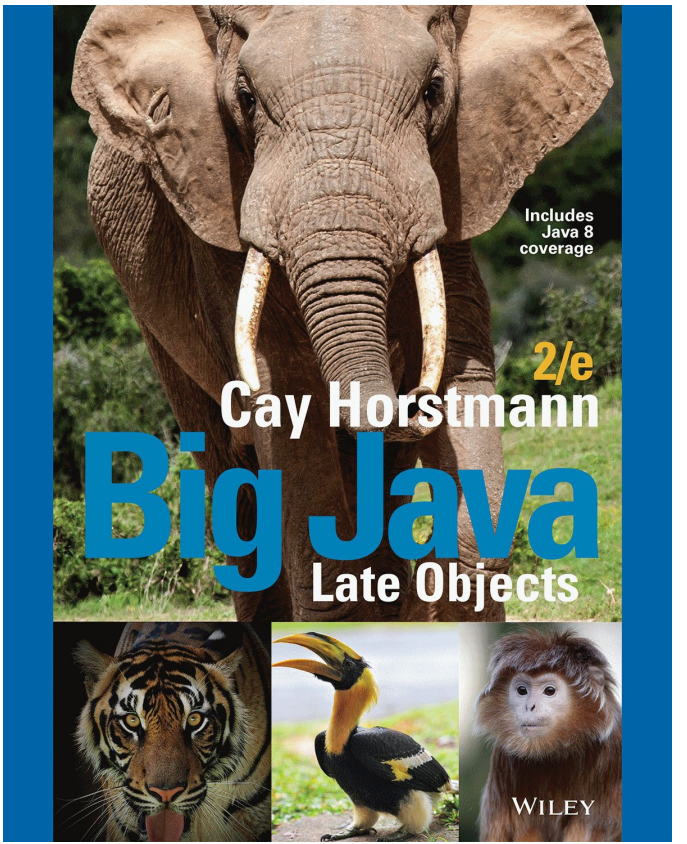
Chapter 8 – Objects and Classes



Chapter Goals

- To understand the concepts of classes, objects and encapsulation
- To implement instance variables, methods and constructors
- To be able to design, implement, and test your own classes
- To understand the behavior of object references, static variables and static methods

Object-Oriented Programming

- You have learned structured programming
  - Breaking tasks into subtasks
  - Writing re-usable methods to handle tasks
- We will now study Objects and Classes
  - To build larger and more complex programs
  - To model objects we use in the world

A class describes objects with the same behavior. For example, a Car class describes all passenger vehicles that have a certain capacity and shape.

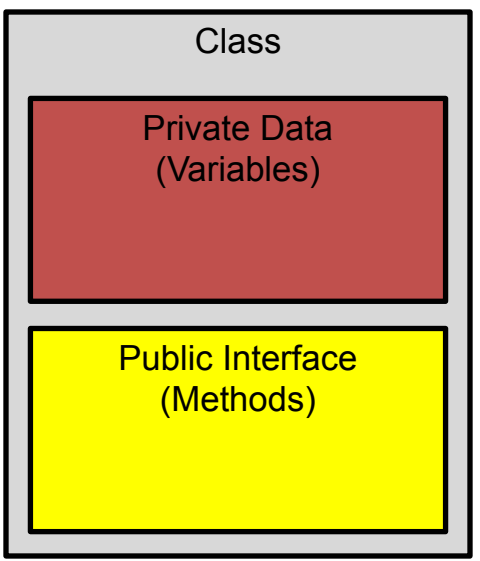
Objects and Programs

- Java programs are made of objects that interact with each other
  - Each object is based on a class
  - A class describes a set of objects with the same behavior
- Each class defines a specific set of methods to use with its objects
  - For example, the `String` class provides methods:
    - Examples: `length()` and `charAt()` methods

```
String greeting = "Hello World";
int len = greeting.length();
char c1 = greeting.charAt(0);
```

Diagram of a Class

- Private Data
  - Each object has its own private data that other objects cannot directly access
  - Methods of the public interface provide access to private data, while hiding implementation details:
  - This is called Encapsulation
- Public Interface
  - Each object has a set of methods available for other objects to use



Self Check 8.1

Is the method call `"Hello, World".println()` legal? Why or why not?

Answer: No—the object `"Hello, World"` belongs to the `String` class, and the `String` class has no `println` method.

Self Check 8.2

When using a `String` object, you do not know how it stores its characters. How can you access them?

Answer: Through the `substring` and `charAt` methods.

Self Check 8.3

Describe a way in which a `String` object might store its characters.

Answer: As an `ArrayList<Character>`. As a `char` array.

Self Check 8.4

Suppose the providers of your Java compiler decide to change the way that a `String` object stores its characters, and they update the `String` method implementations accordingly. Which parts of your code do you need to change when you get the new compiler?

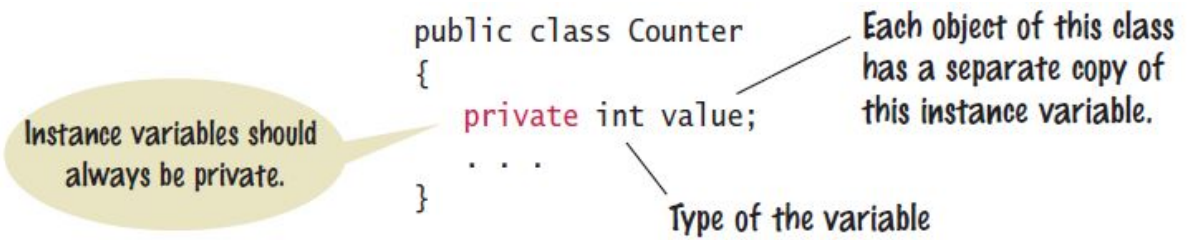
Answer: None. The methods will have the same effect, and your code could not have manipulated `String` objects in any other way.

Implementing a Simple Class

- Example: Tally Counter: A class that models a mechanical device that is used to count people
  - For example, to find out how many people attend a concert or board a bus
- What should it do?
  - Increment the tally
  - Get the current total

Tally Counter Class

- Specify instance variables in the class declaration:



- Each object instantiated from the class has its own set of instance variables
  - Each tally counter has its own current `count`
- Access Specifiers:
  - Classes (and interface methods) are `public`
  - Instance variables are always `private`

Instantiating Objects

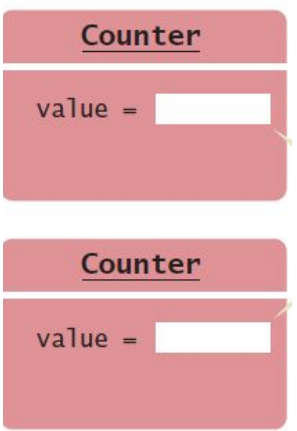
- Objects are created based on classes
  - Use the `new` operator to construct objects
  - Give each object a unique name (like variables)
- You have used the `new` operator before:

```
Scanner in = new Scanner(System.in);
```

- Creating two instances of `Counter` objects:

Class name Object name Class name

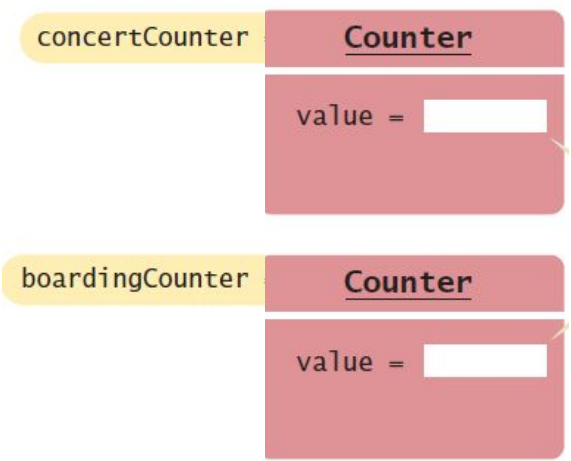
```
Counter concertCounter  = new Counter();
Counter boardingCounter = new Counter();
```



Use the `new` operator to construct objects of a class.

Tally Counter Methods

- Design a method named `count` that adds 1 to the instance variable
- Which instance variable?
  - Use the name of the object
    - `concertCounter.count()`
    - `boardingCounter.count()`




```
public class Counter
{
   private int value;

   public void count()
   {
     value = value + 1;
   }

   public int getValue()
   {
     return value;
   }
}
```

Self Check 8.5

Supply the body of a method `public void reset()` that resets the counter back to zero.

Answer:

```
public void reset()
{
   value = 0;
}
```

Self Check 8.6

Consider a change to the implementation of the counter. Instead of using an integer counter, we use a string of `|` characters to keep track of the clicks, just like a human might do.

```
public class Counter
{
   private String strokes = "";
   public void count()
   {
      strokes = strokes + "|";
   }
   . . .
}
```

How do you implement the `getValue` method with this data representation?

Answer:

```
public int getValue()
{
   return strokes.length();
}
```

Self Check 8.7

Suppose another programmer has used the original `Counter` class. What changes does that programmer have to make in order to use the modified class?

Answer: None—the public interface has not changed.

Self Check 8.8

Suppose you use a class `Clock` with private instance variables `hours` and `minutes`. How can you access these variables in your program?

Answer: You cannot access the instance variables directly. You must use the methods provided by the `Clock` class.

Public Interface of a Class

- When you design a class, start by specifying the public interface of the new class
  - Example: A Cash Register Class
    - What tasks will this class perform?
    - What methods will you need?
    - What parameters will the methods need to receive?
    - What will the methods return?

Task	Method	Returns
Add the price of an item	`addItem(double)`	void
Get the total amount owed	`getTotal()`	double
Get the count of items purchased	`getCount()`	int
Clear the cash register for a new sale	`clear()`	void

Writing the Public Interface

```
/**
   A simulated cash register that tracks the item count
   and the total amount due.
*/
public class CashRegister
{
   /**
      Adds an item to this cash register.
      @param price: the price of this item
   */
   public void addItem(double price)
   {
      // Method body
   }
   /**
      Gets the price of all items in the current sale.
      @return the total price
   */
   public double getTotal()  ...
```

Javadoc style comments document the class and the behavior of each method

The method declarations make up the *public interface* of the class

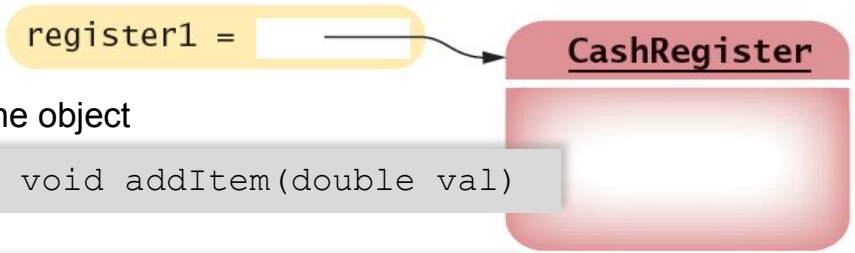
The data and method bodies make up the *private implementation* of the class

Non-static Methods Means…

- We have been writing *class* methods using the `static` modifier:

```
public static void addItem(double val)
```

- For non-static (*instance*) methods, you must instantiate an object of the class before you can invoke methods



- Then invoke methods of the object

```
public static void main(String[] args)
{
  // Construct a CashRegister object
  CashRegister register1 = new CashRegister();
  // Invoke a non-static method of the object
  register1.addItem(1.95);
}
```

Accessor and Mutator Methods

- Many methods fall into two categories:
  - 1) Accessor Methods: '**get**' methods
    - Asks the object for information without changing it
    - Normally return a value of some type

```
public double getTotal() {   }
public int getCount() {   }
```

  - 2) Mutator Methods: '**set**' methods
    - Changes values in the object
    - Usually take a parameter that will change an instance variable
    - Normally return void

```
public void addItem(double price) {   }
public void clear() {   }
```

Self Check 8.9

What does the following code segment print?

```
CashRegister reg = new CashRegister();
reg.clear();
reg.addItem(0.95);
reg.addItem(0.95);
System.out.println(reg.getCount() + " " + reg.getTotal());
```

Answer: `2 1.90`

Self Check 8.10

What is wrong with the following code segment?

```
CashRegister reg = new CashRegister();
reg.clear();
reg.addItem(0.95);
System.out.println(reg.getAmountDue());
```

Answer: There is no method named `getAmountDue`.

Self Check 8.11

Declare a method `getDollars` of the `CashRegister` class that yields the amount of the total sale as a dollar value without the cents.

Answer: `public int getDollars();`

Self Check 8.12

Name two accessor methods of the `String` class.

Answer: `length`, `substring`. In fact, all methods of the `String` class are accessors.

Self Check 8.13

Is the `nextInt` method of the `Scanner` class an accessor or a mutator?

Answer: A mutator. Getting the next number removes it from the input, thereby modifying it. Not convinced? Consider what happens if you call the `nextInt` method twice. You will usually get two different numbers. But if you call an accessor twice on an object (without a mutation between the two calls), you are sure to get the same result.

Self Check 8.14

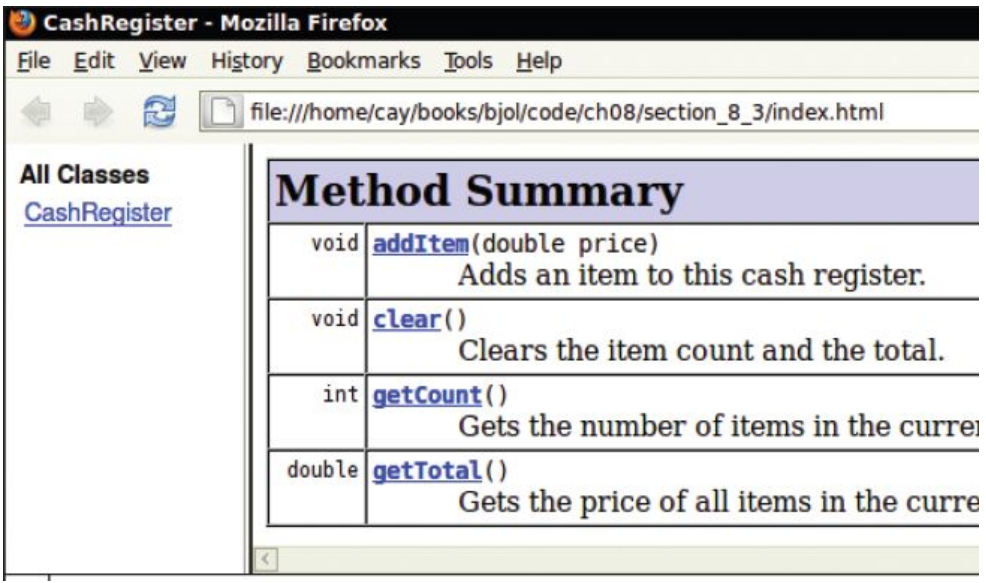
Provide documentation comments for the `Counter` class of Section 8.2.

Answer:

```
/**
   This class models a tally counter.
*/
public class Counter
{
   private int value;
   /**
      Gets the current value of this counter.
      @return the current value
   */
   public int getValue()
   {
      return value;
   }
   /**
      Advances the value of this counter by 1.
   */
   public void count()
   {
      value = value + 1;
   }
}
```

Special Topic: Javadoc

- The Javadoc utility generates a set of HTML files from the Javadoc style comments in your source code
  - Methods document parameters and returns:
    - `@param`
    - `@return`



Designing the Data Representation

- An object stores data in instance variables
  - Variables declared inside the class
  - All methods inside the class have access to them
    - Can change or access them
  - What data will our `CashRegister` methods need?

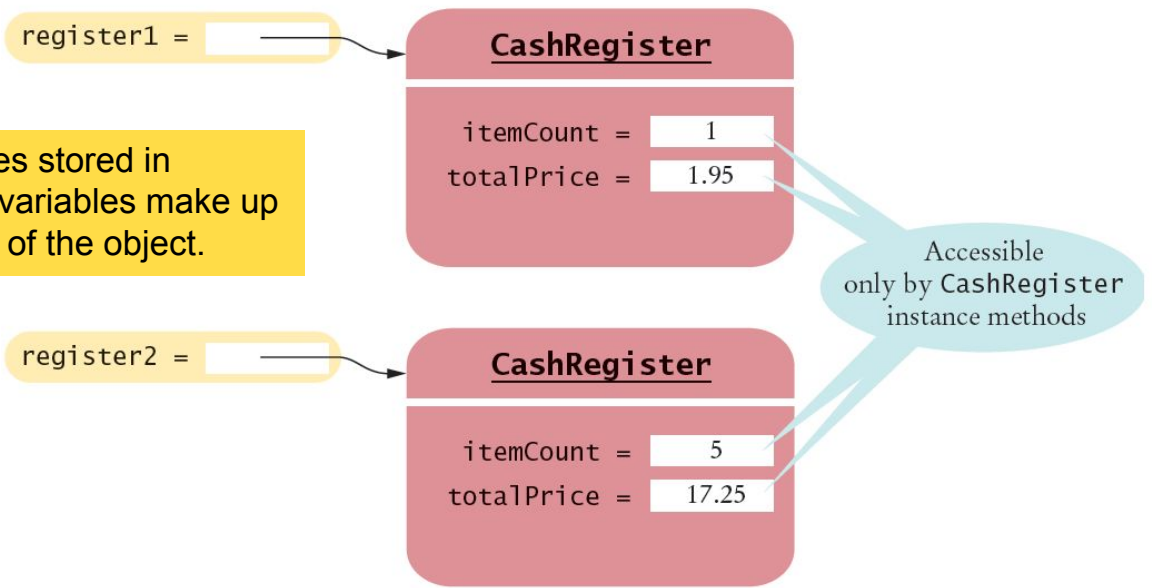
Task	Method	Data Needed
Add the price of an item	`addItem()`	`total, count`
Get the total amount owed	`getTotal()`	`total`
Get the count of items purchased	`getCount()`	`count`
Clear the cash register for a new sale	`clear()`	`total, count`

An object holds instance variables that are accessed by methods

Instance Variables of Objects

- Each object of a class has a separate set of instance variables.

The values stored in instance variables make up the **state** of the object.



Accessing Instance Variables

- `private` instance variables cannot be accessed from methods outside of the class

```
public static void main(String[] args)
{
   . . .
   System.out.println(register1.itemCount); // Error
   . . .
}
```

The compiler will not allow this violation of privacy

- Use accessor methods of the class instead!

```
public static void main(String[] args)
{
   . . .
   System.out.println( register1.getCount() ); // OK
   . . .
}
```

Encapsulation provides a public interface and hides the implementation details.

Self Check 8.15

What is wrong with this code segment?

```
CashRegister register2 = new CashRegister();
register2.clear();
register2.addItem(0.95);
System.out.println(register2.totalPrice);
```

Answer: The code tries to access a private instance variable.

Self Check 8.16

Consider a class `Time` that represents a point in time, such as 9 a.m. or 3:30 p.m. Give two sets of instance variables that can be used for implementing the `Time` class. (*Hint for the second set:* Military time.)

Answer:

(1)
```
int hours; // Between 1 and 12
int minutes; // Between 0 and 59
boolean pm; // True for p.m., false for a.m.
```

(2)
```
int hours; // Military time, between 0 and 23
int minutes; // Between 0 and 59
```

(3)
```
int totalMinutes // Between 0 and 60 * 24 - 1
```

Self Check 8.17

Suppose the implementor of the `Time` class changes from one implementation strategy to another, keeping the public interface unchanged. What do the programmers who use the `Time` class need to do?

Answer: They need not change their programs at all because the public interface has not changed. They need to recompile with the new version of the `Time` class.

Self Check 8.18

Consider a class `Grade` that represents a letter grade, such as `A+` or `B`. Give two different sets of instance variables that can be used for implementing the `Grade` class.

Answer:

(1) `String letterGrade; // "A+", "B"`

(2) `double numberGrade; // 4.3, 3.0`

Implementing Instance Methods

- Implement instance methods that will use the private instance variables

```
public void addItem(double price)
{
  itemCount++;
  totalPrice = totalPrice + price;
}
```

Task	Method	Returns
Add the price of an item	`addItem(double)`	`void`
Get the total amount owed	`getTotal()`	`double`
Get the count of items purchased	`getCount()`	`int`
Clear the cash register for a new sale	`clear()`	`void`

Syntax 8.2 Instance Methods

- Use instance variables inside methods of the class
  - There is no need to specify the implicit parameter (name of the object) when using instance variables inside the class
  - Explicit parameters must be listed in the method declaration

Syntax

modifiers returnType methodName(parameterType parameterName, . . .)
{
  method body
}

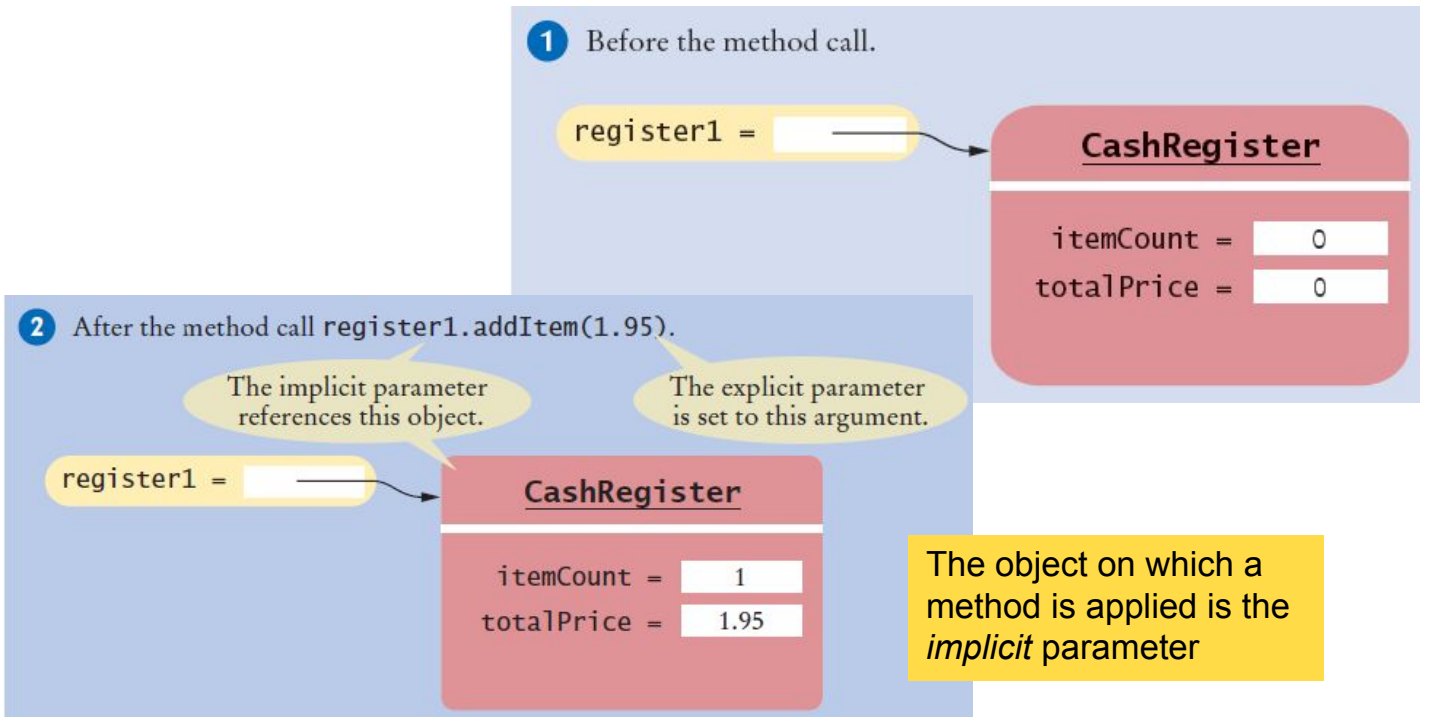
```
public class CashRegister
{
   . . .
   public void addItem(double price)
   {
      itemCount++;
      totalPrice = totalPrice + price;
   }
   . . .
}
```

Explicit parameter

Instance variables of the implicit parameter

Implicit and Explicit Parameters

- When an item is added, it affects the instance variables of the object on which the method is invoked



The object on which a method is applied is the *implicit* parameter

Self Check 8.19

What are the values of `register1.itemCount`, `register1.totalPrice`, `register2.itemCount`, and `register2.totalPrice` after these statements?

```
CashRegister register1 = new CashRegister();
register1.addItem(0.90);
register1.addItem(0.95);
CashRegister register2 = new CashRegister();
register2.addItem(1.90);
```

Answer: `2 1.85 1 1.90`

Self Check 8.20

Implement a method `getDollars` of the `CashRegister` class that yields the amount of the total sale as a dollar value without the cents.

Answer:

```
public int getDollars()
{
   int dollars = (int) totalPrice; // Truncates cents
   return dollars;
}
```

Self Check 8.21

Consider the `substring` method of the `String` class that is described in Section 2.5.6. How many parameters does it have, and what are their types?

Answer: Three parameters: two explicit parameters of type `int`, and one implicit parameter of type `String`.

Self Check 8.22

Consider the `length` method of the `String` class. How many parameters does it have, and what are their types?

Answer: One parameter: the implicit parameter of type `String`. The method has no explicit parameters.

Constructors

- A *constructor* is a method that initializes instance variables of an object
  - It is automatically called when an object is created
  - It has exactly the same name as the class

```
public class CashRegister
{
   . . .
   /**
      Constructs a cash register with cleared item count and total.
   */
   public CashRegister() // A constructor
   {
      itemCount = 0;
      totalPrice = 0;
   }
}
```

Constructors never return values, but do not use `void` in their declaration

Multiple Constructors

- A class can have more than one constructor
  - Each must have a unique set of parameters

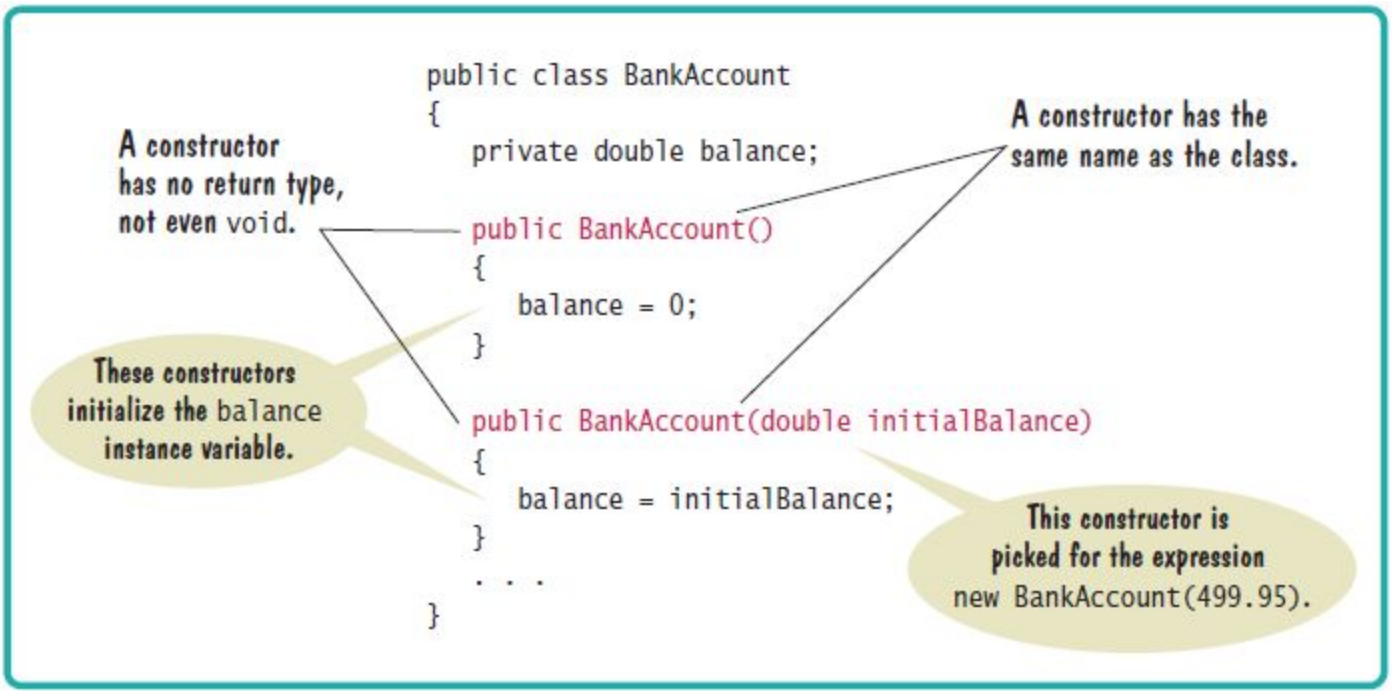
```
public class BankAccount
{
   . . .
   /**
      Constructs a bank account with a zero balance.
   */
   public BankAccount( ) { . . . }
   /**
      Constructs a bank account with a given balance.
      @param initialBalance the initial balance
   */
   public BankAccount(double initialBalance) { . . . }
}
```

The compiler picks the constructor that matches the construction parameters.

```
BankAccount joesAccount = new BankAccount();
BankAccount lisasAccount = new BankAccount(499.95);
```

Syntax 8.2 Constructors

- One constructor is invoked when the object is created with the `new` keyword based on arguments you supply



Initializing Instance Variables

- A constructor creates an object by initializing all instance variables defined in the class
- If you don't initialize an instance variable explicitly, Java does it for you by default:
  - Numbers are set to zero
  - Boolean variables are initialized as false
  - Object and array references are set to the special value null that indicates no object is associated with the variable
- It is a good programming practice to initialize all the instance variables in a class

Null Object References

- Uninitialized object references in a constructor are set to by `null` default
- Calling a method on a null reference results in a runtime error: **`NullPointerException`**

```
public class BankAccount
{
  private String name;    // default constructor will set to null

  public void showStrings()
  {
    String localName;
    System.out.println(name.length());
    System.out.println(localName.length());
  }
}
```

Runtime Error:
java.lang.NullPointerException

Compiler Error: variable localName might not have been initialized

The Default Constructor

- If you do not supply any constructors, the compiler will make a default constructor automatically
  - It takes no parameters
  - It initializes all instance variables

```
public class CashRegister
{
   . . .
   /**
      Does exactly what a compiler generated constructor would do.
   */
   public CashRegister()
   {
      itemCount = 0;
      totalPrice = 0;
   }
}
```

By default, numbers are initialized to `0`, booleans to `false`, and objects as `null`.

CashRegister.java

```
1  /**
2     A simulated cash register that tracks th
3     the total amount due.
4  */
5  public class CashRegister
6  {
7     private int itemCount;
8     private double totalPrice;
9
10    /**
11       Constructs a cash register with clea
12    */
13    public CashRegister()
14    {
15       itemCount = 0;
16       totalPrice = 0;
17    }
18
19    /**
20       Adds an item to this cash register.
21       @param price the price of this item
22    */
23    public void addItem(double price)
24    {
25       itemCount++;
26       totalPrice = totalPrice + price;
27    }
28
29    /**
30       Gets the price of all items in the current sale.
31       @return the total amount
32    */
33    public double getTotal()
34    {
35       return totalPrice;
36    }
37
38    /**
39       Gets the number of items in the current sale.
40       @return the item count
41    */
42    public int getCount()
43    {
44       return itemCount;
45    }
46
47    /**
48       Clears the item count and the total.
49    */
50    public void clear()
51    {
52       itemCount = 0;
53       totalPrice = 0;
54    }
55 }
```

Self Check 8.23

Consider this class:

```
public class Person
{
   private String name;

   public Person(String firstName, String lastName)
   {
      name = lastName + ", " + firstName;
   }
   . . .
}
```

If an object is constructed as

```
Person harry = new Person("Harry", "Morgan");
```

what is its name instance variable?

Answer: `"Morgan, Harry"`

Self Check 8.24

Provide an implementation for a `Person` constructor so that after the call

```
Person p = new Person();
```

the name instance variable of `p` is "`unknown`".

Answer: `public Person() { name = "unknown"; }`

Self Check 8.25

What happens if you supply no constructor for the `CashRegister` class?

Answer: A constructor is generated that has the same effect as the constructor provided in this section. It sets both instance variables to zero.

Self Check 8.26

Consider the following class:

```
public class Item
{
   private String description;
   private double price;
   public Item() { . . . }
   // Additional methods omitted
}
```

Provide an implementation for the constructor.

Answer:

```
public Item()
{
  price = 0;
  description = "";
}
```

The `price` instance variable need not be initialized because it is set to zero by default, but it is clearer to initialize it explicitly.

Self Check 8.27

Which constructors should be supplied in the `Item` class so that each of the following declarations compiles?

a. `Item item2 = new Item("Corn flakes");`
b. `Item item3 = new Item(3.95);`
c. `Item item4 = new Item("Corn flakes", 3.95);`
d. `Item item1 = new Item();`
e. `Item item5;`

Answer: (a) `Item(String)` (b) `Item(double)` (c) `Item(String, double)` (d) `Item()` (e) No constructor has been called.

Common Error

- Trying to Call a Constructor
  - You cannot call a constructor like other methods
  - It is 'invoked' for you by the new reserved word

```
CashRegister register1 = new CashRegister();
```

  - You cannot invoke the constructor on an existing object:

```
register1.CashRegister(); // Error
```

  - But you can create a new object using your existing reference

```
CashRegister register1 = new CashRegister();
Register1.newItem(1.95);
CashRegister register1 = new CashRegister();
```

Common Error

- Declaring a constructor as `void`
  - A constructor is not a method and doesn't return a value
  - Constructors are never give return types

```
public void class BankAccount  //Syntax error … don't use void!
```

Special Topic

- Overloading
  - We have seen that multiple constructors can have exactly the same name
    - They require different lists of parameters
  - Actually any method can be overloaded
    - Same method name with different parameters

```
void print(CashRegister register)    { . . . }
void print(BankAccount account)      { . . . }
void print(int value)            { . . . }
Void print(double value)         { . . . }
```

  - We will not be using overloading in this book
    - Except as required for constructors

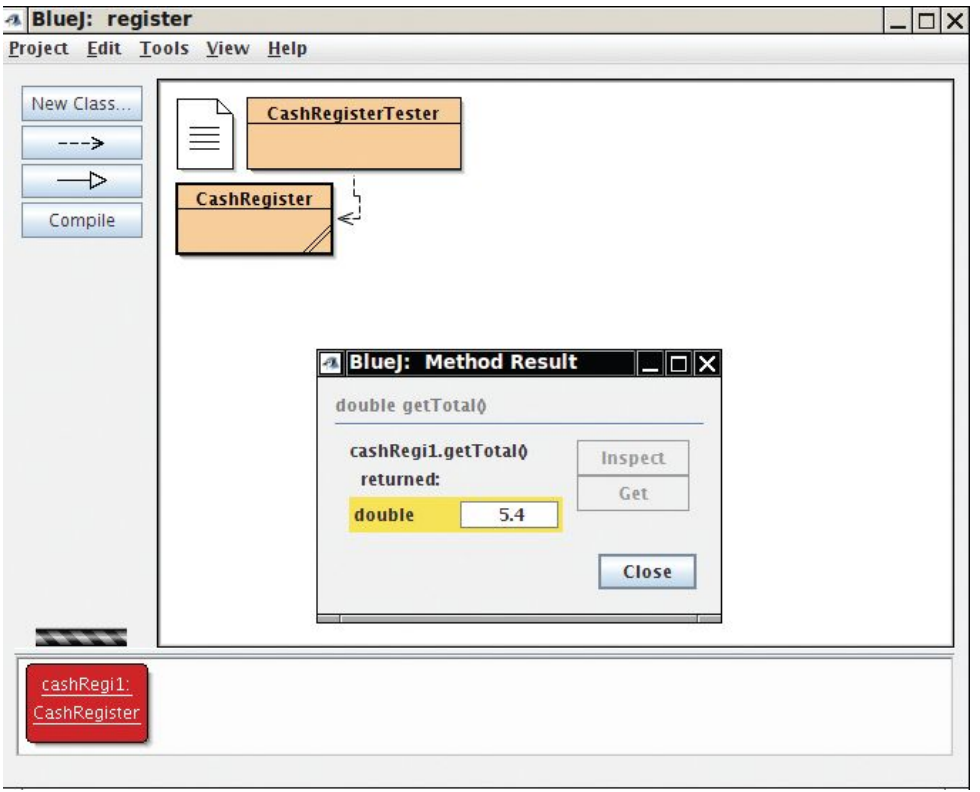
Testing a Class

- We wrote a `CashRegister` class but…
  - You cannot execute the class – it has no `main` method
- It can become part of a larger program
  - Test it first though with **unit testing**
- To test a new class, you can use:
  - Programming tools that interactively create objects:
    - DrJava: www.drjava.org
    - BlueJ: www.bluej.org
  - Or write a tester class:
    - With a `main`

```
public class CashRegisterTester
{
  public static void main(String[] args)
  {
    CashRegister c1 = new CashRegister();
    ...
```

BlueJ: An IDE for Testing

- BlueJ can interactively instantiate objects of a class, and allows you to invoke their methods
  - Great for testing!



CashRegisterTester.java

- Test all methods
  - Print expected results
  - Output actual results
  - Compare results

A unit test verifies that a class works correctly in isolation, outside a complete program.

```
1  /**
2     This program tests the CashRegister class.
3  */
4  public class CashRegisterTester
5  {
6     public static void main(String[] args)
7     {
8        CashRegister register1 = new CashRegister();
9        register1.addItem(1.95);
10       register1.addItem(0.95);
11       register1.addItem(2.50);
12       System.out.println(register1.getCount());
13       System.out.println("Expected: 3");
14       System.out.printf("%.2f\n", register1.getTotal());
15       System.out.println("Expected: 5.40");
16    }
17 }
```

Program Run

```
3
Expected: 3
5.40
Expected: 5.40
```

Self Check 8.28

How would you enhance the tester class to test the `clear` method?

Answer: Add these lines:

```
register1.clear();
System.out.println(register1.getCount());
System.out.println("Expected: 0");
System.out.printf("%.2f%n", register1.getTotal());
System.out.println("Expected: 0.00");
```

Self Check 8.29

When you run the `CashRegisterTester` program, how many objects of class `CashRegister` are constructed? How many objects of type `CashRegisterTester`?

Answer: 1, 0

Self Check 8.30

Why is the `CashRegisterTester` class unnecessary in development environments that allow interactive testing, such as BlueJ?

Answer: These environments allow you to call methods on an object without creating a `main` method.

Steps to Implementing a Class

1) Get an informal list of responsibilities for your objects

Display the menu.
Get user input.

2) Specify the public interface

```
public Menu();
public void addOption(String option);
public int getInput()
```

3) Document the public interface

- Javadoc comments

```
/**
   Adds an option to the end of this menu.
   @param option the option to add
*/
```

4) Determine the instance variables

```
private ArrayList<String> options;
```

5) Implement constructors and methods

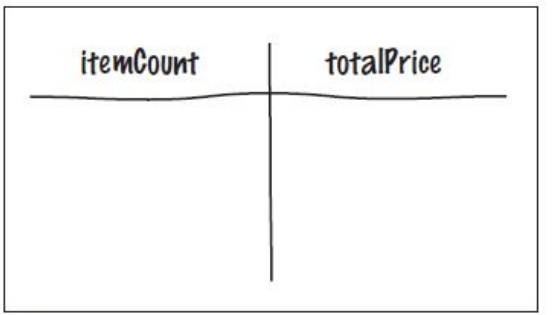
```
public void addOption(String option)
{
   options.add(option);
}
```

6) Test your class

Problem Solving: Tracing Objects

- Use an Index card for each object

front



back

  - An object is manipulated through the public interface (front of the card)
  - The encapsulated data is on the back of the card

Mutator Methods and Cards

- As mutator methods are called, keep track of the value of instance variables

```
CashRegister reg2(7.5); // 7.5 percent sales tax
reg2.addItem(3.95, false); // Not taxable
reg2.addItem(19.95, true); // Taxable
```

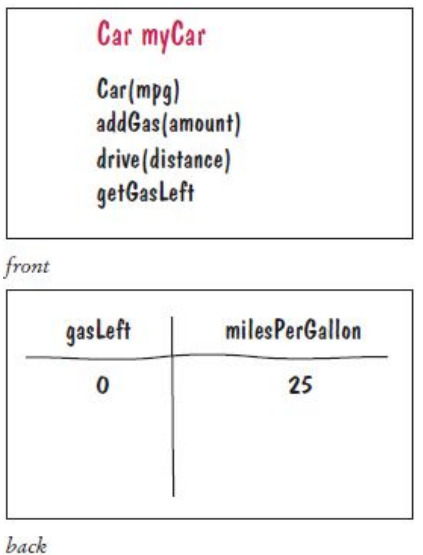
itemCount	totalPrice	taxableTotal	taxRate
~~0~~	~~0~~	~~0~~	7.5
~~1~~	~~3.95~~		
2	23.90	19.95	

Self Check 8.31

Consider a `Car` class that simulates fuel consumption in a car. We will assume a fixed efficiency (in miles per gallon) that is supplied in the constructor. There are methods for adding gas, driving a given distance, and checking the amount of gas left in the tank.

Make a card for a `Car` object, choosing suitable instance variables and showing their values after the object was constructed.

Answer:

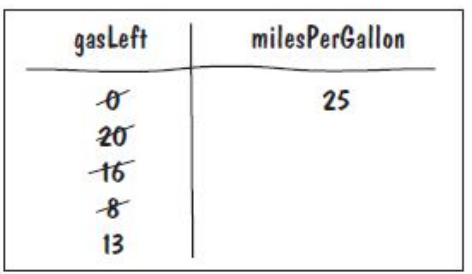


Self Check 8.32

Trace the following method calls:

```
Car myCar = new Car(25);
myCar.addGas(20);
myCar.drive(100);
myCar.drive(200);
myCar.addGas(5);
```

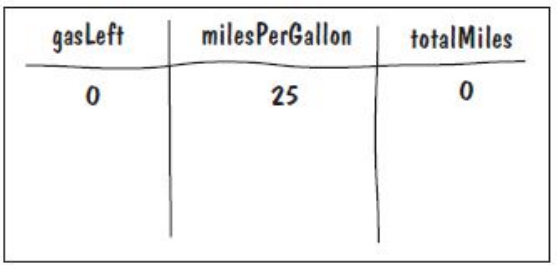
Answer:



Self Check 8.33

Suppose you are asked to simulate the odometer of the car, by adding a method `getMilesDriven`. Add an instance variable to the object's card that is suitable for computing this method.

Answer:



Self Check 8.34

Trace the methods of Self Check 32, updating the instance variable that you added in Self Check 33.

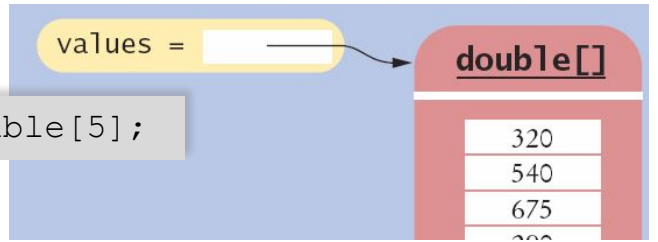
Answer:

gasLeft	milesPerGallon	totalMiles
~~0~~	25	0
~~20~~		
~~16~~		100
~~8~~		300
13		

Object References

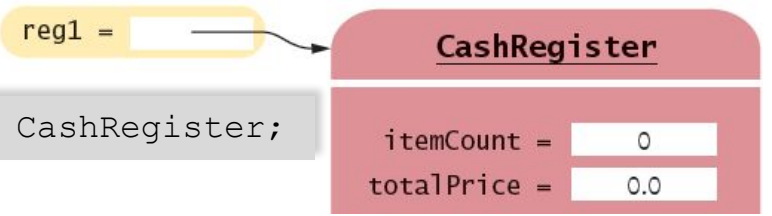
- Objects are similar to arrays because they always have reference variables
  - Array Reference

```
double[] values = new double[5];
```



  - Object Reference

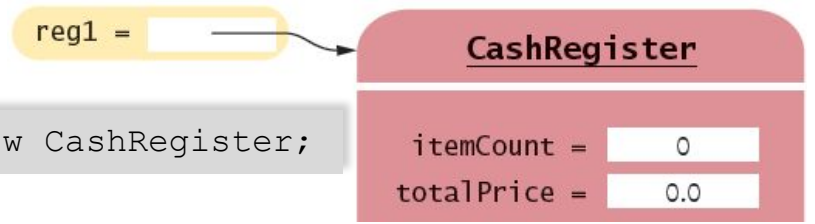
```
CashRegister reg1 = new CashRegister;
```



An object reference specifies the *memory location* of the object

Shared References

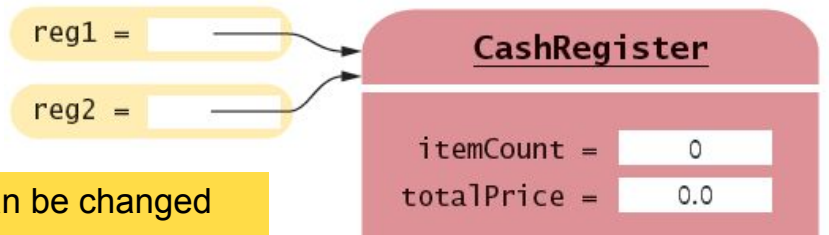
- Multiple object variables may contain references to the same object.
  - Single Reference




```
CashRegister reg1 = new CashRegister;
```

  - Shared References

```
CashRegister reg2 = reg1;
```

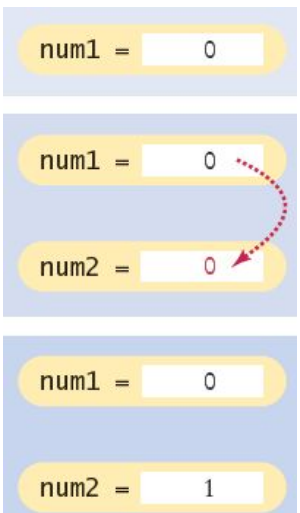


The internal values can be changed through either reference

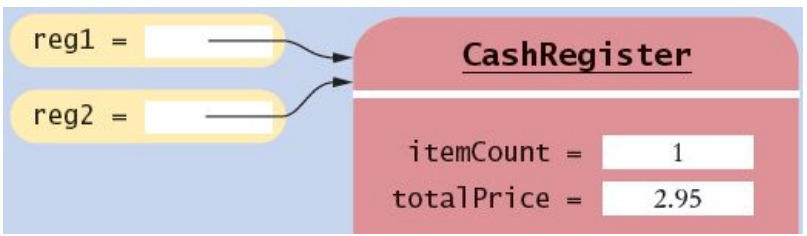
Primitive versus Reference Copy

- Primitive variables can be copied, but work differently than object references
  - Primitive Copy — Two locations
  - Reference Copy — One location for both

```
int num1 = 0;
int num2 = num1;
num2++;
```




```
CashRegister reg1 = new CashRegister;
CashRegister reg2 = reg1;
reg2.addItem(2.95);
```



Why? Primitives take much less storage space than objects!

The `null` Reference

- A reference may point to 'no' object
  - You cannot invoke methods of an object via a `null` reference – causes a run-time error

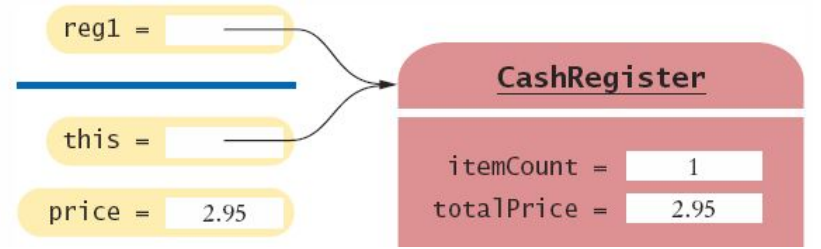
```
CashRegister reg = null;
System.out.println(reg.getTotal());   // Runtime Error!
```

  - To test if a reference is `null` before using it:

```
String middleInitial = null; // No middle initial

if (middleInitial == null)
  System.out.println(firstName + " " + lastName);
else
  System.out.println(firstName + " " + middleInitial + ". "
    + lastName);
```

The `this` Reference

- Methods receive the 'implicit parameter' in a reference variable called `this`
  - It is a reference to the object the method was invoked on:



  - It can clarify when instance variables are used:

```
void addItem(double price)
{
   this.itemCount++;
   this.totalPrice = this.totalPrice + price;
}
```

Constructor `this` Reference

- Sometimes people use the `this` reference in constructors
  - It makes it very clear that you are setting the instance variable:

```
public class Student
{
  private int id;
  private String name;
  public Student(int id, String name)
  {
    this.id = id;
    this.name = name;
  }
}
```

Self Check 8.35

Suppose we have a variable

```
String greeting = "Hello";
```

What is the effect of this statement?

```
String greeting2 = greeting;
```

Answer: Both `greeting` and `greeting2` refer to the same string `"Hello"`.

Self Check 8.36

After calling `String greeting3 = greeting2.toUpperCase()` , what are the contents of `greeting` and `greeting2` ?

Answer: They both still refer to the string `"Hello"`. The `toUpperCase` method computes the string `"HELLO"`, but it is not a mutator—the original string is unchanged.

Self Check 8.37

What is the value of `s.length()` if `s` is
a. the empty string `""`?
b. `null`?

Answer: (a) 0
(b) A null pointer exception is thrown.

Self Check 8.38

What is the type of `this` in the call `greeting.substring(1, 4)` ?

Answer: It is a reference of type `String`.

Self Check 8.39

Supply a method `addItems(int quantity, double price)` in the `CashRegister` class to add multiple instances of the same item. Your implementation should repeatedly call the `addItem` method. Use the `this` reference.

Answer:

```
public void addItems(int quantity, double price)
{
   for (int i = 1; i <= quantity; i++)
   {
      this.addItem(price);
   }
}
```

Common Error

- Not initializing object references in constructor
  - References are by default initialized to `null`
  - Calling a method on a null reference results in a runtime error: **`NullPointerException`**
  - The compiler catches uninitialized local variables for you

```
public class BankAccount
{
  private String name;    // default constructor will set to null

  public void showStrings()
  {
    String localName;
    System.out.println(name.length());
    System.out.println(localName.length());
  }
}
```

Runtime Error:
java.lang.NullPointerException

Compiler Error: variable localName might not have been initialized

Special Topic

- Calling one constructor from another
  - Use `this` to call another constructor of the same class

```
public class BankAccount
{
   public BankAccount(double initialBalance)
   {
      balance = initialBalance;
   }
   public BankAccount()
   {
      this(0);
   }
   . . .
}
```

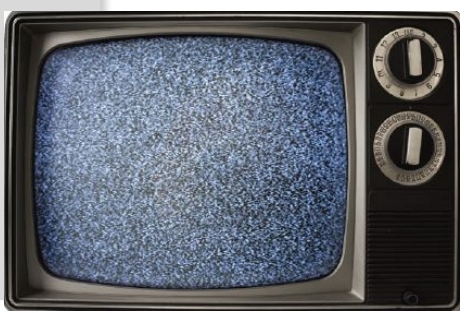
Special Topic

- When `this` is followed by parentheses and zero or more parameters, it denotes a constructor call – `this(0)`
- We will not use this technique in the book

Static Variables and Methods

- Variables can be declared as `static` in the Class declaration
  - There is one copy of a `static` variable that is shared among all objects of the Class

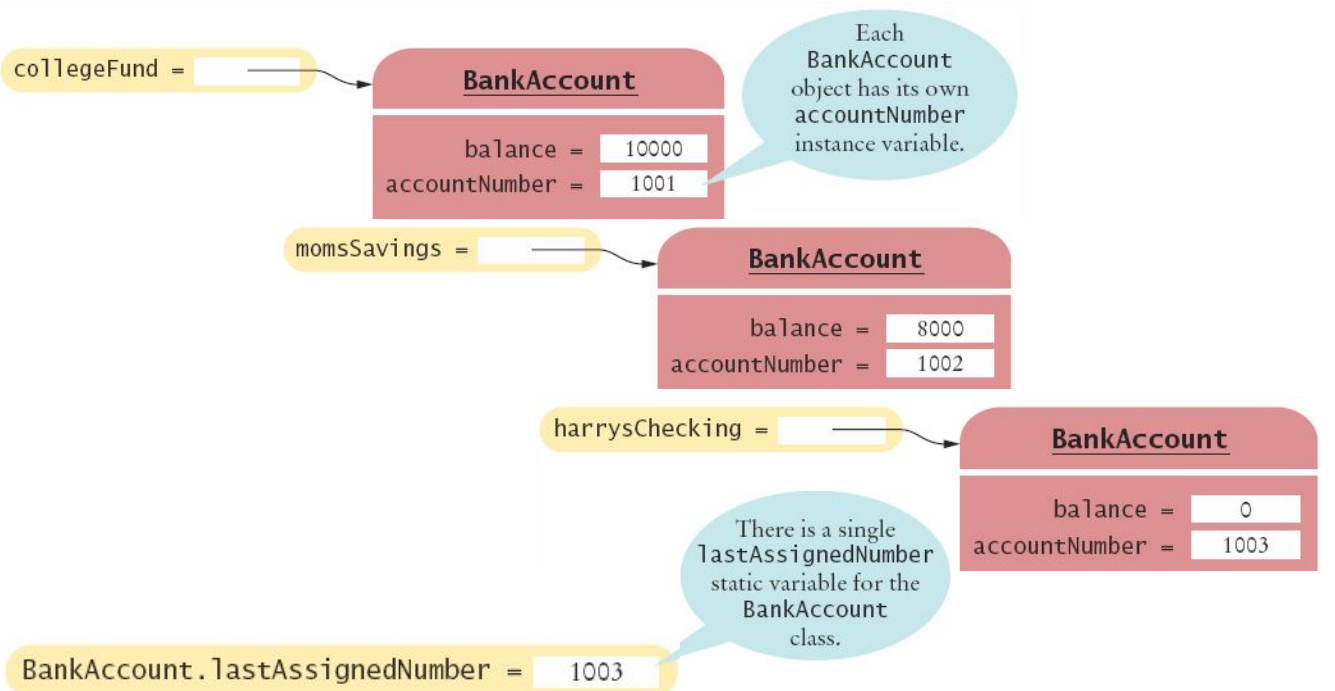
```
public class BankAccount
{
  private double balance;
  private int accountNumber;
  private static int lastAssignedNumber = 1000;

  public BankAccount()
  {
    lastAssignedNumber++;
    accountNumber = lastAssignedNumber;
  }
  . . .
}
```



Methods of any object of the class can use or change the value of a static variable

Using Static Variables

- Example:
  - Each time a new account is created, the `lastAssignedNumber` variable is incremented by the constructor
- Access the `static` variable using:
  - `ClassName.variableName`



Using Static Methods

- The Java API has many classes that provide methods you can use without instantiating objects
  - The `Math` class is an example we have used
  - `Math.sqrt(value)` is a `static` method that returns the square root of a value
  - You do not need to instantiate the `Math` class first
- Access `static` methods using:
  - `ClassName.methodName()`

Writing Your Own Static Methods

- You can define your own `static` methods

```
public class Financial
{
   /**
      Computes a percentage of an amount.
      @param percentage the percentage to apply
      @param amount the amount to which the percentage is applied
      @return the requested percentage of the amount
   */
   public static double percentOf(double percentage, double amount)
   {
      return (percentage / 100) * amount;
   }
}
```

`static` methods usually return a value. They can only access `static` variables and methods.

- Invoke the method on the Class, not an object

```
double tax = Financial.percentOf(taxRate, total);
```

Self Check 8.40

Name two static variables of the `System` class.

Answer: `System.in` and `System.out`

Self Check 8.41

Name a static constant of the `Math` class.

Answer: `Math.PI`

Self Check 8.42

The following method computes the average of an array of numbers:

```
public static double average(double[] values)
```

Why should it not be defined as an instance method?

Answer: The method needs no data of any object. The only required input is the `values` argument.

Self Check 8.43

Harry tells you that he has found a great way to avoid those pesky objects: Put all code into a single class and declare all methods and variables `static`. Then `main` can call the other static methods, and all of them can access the static variables. Will Harry's plan work? Is it a good idea?

Answer: Yes, it works. Static methods can call each other and access static variables—any method can. But it is a terrible idea. A program that consists of a single class with many methods is hard to understand.

Problem Solving

- Patterns for Object Data
- Common patterns when designing instance variables
  - Keeping a Total
  - Counting Events
  - Collecting Values
  - Managing Object Properties
  - Modeling Objects with Distinct States
  - Describing the Position of an Object

Patterns: Keeping a Total

- Examples
  - Bank account balance
  - Cash Register total
  - Car gas tank fuel level
- Variables needed
  - Total (`totalPrice`)
- Methods Required
  - Add (`addItem`)
  - Clear
  - `getTotal`

```
public class CashRegister
{
  private double totalPrice;

  public void addItem(double price)
  {
    totalPrice += price;
  }
  public void clear()
  {
    totalPrice = 0;
  }
  public double getTotal()
  {
    return totalPrice;
  }
}
```

Patterns: Counting Events

- Examples
  - Cash Register items
  - Bank transaction fee
- Variables needed
  - Count
- Methods Required
  - Add
  - Clear
  - Optional: `getCount`

```
public class CashRegister
{
  private double totalPrice;
  private int itemCount;
  public void addItem(double price)
  {
    totalPrice += price;
    itemCount++;
  }
  public void clear()
  {
    totalPrice = 0;
    itemCount = 0;
  }
  public double getCount()
  {
    return itemCount;
  }
}
```

Patterns: Collecting Values

- Examples
  - Multiple choice question
  - Shopping cart
- Storing values
  - Array or ArrayList
- Constructor
  - Initialize to empty collection
- Methods Required
  - Add

```
public class Question
{
    private ArrayList<String> choices;
    public Question()
    {
        choices = new ArrayList<String>();
    }
    public void add(String choice)
    {
        choices.add(choice);
    }
}
```

Patterns: Managing Properties

- A property of an object can be set and retrieved
- Examples
  - Student: name, ID
- Constructor
  - Set a unique value
- Methods Required
  - set
  - get

```
public class Student
{
  private String name;
  private int ID;
  public Student(int anID)
  {
     ID = anID;
  }
  public void setName(String newname)
  {
    if (newName.length() > 0)
      name = newName;
  }
  public getName()
  {
     return name;
  }
}
```

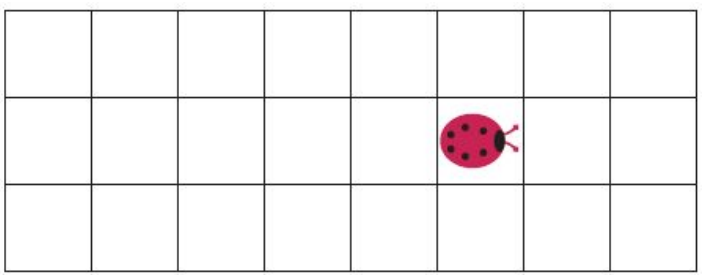
Patterns: Modeling Stateful Objects

- Some objects can be in one of a set of distinct states.
- Example: A fish
  - Hunger states:
    - Somewhat Hungry
    - Very Hungry
    - Not Hungry
- Methods will change the state
  - eat
  - move

```
public class Fish
{
  private int hungry;
  public static final int NOT_HUNGRY
    = 0;
  public static final int
    SOMEWHAT_HUNGRY = 1;
  public static final int VERY_HUNGRY
    = 2;

  public void eat()
  {
     hungry = NOT_HUNGRY;
  }
  public void move()
  {
  if (hungry < VERY_HUNGRY)
    { hungry++; }
}
```

Patterns: Object Position

- Examples
  - Game object
  - Bug (on a grid)
  - Cannonball
- Storing values
  - Row, column, direction, speed. . .
- Methods Required
  - move
  - turn



```
public class Bug
{
  private int row;
  private int column;
  private int direction;
// 0 = N, 1 = E, 2 = S, 3 = W
  public void moveOneUnit()
  {
    switch(direction) {
      case 0: row--; break;
      case 1: column++; break;
      . . .
    }
  }
}
```

Self Check 8.44

Suppose we want to count the number of transactions in a bank account in a statement period, and we add a counter to the `BankAccount` class:

```
public class BankAccount
{
   private int transactionCount;
   . . .
}
```

In which methods does this counter need to be updated?

Answer: It needs to be incremented in the `deposit` and `withdraw` methods. There also needs to be some method to reset it after the end of a statement period.

Self Check 8.45

In the example in Section 8.11.3, why is the add method required? That is, why can't the user of a `Question` object just call the add method of the `ArrayList<String>` class?

Answer: The `ArrayList<String>` instance variable is private, and the class users cannot access it.

Self Check 8.46

Suppose we want to enhance the `CashRegister` class in Section 8.6 to track the prices of all purchased items for printing a receipt. Which instance variable should you provide? Which methods should you modify?

Answer: Add an `ArrayList<Double>` prices. In the `addItem` method, add the current price. In the `reset` method, replace the array list with an empty one. Also supply a method `printReceipt` that prints the prices.

Self Check 8.47

Consider an `Employee` class with properties for tax ID number and salary. Which of these properties should have only a getter method, and which should have getter and setter methods?

Answer: The tax ID of an employee does not change, and no setter method should be supplied. The salary of an employee can change, and both getter and setter methods should be supplied.

Self Check 8.48

Look at the `direction` instance variable in the bug example in Section 8.11.6. This is an example of which pattern?

Answer: It is an example of the “state pattern” described in Section 8.11.5. The direction is a state that changes when the bug turns, and it affects how the bug moves.

Packages

- Related classes are organized into Java packages

Table 1 Important Packages in the Java Library

Package	Purpose	Sample Class
java.lang	Language support	Math
java.util	Utilities	Random
java.io	Input and output	PrintStream
java.awt	Abstract Windowing Toolkit	Color
java.applet	Applets	Applet
java.net	Networking	Socket
java.sql	Database access through Structured Query Language	ResultSet
javax.swing	Swing user interface	JButton
org.w3c.dom	Document Object Model for XML documents	Document

Organizing Your Classes

- To put one of your classes in a package, add a line as the first instruction of the source containing the class

```
package packagename;
```

- The package name consists of one or more identifiers separated by periods (see 8.12.3)

```
package com.horstmann.bigjava;
public class Financial
{
   . . .
}
```

The `package` statement adds the `Financial` class to the `com.horstmann.bigjava`package.

Importing Classes

- To use a class from a package, you can refer to it by its full name (package name plus class name)

```
java.util.Scanner in =  new java.util.Scanner(System.in);
```

- Using package names in this way can be inconvenient, so Java allows classes to be imported

```
import java.util.Scanner;
```

- Imported classes can be referenced without using the package name prefix

Importing Multiple Classes

- You can import all classes of a package with an import statement that ends in `.*`

```
import java.util.*;
```

This `import` statement allows you to refer to the `Scanner` or `Random` classes without qualifying the names with `java.util`.

- You never need to import the classes in the `java.lang` package explicitly
- Effectively, an automatic import `java.lang.*;` statement has been placed into every source file
- You don't need to import other classes in the same package

Syntax 8.4 Package Specification

- Organize the classes in your source file with a `package` statement

Syntax `package packageName;`

```
package com.horstmann.bigjava;
```

The classes in this file belong to this package.

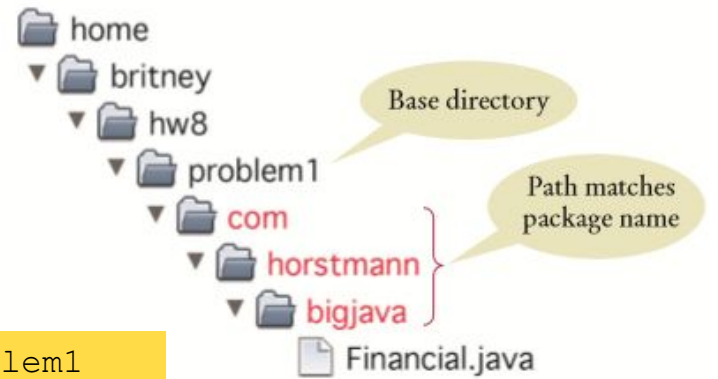
A good choice for a package name is a domain name in reverse.

Package Names

- When two classes have the same name, **name clashes** are avoided by putting them into different packages
- Two different `Timer` classes
  - `java.util.Timer`
  - `javax.swing.Timer`
- Unique package names are often constructed by reversing domain names or email addresses
  - `com.horstman`
  - `walters@cs.sjsu.edu`

Package and Source Files

- A source file must be located in a subdirectory that matches the package name
- Parts of a package name between periods represent successively nested directories



A class we are writing in the `problem1` directory can `import` the `Financial.java` class from the `com.horstmann.bigjava` subdirectory

Self Check 8.49

Which of the following are packages?

a. `java`
b. `java.lang`
c. `java.util`
d. `java.lang.Math`

Answer: (a) No; (b) Yes; (c) Yes; (d) No

Self Check 8.50

Is a Java program without `import` statements limited to using the default and `java.lang` packages?

Answer: No—you can use fully qualified names for all other classes, such as `java.util.Random` and `java.awt.Rectangle`.

Self Check 8.51

Suppose your homework assignments are located in the directory `/home/me/cs101 (c:\Users\Me\cs101 on Windows)` . Your instructor tells you to place your homework into packages. In which directory do you place the class `hw1.problem1. TicTacToeTester` ?

Answer: `/home/me/cs101/hw1/problem1`or, on Windows, `c:\Users\Me\cs101\hw1\problem1`

Common Error

- Dots (`.`) are used in several situations which can be confusing
  - Between package names (`java.util`)
  - Between package and class names (`homework1.Bank`)
  - Between class and inner class names (`Ellipse2D.Double`)
  - Between class and instance variable names (`Math.PI`)
  - Between objects and methods (`account.getBalance()`)
- Consider `java.lang.System.out.println(x);`
  - `out` – an object of type `PrintStream`
  - `System` – without context, might be an object with a public variable `out`, or a class with a static variable
- Start class names with an uppercase letter and variables, methods and packages with lowercase

Special Topic

- Package Access
  - A class, instance variable or method without an access modifier has package access
  - Features with package access can be accessed by all classes in the same package, which is usually not desirable.

```
public class Window extends Container
{
   String warningString;
   ...
}
```

The variable `warningString` has package access and can be accessed by any other class in `java.awt` – the package that contains the `Window` class