains the methods `doubleValue`, `floatValue`, `intValue`, `longValue`, `shortValue`, and `byteValue` to “convert” objects into primitive type values
  - The methods `doubleValue`, `floatValue`, `intValue`, `longValue` are **abstract**
  - The methods `byteValue` and `shortValue` are not abstract, which simply return `(byte)intValue()` and `(short)intValue()`, respectively
  - Each numeric wrapper class implements the abstract methods `doubleValue`, `floatValue`, `intValue` and `longValue`
The **Integer** and **Double** Classes

```java
java.lang.Number
+byteValue(): byte
+shortValue(): short
+intValue(): int
+longValue(): long
+floatValue(): float
+doubleValue(): double

java.lang.Comparable
+compareTo(o: Object): int

java.lang.Integer
-value: int
+MAX_VALUE: int
+MIN_VALUE: int
+Integer(value: int)
+Integer(s: String)
+valueOf(s: String): Integer
+valueOf(s: String, radix: int): Integer
+parseInt(s: String): int
+parseInt(s: String, radix: int): int

java.lang.Double
-value: double
+MAX_VALUE: double
+MIN_VALUE: double
+Double(value: double)
+Double(s: String)
+valueOf(s: String): Double
+valueOf(s: String, radix: int): Double
+parseDouble(s: String): double
+parseDouble(s: String, radix: int): double
```
Wrapper Classes

• You can construct a wrapper object either from a primitive data type value or from a string representing the numeric value.

• The constructors for Integer and Double are:

    public Integer(int value)
    public Integer(String s)
    public Double(double value)
    public Double(String s)
Numeric Wrapper Class Constants

- Each numerical wrapper class has the constants `MAX VALUE` and `MIN VALUE`:
  - `MAX VALUE` represents the maximum value of the corresponding primitive data type
  - For `Float` and `Double`, `MIN VALUE` represents the minimum positive float and double values
  - The maximum integer: 2,147,483,647
  - The minimum positive float: 1.4E-45
  - The maximum double floating-point number: 1.79769313486231570e+308d
The Static `valueOf` Methods

- The numeric wrapper classes have a static method `valueOf(String s)` to create a new object initialized to the value represented by the specified string:

```java
Double doubleObject = Double.valueOf("12.4");
Integer integerObject = Integer.valueOf("12");
```

- Each numeric wrapper class has overloaded parsing methods to parse a numeric string into an appropriate numeric value:

```java
double d = Double.parseDouble("12.4");
int i = Integer.parseInt("12");
```
public class GenericSort {
    public static void main(String[] args) {
        Integer[] intArray={new Integer(2),new Integer(4),new Integer(3)};
        sort(intArray);
        printList(intArray);
    }
    public static void sort(Object[] list) {
        Object currentMax;
        int currentMaxIndex;
        for (int i = list.length - 1; i >= 1; i--) {
            currentMax = list[i];
            currentMaxIndex = i; // Find the maximum in the list[0..i]
            for (int j = i - 1; j >= 0; j--) {
                if (((Comparable)currentMax).compareTo(list[j]) < 0) {
                    currentMax = list[j];
                    currentMaxIndex = j;
                }
            }
            list[currentMaxIndex] = list[i];
            list[i] = currentMax;
        }
    }
    public static void printList(Object[] list) {
        for (int i=0;i<list.length;i++) System.out.print(list[i]+" ");
    }
}

The objects are instances of the Comparable interface and they are compared using the compareTo method.
Java provides a static `sort` method for sorting an array of `Object` in the `java.util.Arrays` class:

```java
java.util.Arrays.sort(intArray);
```
Arrays of Objects

- Arrays are objects:
  - An array is an instance of the `Object` class
  - If A is a subclass of B, every instance of A[] is an instance of B[]

```java
new int[10] instanceof Object  true
new GregorianCalendar[10] instanceof Calendar[]; true
new Calendar[10] instanceof Object[] true
new Calendar[10] instanceof Object true
```

- Although an int value can be assigned to a double type variable, int[] and double[] are two incompatible types:
  - We cannot assign an int[] array to a variable of double[] array
Wrapper Classes

- Automatic Conversion Between Primitive Types and Wrapper Class Types:
  - JDK 1.5 allows primitive type and wrapper classes to be converted automatically = boxing

```java
Integer[] intArray = {new Integer(2),
  new Integer(4),
  new Integer(3)};
```

(a) Equivalent

```java
Integer[] intArray = {2, 4, 3};
```

(b) New JDK 1.5 boxing

```java
Integer[] intArray = {1, 2, 3};
System.out.println(intArray[0] + intArray[1] + intArray[2]);
```

Unboxing
BigInteger and BigDecimal

- **BigInteger** and **BigDecimal** classes in the java.math package:
  - For computing with very large integers or high precision floating-point values
    - **BigInteger** can represent an integer of any size
    - **BigDecimal** has no limit for the precision (as long as it’s finite=terminates)
  - Both are **immutable**
  - Both extend the **Number** class and implement the **Comparable** interface.
BigInteger and BigDecimal

```
BigInteger a = new BigInteger("9223372036854775807");
BigInteger b = new BigInteger("2");
BigInteger c = a.multiply(b); // 9223372036854775807 * 2
System.out.println(c);
18446744073709551614

BigDecimal a = new BigDecimal(1.0);
BigDecimal b = new BigDecimal(3);
BigDecimal c = a.divide(b, 20, BigDecimal.ROUND_UP);
System.out.println(c);
0.33333333333333333334
```
import java.math.*;

public class LargeFactorial {
    public static void main(String[] args) {
        System.out.println("50! is \n" + factorial(50));
    }

    public static BigInteger factorial(long n) {
        BigInteger result = BigInteger.ONE;
        for (int i = 1; i <= n; i++)
            result = result.multiply(new BigInteger(i+""));
        return result;
    }
}

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