Chapter 2 Elementary Programming

Hu Zheng
huzheng@bupt.edu.cn

Motivations

In the preceding chapter, you learned how to create, compile, and run a Java program. Starting from this chapter, you will learn how to solve practical problems programmatically. Through these problems, you will learn Java primitive data types and related subjects, such as variables, constants, data types, operators, expressions, and input and output.

Objectives

- **To write Java programs to perform simple computations (§2.2).**
- **To obtain input from the console using the Scanner class (§2.3).**
- **To use identifiers to name variables, constants, methods, and classes (§2.4).**
- **To use variables to store data (§§2.5–2.6).**
- **To program with assignment statements and assignment expressions (§2.6).**
- **To use constants to store permanent data (§2.7).**
- **To name classes, methods, variables, and constants by following their naming conventions (§2.8).**
- **To explore Java numeric primitive data types: byte, short, int, long, float, and double (§2.9.1).**
- **To read a byte, short, int, long, float, or double value from the keyboard (§2.9.2).**
- **To perform operations using operators +, -, *, /, and % (§2.9.3).**
- **To perform exponent operations using Math.pow(a, b) (§2.9.4).**
- **To write integer literals, floating-point literals, and literals in scientific notation (§2.10).**
- **To write and evaluate numeric expressions (§2.11).**
- **To obtain the current system time using System.currentTimeMillis() (§2.12).**
- **To use augmented assignment operators (§2.13).**
- **To distinguish between postincrement and preincrement and between postdecrement and predecrement (§2.14).**
- **To cast the value of one type to another type (§2.15).**
- **To describe the software development process and apply it to develop the loan payment program (§2.16).**
- **To write a program that converts a large amount of money into smaller units (§2.17).**
- **To avoid common errors and pitfalls in elementary programming (§2.18).**

Introducing Programming with an Example

Ex 2.1 Computing the Area of a Circle

ComputeArea

animation

Trace a Program Execution

```
public class ComputeArea {
  /** Main method */
  public static void main(String[] args) {
    double radius;
    double area;

    // Assign a radius
    radius = 20;

    // Compute area
    area = radius * radius * 3.14159;

    // Display results
    System.out.println("The area for the circle of radius
      " +
      radius + " is " + area);
  }
}
```

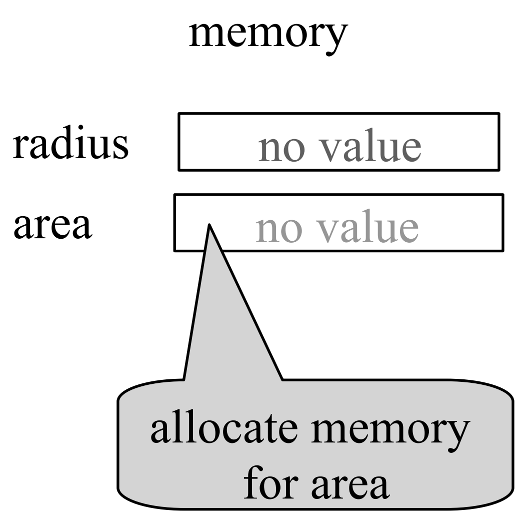
allocate memory for radius

radius | no value

animation

Trace a Program Execution

```
public class ComputeArea {
  /** Main method */
  public static void main(String[] args) {
    double radius;
    double area;

    // Assign a radius
    radius = 20;

    // Compute area
    area = radius * radius * 3.14159;

    // Display results
    System.out.println("The area for the circle of radius
      " +
      radius + " is " + area);
  }
}
```



animation

Trace a Program Execution

```
public class ComputeArea {
  /** Main method */
  public static void main(String[] args) {
    double radius;
    double area;

    // Assign a radius
    radius = 20;

    // Compute area
    area = radius * radius * 3.14159;

    // Display results
    System.out.println("The area for the circle of radius
      " +
      radius + " is " + area);
  }
}
```

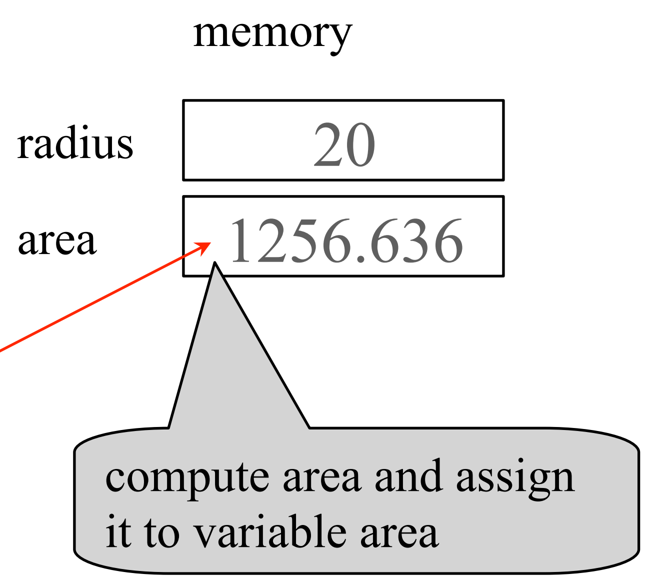
assign 20 to radius

radius	20
area	no value

animation

Trace a Program Execution

```
public class ComputeArea {
  /** Main method */
  public static void main(String[] args) {
    double radius;
    double area;

    // Assign a radius
    radius = 20;

    // Compute area
    area = radius * radius * 3.14159;

    // Display results
    System.out.println("The area for the circle of radius
      " +
      radius + " is " + area);
  }
}
```



animation

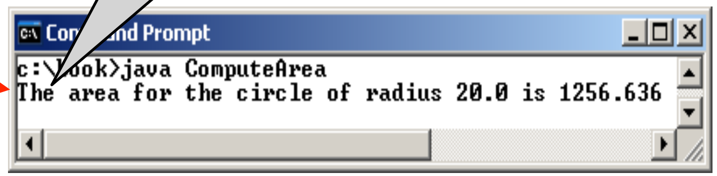
Trace a Program Execution

```
public class ComputeArea {
  /** Main method */
  public static void main(String[] args) {
    double radius;
    double area;

    // Assign a radius
    radius = 20;

    // Compute area
    area = radius * radius * 3.14159;

    // Display results
    System.out.println("The area for the circle of radius
     " +
     radius + " is " + area);
  }
}
```

memory

radius	20
area	1256.636

print a message to the console



Reading Input from the Console

1. Create a Scanner object

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

2. Use the method nextDouble() to obtain to a double value. For example,

```
System.out.print("Enter a double value: ");
Scanner input = new Scanner(System.in);
double d = input.nextDouble();
```

ComputeAreaWithConsoleInput

ComputeAverage

Identifiers

- **An identifier is a sequence of characters that consist of letters, digits, underscores (_), and dollar signs ($).**
  - **Character. isJavaIdentifierPart() returns `true`**
  - **In Unicode Charsets: Characters bigger than 0xC0**
- **An identifier must start with a letter, an underscore (_), or a dollar sign ($). It cannot start with a digit.**
  - **Character.isJavaIdentifierStart() returns `true`**
- **An identifier cannot be a reserved word.**
- **An identifier cannot be `true`, `false`, or `null`.**
- **An identifier can be of any length.**

- **Correct Identifiers:**
  - **Body, _test, $hello**
- **Wrong Identifiers:**
  - **5Test, hello*, world#, class**

Keywords

Some noteworthy points regarding Java keywords:

- **const** and **goto** are resevered words but not used.
- **true**, **false** and **null** are literals, not keywords.
- all keywords are in lower-case.

The following table shows the keywords grouped by category:

Category	Keywords
Access modifiers	**private, protected, public**
Class, method, variable modifiers	**abstract, class, extends, final, implements, interface, native, new, static, strictfp, synchronized, transient, volatile**
Flow control	**break, case, continue, default, do, else, for, if, instanceof, return, switch, while**
Package control	**import, package**
Primitive types	**boolean, byte, char, double, float, int, long, short**
Error handling	**assert, catch, finally, throw, throws, try**
Enumeration	**enum**
Others	**super, this, void**
Unused	**const, goto**

Variables

```
// Compute the first area
radius = 1.0;
area = radius * radius * 3.14159;
System.out.println("The area is " +
  area + " for radius "+radius);

// Compute the second area
radius = 2.0;
area = radius * radius * 3.14159;
System.out.println("The area is " +
  area + " for radius "+radius);
```

Declaring Variables

```
int x;           // Declare x to be an
                 // integer variable;
double radius;   // Declare radius to
                 // be a double variable;
char a;          // Declare a to be a
                 // character variable;
```

Assignment Statements

```
x = 1;               // Assign 1 to x;
radius = 1.0;        // Assign 1.0 to radius;
a = 'A';             // Assign 'A' to a;
```

Declaring and Initializing in One Step

- `int x = 1;`
- `double d = 1.4;`

Named Constants

```
final datatype CONSTANTNAME = VALUE;

final double PI = 3.14159;
final int SIZE = 3;
```

Naming Conventions

- **Choose meaningful and descriptive names.**

- **variables and method names:**
  - **Use lowercase. If the name consists of several words, concatenate all in one, use lowercase for the first word, and capitalize the first letter of each subsequent word in the name. For example, the variables `radius` and `area`, and the method `computeArea`.**

Naming Conventions, cont.

- **Class names:**
  - **Capitalize the first letter of each word in the name. For example, the class name `ComputeArea`.**
- **Constants:**
  - **Capitalize all letters in constants, and use underscores to connect words. For example, the constant `PI and` MAX_VALUE**

Data Types

- Data Types
  - Primitive types
    - 数值类型 (Numerical Data Types)
      - 整数类型(byte, short, int, long)
      - 浮点类型(float,double)
    - 字符类型(char)
    - 布尔类型（boolean）
  - Reference types
    - 类(class)
    - 接口(interface)
    - 数组(array)

Numerical Data Types

Name	Range	Storage Size
`byte`	-2^7 to $2^7 - 1$ (-128 to 127)	8-bit signed
`short`	-2^{15} to $2^{15} - 1$ (-32768 to 32767)	16-bit signed
`int`	-2^{31} to $2^{31} - 1$ (-2147483648 to 2147483647)	32-bit signed
`long`	-2^{63} to $2^{63} - 1$ (i.e., -9223372036854775808 to 9223372036854775807)	64-bit signed
`float`	Negative range: -3.4028235E+38 to -1.4E-45 Positive range: 1.4E-45 to 3.4028235E+38	32-bit IEEE 754
`double`	Negative range: -1.7976931348623157E+308 to -4.9E-324 Positive range: 4.9E-324 to 1.7976931348623157E+308	64-bit IEEE 754

There is NO UNSIGNED integer type in Java

Integer

- **Decimal： 124， -100；**
- **Octal： 0 as prefix, followed by 0~7 : ex. 0134；**
- **Hexadecimal： 0x or 0X as prefix, followed by 0~9 or A~F。**

Reading Numbers from the Keyboard

```
Scanner input = new Scanner(System.in);
int value = input.nextInt();
```

Method	Description
`nextByte()`	reads an integer of the **`byte`** type.
`nextShort()`	reads an integer of the **`short`** type.
`nextInt()`	reads an integer of the **`int`** type.
`nextLong()`	reads an integer of the **`long`** type.
`nextFloat()`	reads a number of the **`float`** type.
`nextDouble()`	reads a number of the **`double`** type.

Numeric Operators

Name	Meaning	Example	Result
+	Addition	34 + 1	35
-	Subtraction	34.0 - 0.1	33.9
*	Multiplication	300 * 30	9000
/	Division	1.0 / 2.0	0.5
%	Remainder	20 % 3	2

Integer Division

+, -, *, /, and %

5 / 2 yields an integer 2.

5.0 / 2 yields a double value 2.5

5 % 2 yields 1 (the remainder of the division)

Problem: Displaying Time

Write a program that obtains minutes and remaining seconds from seconds.

DisplayTime

Floating-Point numbers

Calculations involving floating-point numbers are approximated because these numbers are not stored with complete accuracy.

calculations with integers yield a precise integer result.

double vs. float

The double type values are more accurate than the float type values. For example,

```
System.out.println("1.0 / 3.0 is " + 1.0 / 3.0);
```

S	e’(11bit)	M’(52bit)

```
System.out.println("1.0F / 3.0F is " + 1.0F / 3.0F);
```

S	e’(8bit)	M’(23bit)

Exponent Operations

```
System.out.println(Math.pow(2, 3));
// Displays 8.0
System.out.println(Math.pow(4, 0.5));
// Displays 2.0
System.out.println(Math.pow(2.5, 2));
// Displays 6.25
System.out.println(Math.pow(2.5, -2));
// Displays 0.16
```

Number Literals

A *literal* is a constant value that appears directly in the program.

int i = 34;

long x = 1000000;

double d = 5.0;

Integer Literals

An integer literal can be assigned to an integer variable as long as it can fit into the variable. A compilation error would occur if the literal were too large for the variable to hold.

An integer literal is assumed to be of the int type, whose value is between -2^{31} (-2147483648) to $2^{31}–1$ (2147483647).

Integer literal of the long type, append it with the letter L or l.

Floating-Point Literals

Floating-point literals are written with a decimal point. By default, a floating-point literal is treated as a double type value.

You can make a number a float by appending the letter f or F, and make a number a double by appending the letter d or D.

100.2f or 100.2F for a float number

100.2d or 100.2D for a double number

Scientific Notation

Floating-point literals can also be specified in scientific notation,

1.23456e+2, or 1.23456e2, is equivalent to 123.456

1.23456e-2 is equivalent to 0.0123456

Arithmetic Expressions

$$\boxed{\frac{3+4x}{5} - \frac{10(y-5)(a+b+c)}{x} + 9(\frac{4}{x} + \frac{9+x}{y})}$$

is translated to

(3+4*x)/5 – 10*(y-5)*(a+b+c)/x + 9*(4/x + (9+x)/y)

How to Evaluate an Expression

You can safely apply the arithmetic rule for evaluating a Java expression.

The result of a Java expression and its corresponding arithmetic expression are the same.

```
3 + 4 * 4 + 5 * (4 + 3) - 1
                    (1) inside parentheses first
3 + 4 * 4 + 5 * 7 - 1
                    (2) multiplication
3 + 16 + 5 * 7 - 1
                    (3) multiplication
3 + 16 + 35 - 1
                    (4) addition
19 + 35 - 1
                    (5) addition
    54 - 1
                    (6) subtraction
    53
```

Problem: Converting Temperatures

Write a program that converts a Fahrenheit degree to Celsius using the formula:

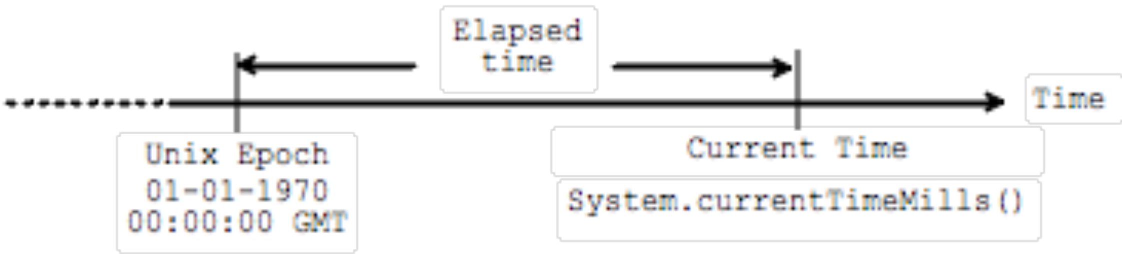
$$celsius = (\tfrac{5}{9})(fahrenheit - 32)$$

Note: you have to write
celsius = (5.0 / 9) * (fahrenheit – 32)

Problem: Showing Current Time

Write a program that displays current time in GMT in the format hour:minute:second such as 1:45:19.

Using *currentTimeMillis()* method in *System* class returns the current time in milliseconds since the midnight, January 1, 1970 GMT.



ShowCurrentTime.java

Augmented Assignment Operators

Operator	*Name*	*Example*	*Equivalent*
`+=`	Addition assignment	`i += 8`	`i = i + 8`
`-=`	Subtraction assignment	`i -= 8`	`i = i - 8`
`*=`	Multiplication assignment	`i *= 8`	`i = i * 8`
`/=`	Division assignment	`i /= 8`	`i = i / 8`
`%=`	Remainder assignment	`i %= 8`	`i = i % 8`

Increment and Decrement Operators

Operator	*Name*	*Description*	*Example (assume i = 1)*
`++var`	preincrement	Increment `var` by `1`, and use the new `var` value in the statement	`int j = ++i;` `// j is 2, i is 2`
`var++`	postincrement	Increment `var` by `1`, but use the original `var` value in the statement	`int j = i++;` `// j is 1, i is 2`
`--var`	predecrement	Decrement `var` by `1`, and use the new `var` value in the statement	`int j = --i;` `// j is 0, i is 0`
`var--`	postdecrement	Decrement `var` by `1`, and use the original `var` value in the statement	`int j = i--;` `// j is 1, i is 0`

Increment and Decrement Operators, cont.

```
int i = 10;
int newNum = 10 * i++;
```

Same effect as

```
int newNum = 10 * i;
i = i + 1;
```

```
int i = 10;
int newNum = 10 * (++i);
```

Same effect as

```
i = i + 1;
int newNum = 10 * i;
```

Increment and Decrement Operators, cont.

Using increment and decrement operators makes expressions short, but it also makes them complex and difficult to read.

int k = ++i + i.

Assignment Expressions and Assignment Statements

Prior to Java 2, all the expressions can be used as statements.

Since Java 2, only the following types of expressions can be statements:

variable op= expression; // Where op is +, -, *, /, or %

++variable;

variable++;

--variable;

variable--;

Numeric Type Conversion

Consider the following statements:

```
byte i = 100;
long k = i * 3 + 4;
double d = i * 3.1 + k / 2;
```

Conversion Rules

When performing a binary operation involving two operands of different types, Java automatically converts the operand based on the following rules:

1. If one of the operands is double, the other is converted into double.
2. Otherwise, if one of the operands is float, the other is converted into float.
3. Otherwise, if one of the operands is long, the other is converted into long.
4. An integer literal can be assigned to an integer variable as long as it can fit into the variable.
5. Otherwise, both operands are converted into int.

Type Casting

Implicit casting

`double d = 3;` (type widening)

Explicit casting

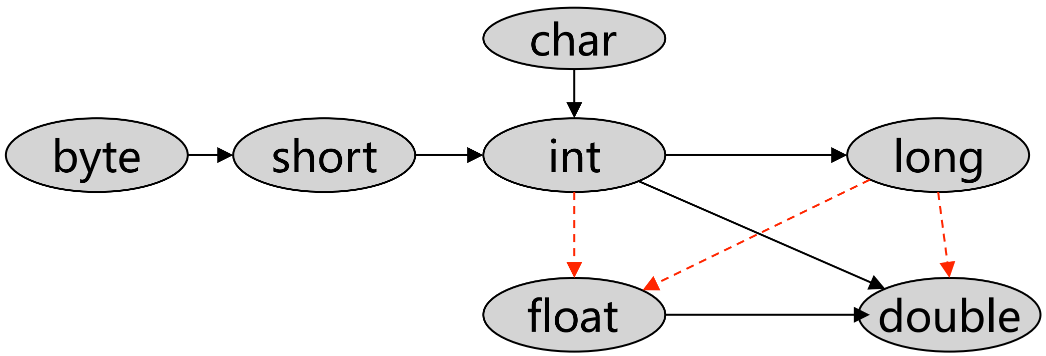
`int i = (int)3.0;` (type narrowing)

`int i = (int)3.9;` (Fraction part is truncated)

What is wrong? ***int x = 5 / 2.0;***

Narrowing -- --->Widening

byte, short, char---> int--> long--> float--> double



Casting in an Augmented Expression

An augmented expression of the form x1 op= x2 is implemented as x1 = (T)(x1 op x2), where T is the type for x1.

Therefore

int *sum =* ***0****;*
sum **+=** ***4.5;***

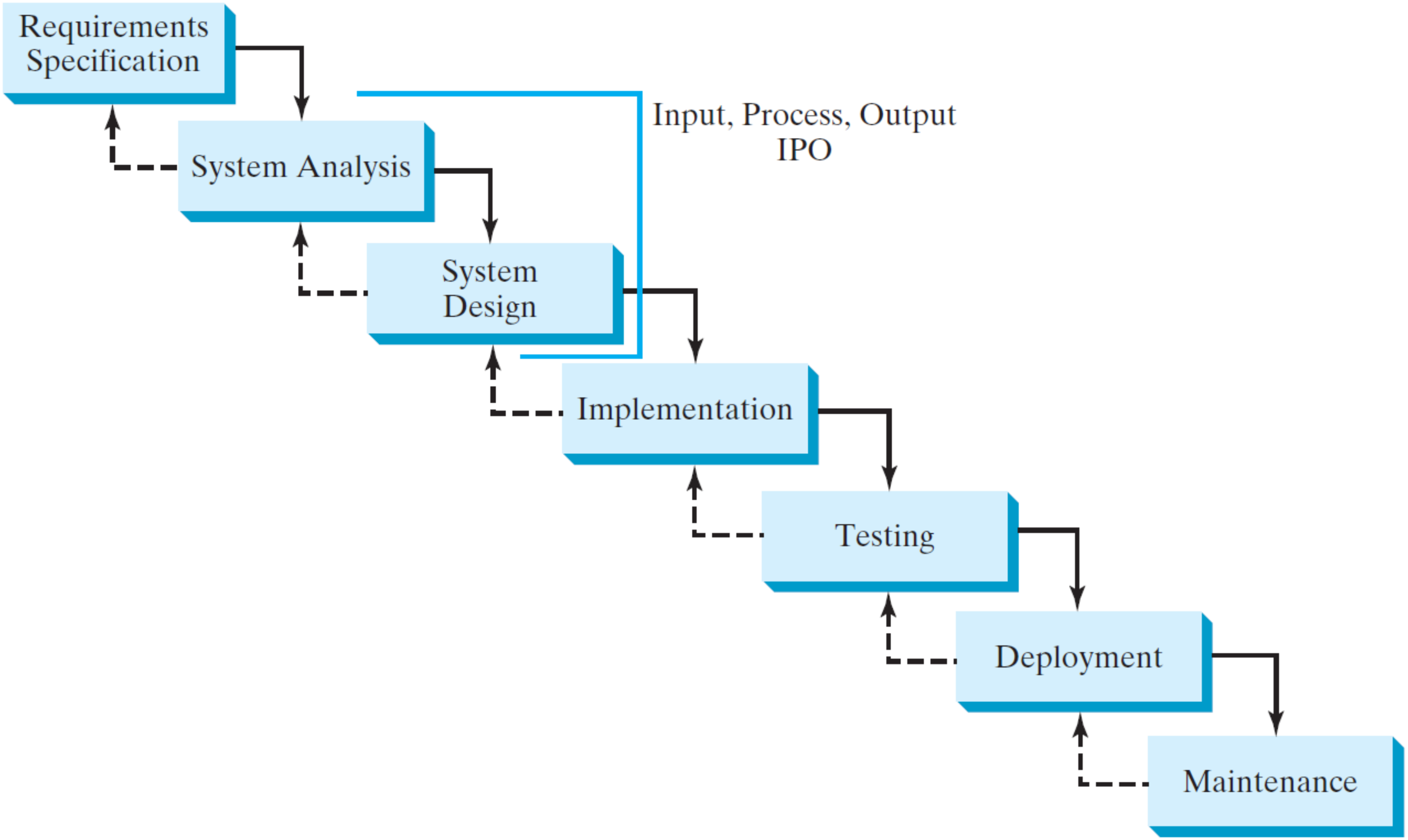
is correct

sum **+=** ***4.5*** is equivalent to ***sum = (int)(sum*** **+** ***4.5)***
// sum becomes 4 after this statement

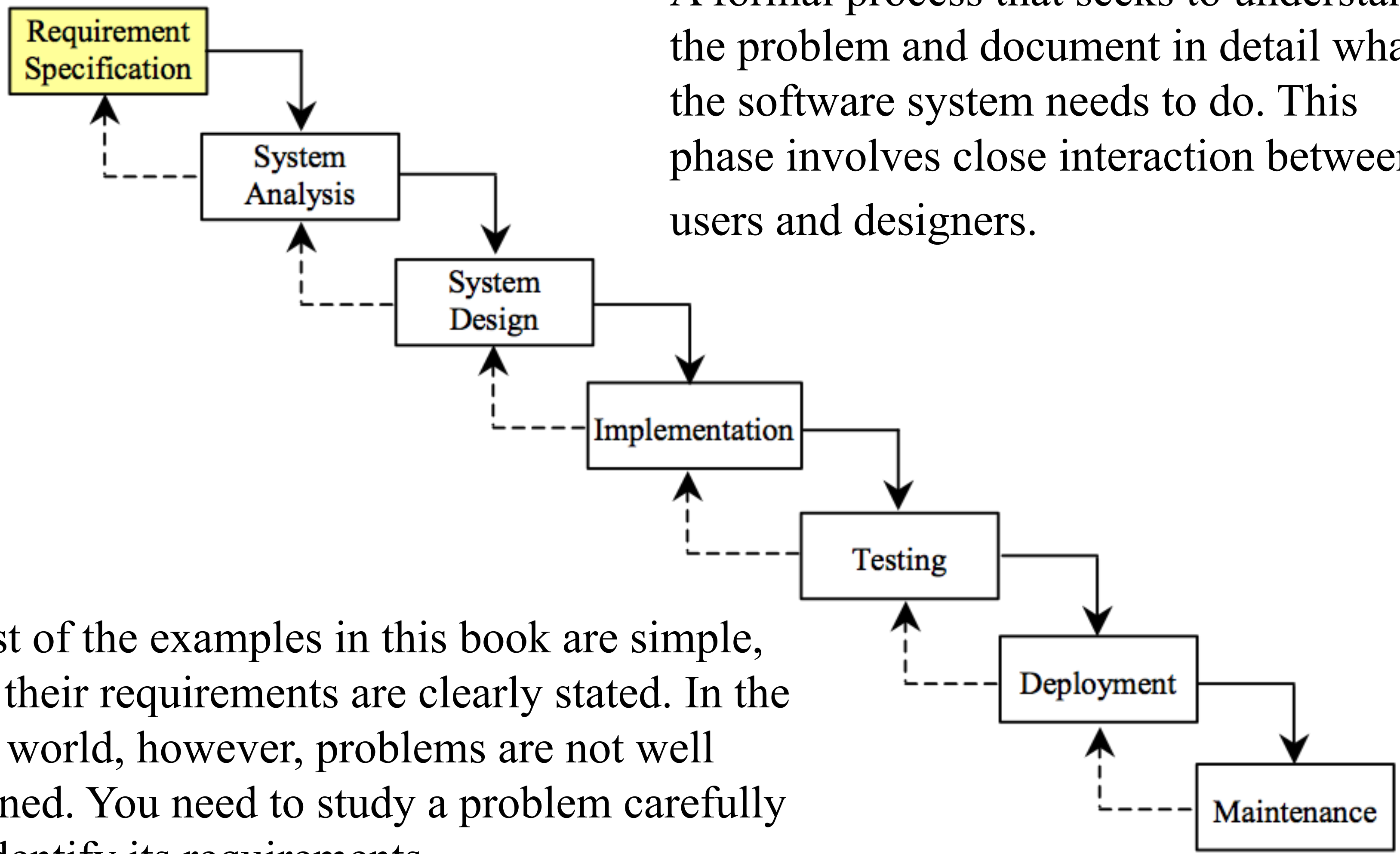
Boolean type and operators

- ***boolean b=false;***
- ***true and false are literals***

Software Development Process *



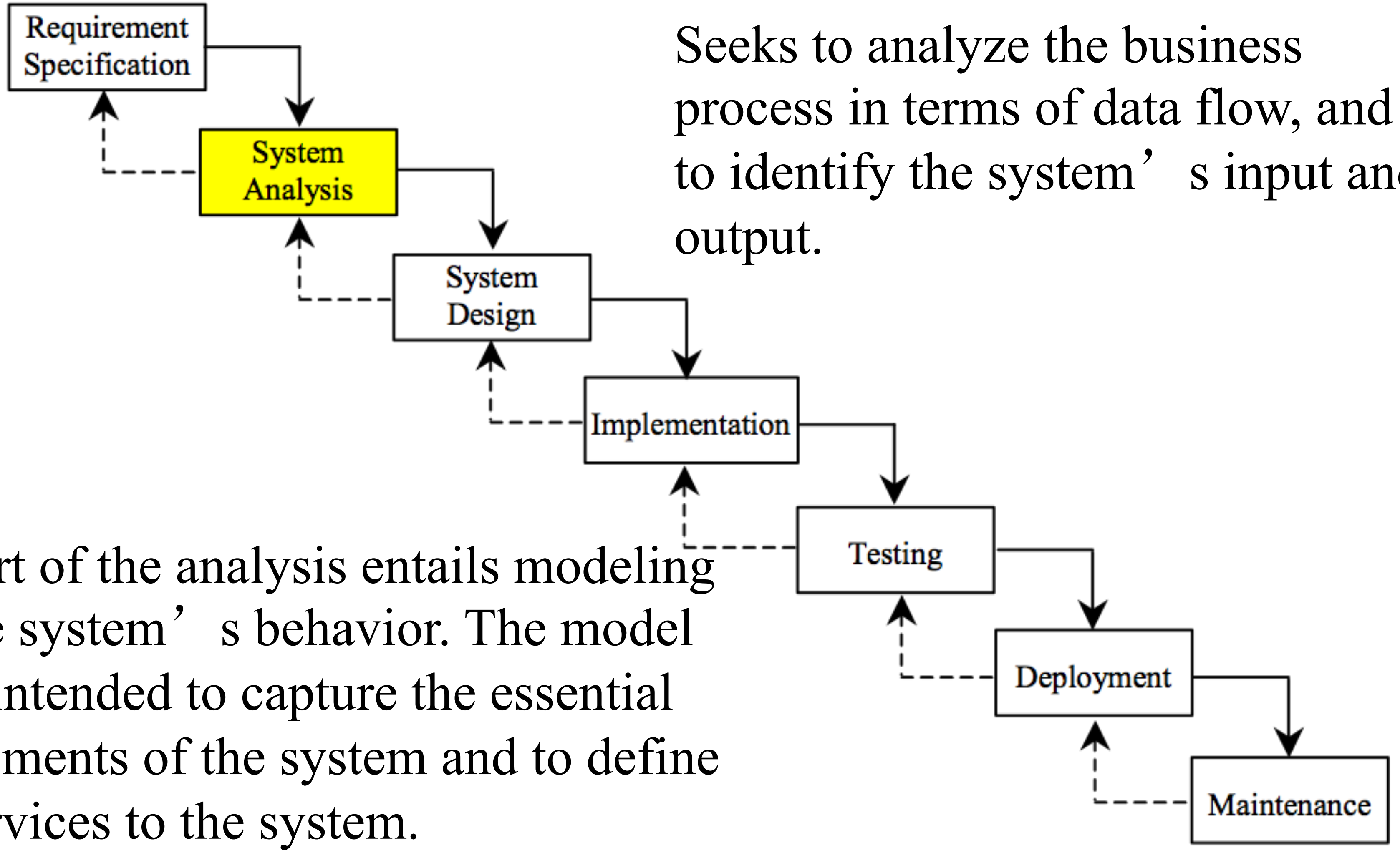
Requirement Specification *



A formal process that seeks to understand the problem and document in detail what the software system needs to do. This phase involves close interaction between users and designers.

Most of the examples in this book are simple, and their requirements are clearly stated. In the real world, however, problems are not well defined. You need to study a problem carefully to identify its requirements.

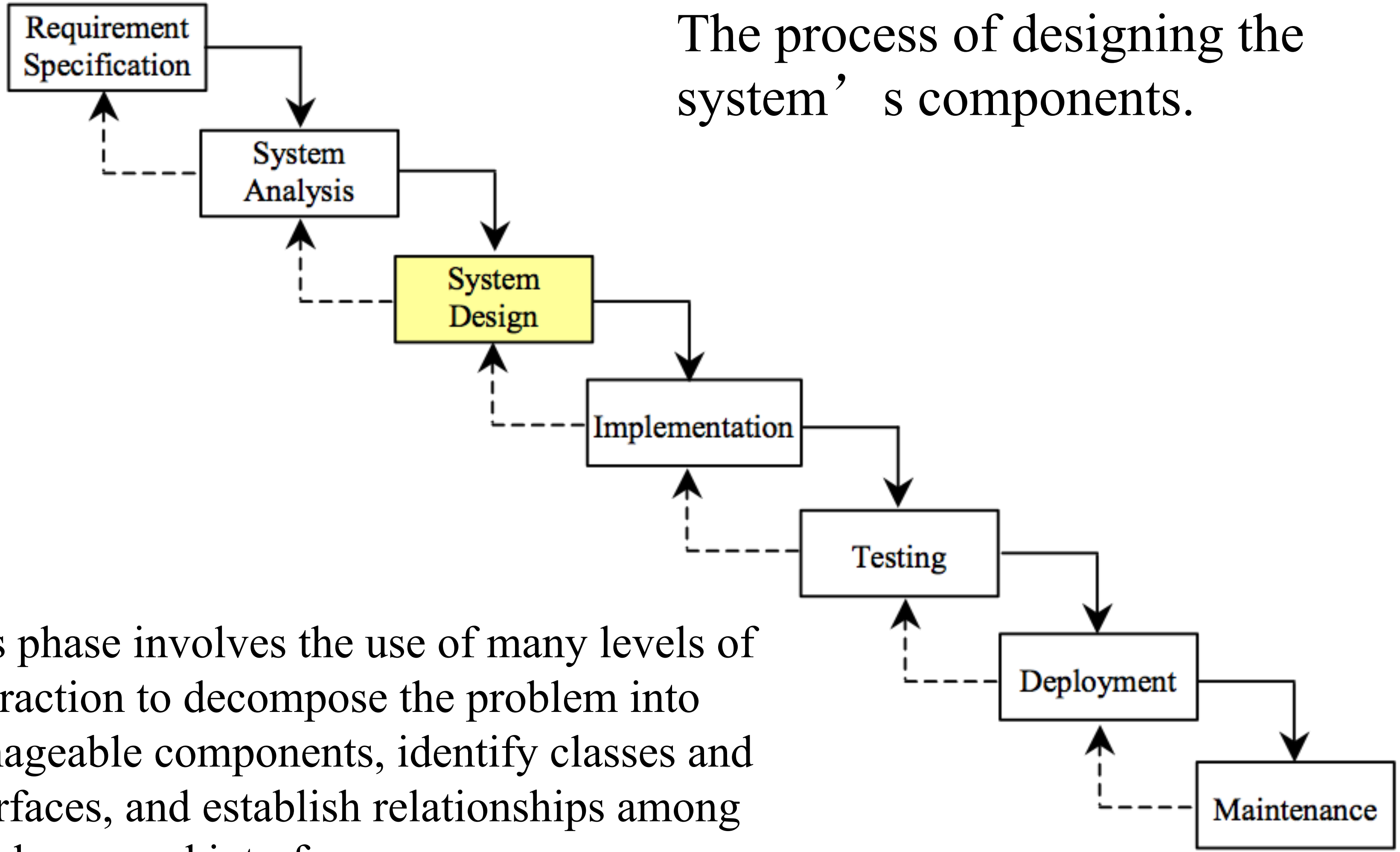
System Analysis *



Seeks to analyze the business process in terms of data flow, and to identify the system’ s input and output.

Part of the analysis entails modeling the system’ s behavior. The model is intended to capture the essential elements of the system and to define services to the system.

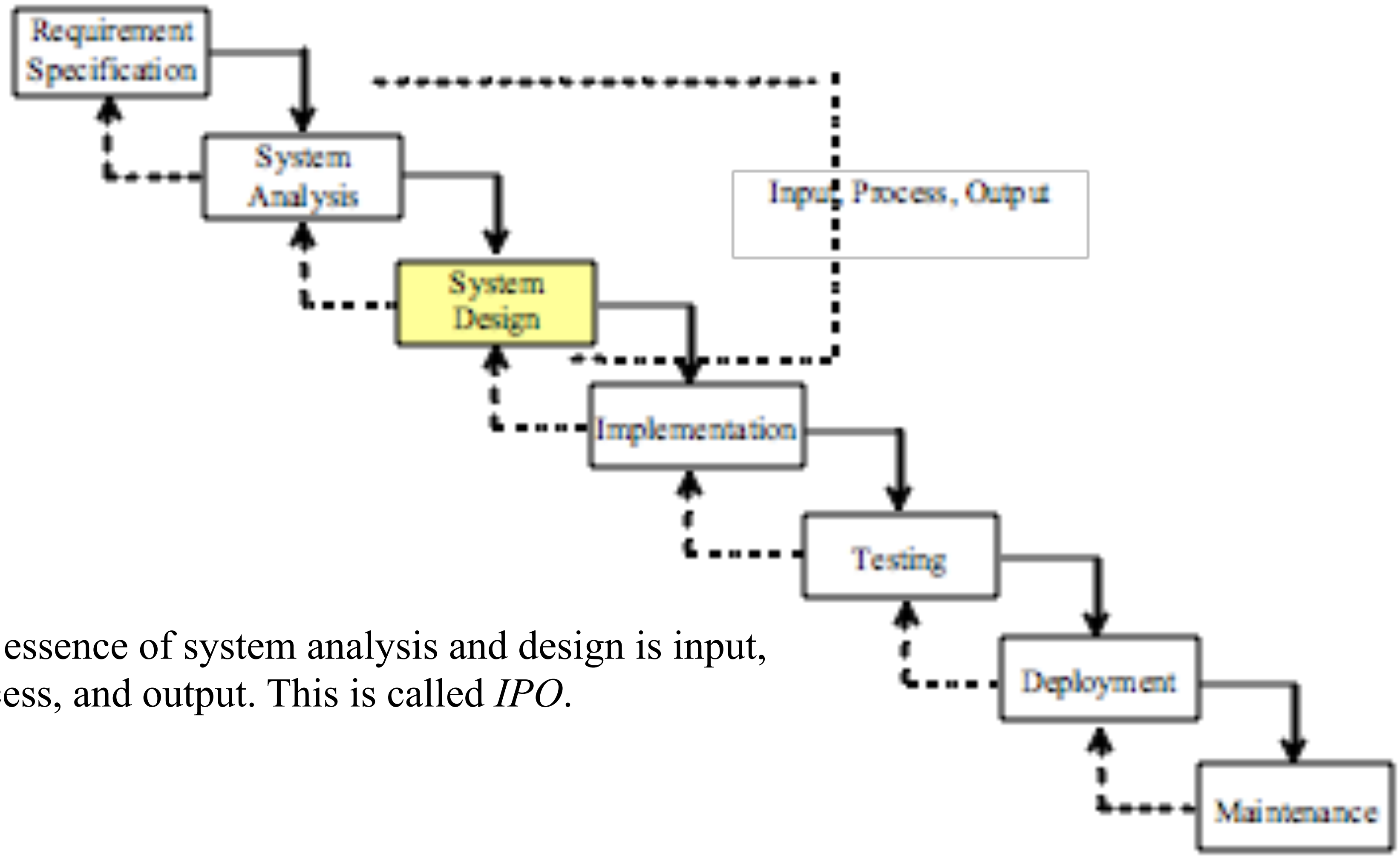
System Design *



The process of designing the system’ s components.

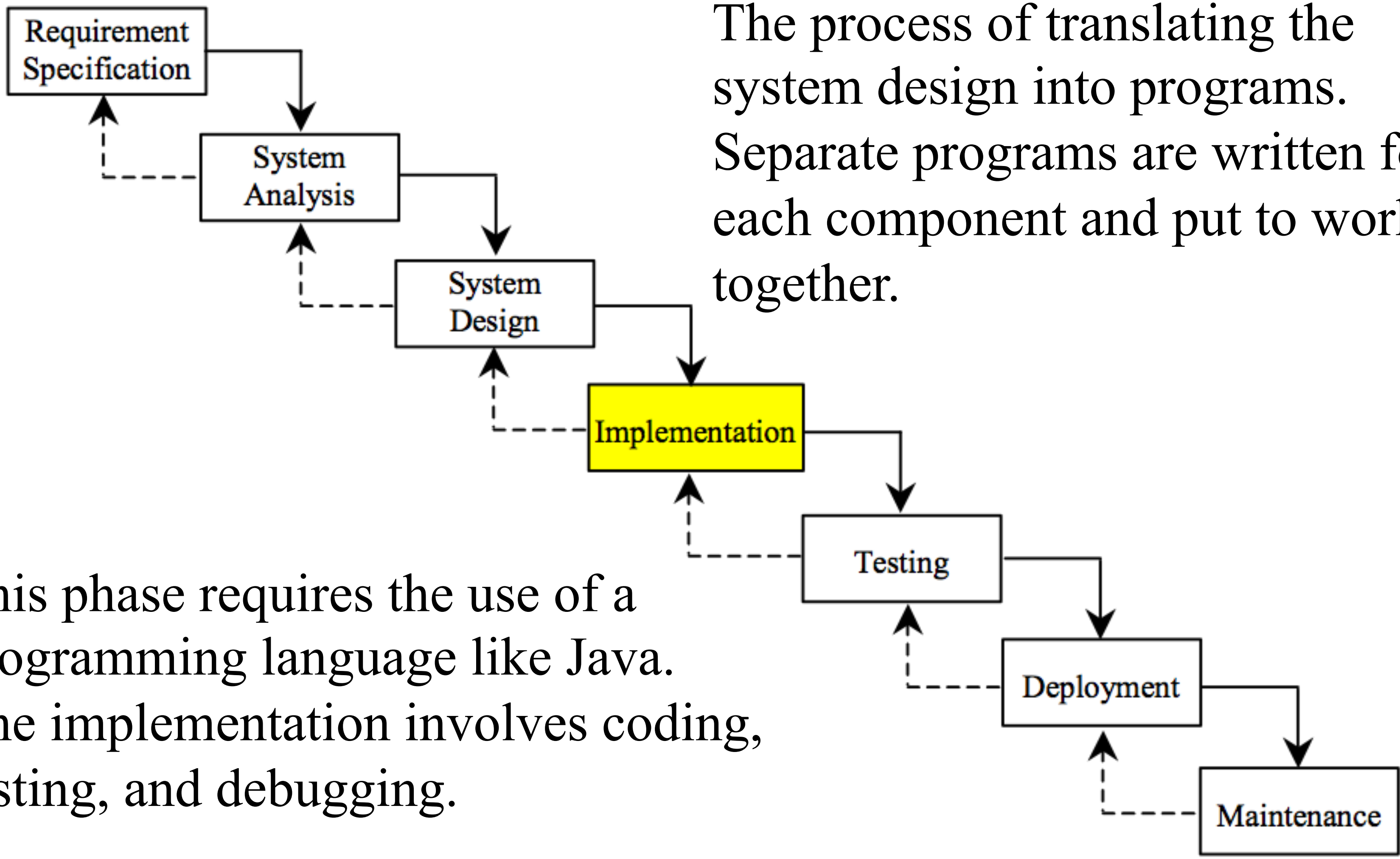
This phase involves the use of many levels of abstraction to decompose the problem into manageable components, identify classes and interfaces, and establish relationships among the classes and interfaces.

IPO *



The essence of system analysis and design is input, process, and output. This is called *IPO*.

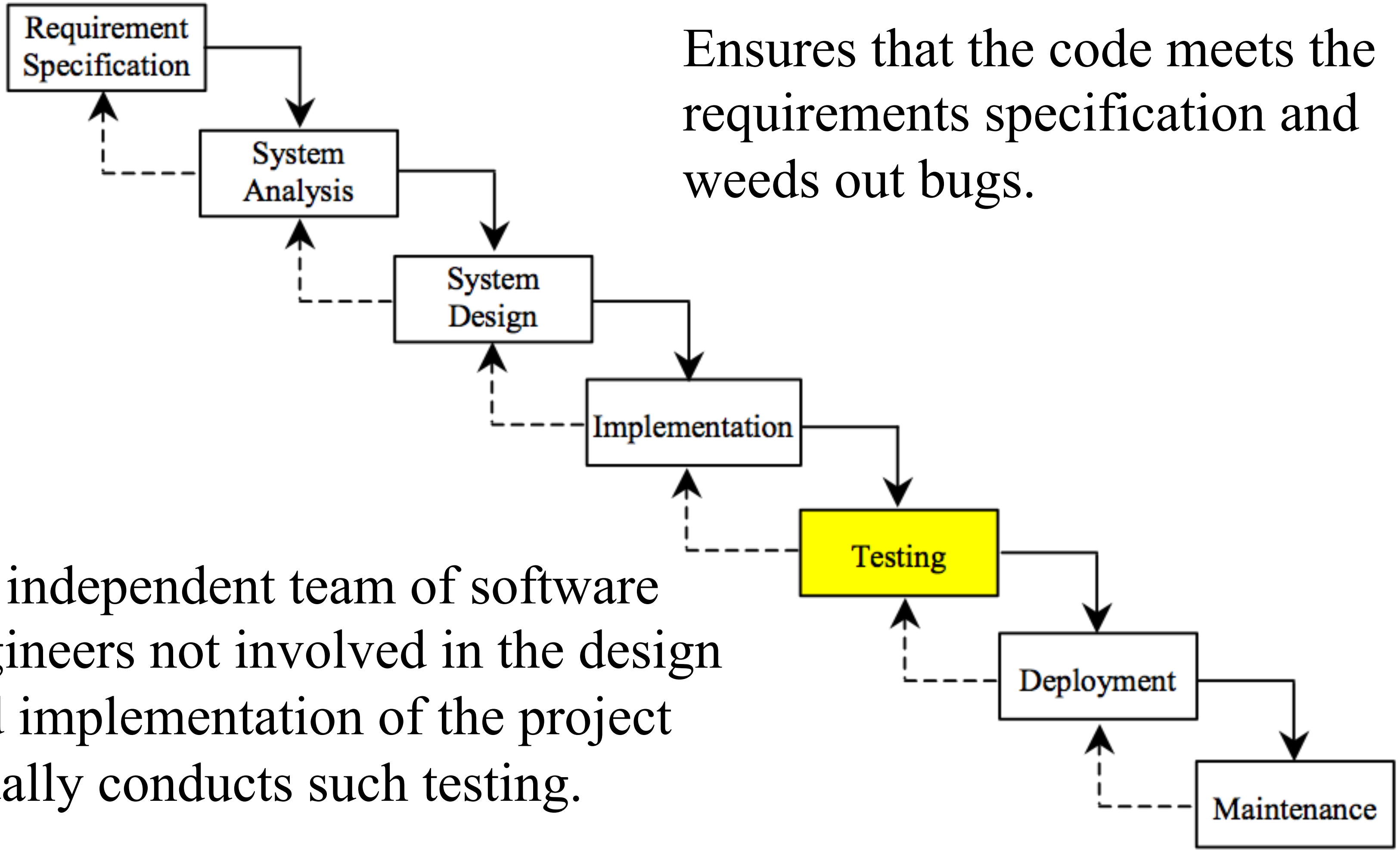
Implementation *



The process of translating the system design into programs. Separate programs are written for each component and put to work together.

This phase requires the use of a programming language like Java. The implementation involves coding, testing, and debugging.

Testing *

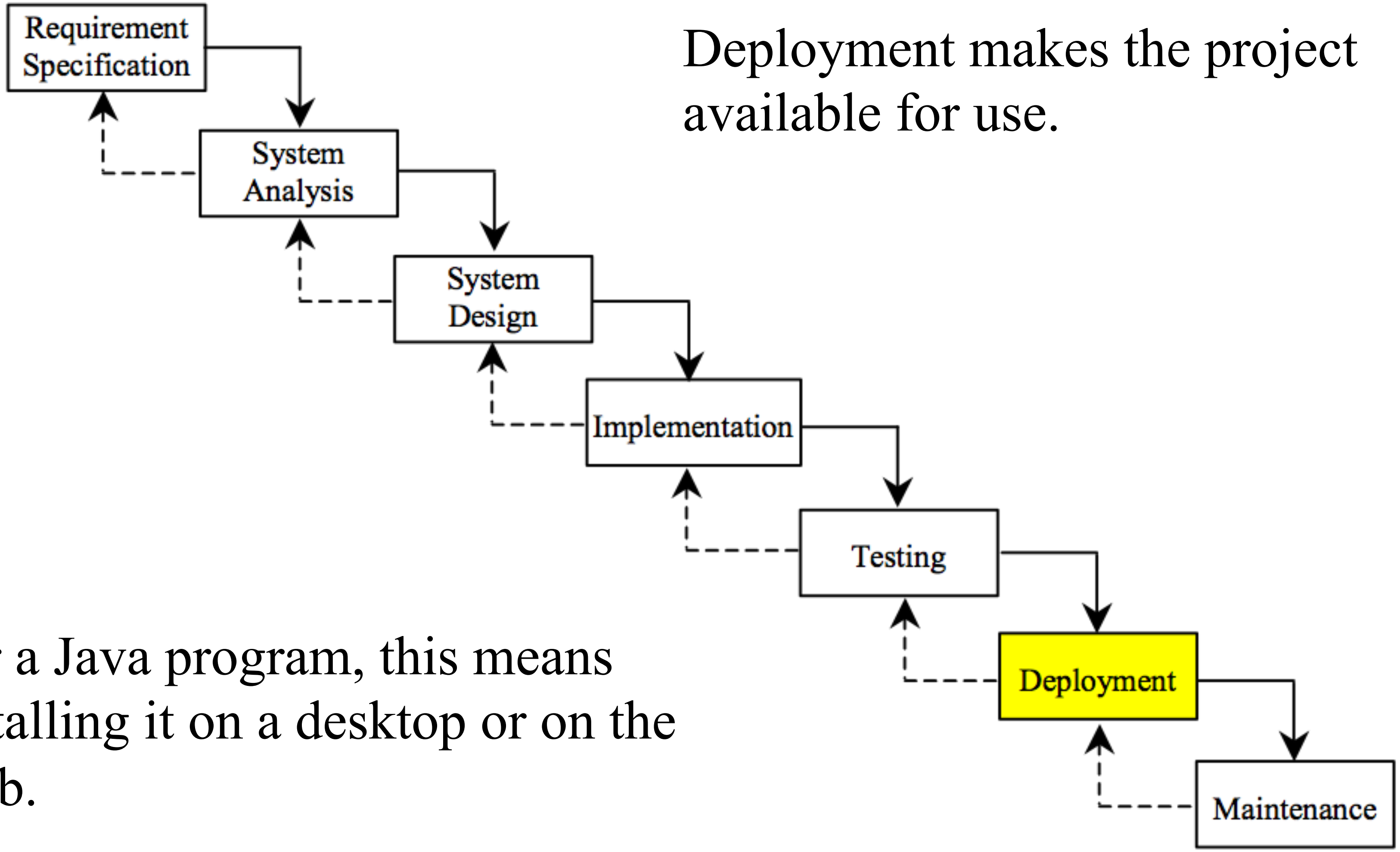


Ensures that the code meets the requirements specification and weeds out bugs.

An independent team of software engineers not involved in the design and implementation of the project usually conducts such testing.

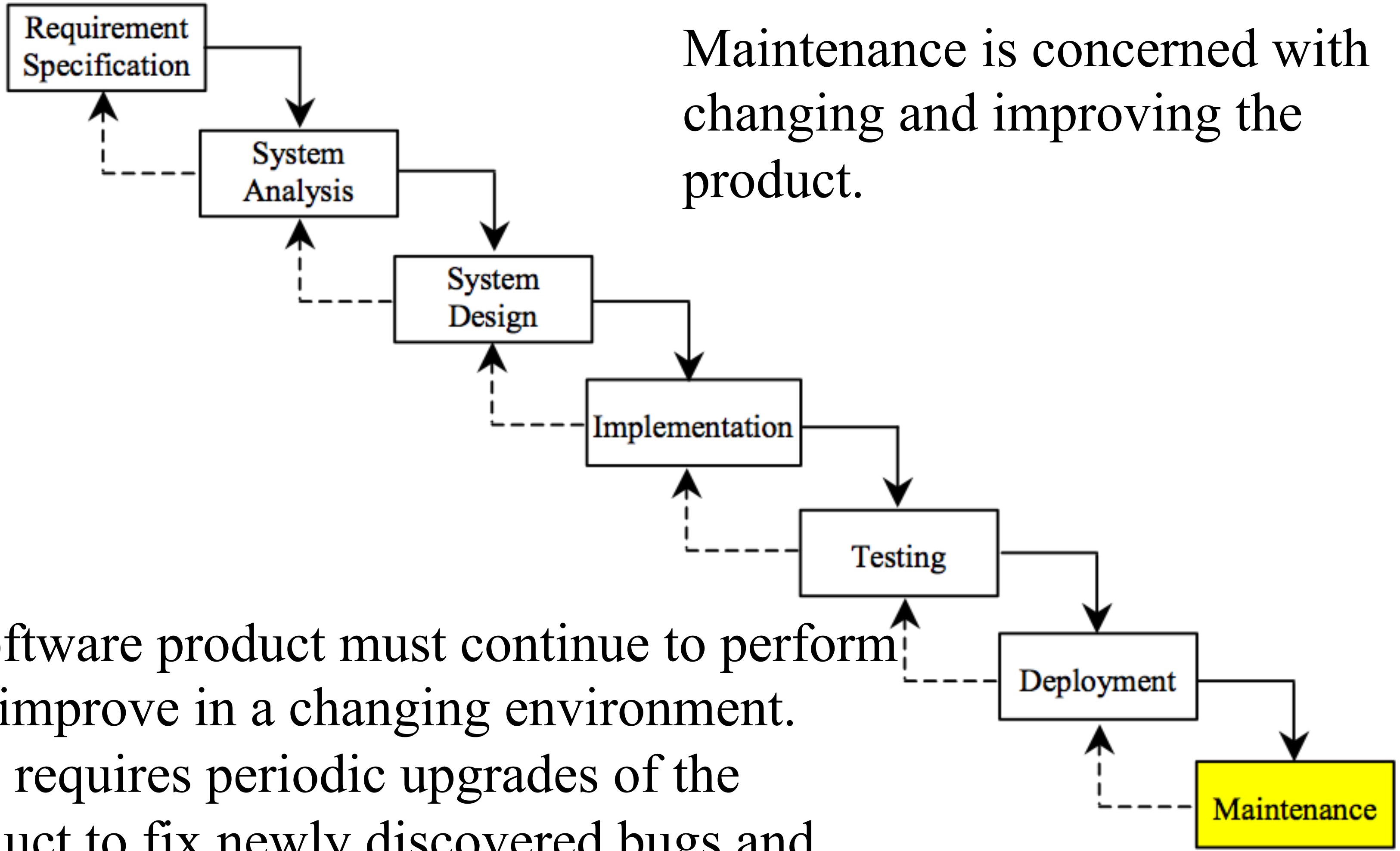
Deployment *

Deployment makes the project available for use.



For a Java program, this means installing it on a desktop or on the Web.

Maintenance *



Maintenance is concerned with changing and improving the product.

A software product must continue to perform and improve in a changing environment. This requires periodic upgrades of the product to fix newly discovered bugs and incorporate changes.

Problem: Computing Loan Payments

This program lets the user enter the interest rate, number of years, and loan amount, and computes monthly payment and total payment.

$$monthlyPayment = \frac{loanAmount \times monthlyInterestRate}{1 - \frac{1}{(1 + monthlyInterestRate)^{numberOfYears \times 12}}}$$

Problem: Monetary Units

This program lets the user enter the amount in decimal representing dollars and cents and output a report listing the monetary equivalent in single dollars, quarters, dimes, nickels, and pennies.

Supplement reading: Common Errors and Pitfalls

- Common Error 1: Undeclared/Uninitialized Variables and Unused Variables
- Common Error 2: Integer Overflow
- Common Error 3: Round-off Errors
- Common Error 4: Unintended Integer Division
- Common Error 5: Redundant Input Objects

- Common Pitfall 1: Redundant Input Objects

Common Error 1: Undeclared/Uninitialized Variables and Unused Variables

double *interestRate =* ***0.05****;*

double *interest = interestrate* **** 45****;*

Common Error 2: Integer Overflow

int *value =* ***2147483647*** *+* ***1****;*

// value will actually be -2147483648

Common Error 3: Round-off Errors

*System.out.println(**1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1**);*

*System.out.println(**1.0 - 0.9**);*

Common Error 4: Unintended Integer Division

int *number1 = 1;*

int *number2 = 2;*

double *average=(number1+number2) / 2;*

double *average=(number1+number2) / 2.0;*

Common Pitfall 1: Redundant Input Objects

```
Scanner input = new Scanner(System.in);
System.out.print("Enter an integer: ");
int v1 = input.nextInt();

Scanner input1 = new Scanner(System.in);
System.out.print("Enter a double value: ");
double v2 = input1.nextDouble();
```

Exercise 02

2.1 财务应用：计算未来投资值

编写程序，读取投资总额、年利率和年数，然后使用下面的公式来显示未来投资金额：

未来投资金额=投资总额×（1+月利率）$^{年数\times 12}$

例如：如果输入的投资金额为**1000**，年利率为**3.25%**，年数为**1**，那么未来投资额为**1032.98**。

2.2 求出年数

编写程序，提示用户输入分钟数（例如十亿），然后显示这些分钟代表多少年和多少天。

为了简化问题，假设一年有**365**天。

`//Submission Deadline: the Next Monday(10/16/2017 9:00am)`