Introduction to Java Programming (for Novices & First-Time Programmers)

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JDK

You should have already installed Java Development Kit (JDK) and written a "Hello-world" program. Otherwise, Read "How to Install JDK".

Programming Text Editor

Do NOT use Notepad (Windows) or TextEdit (macOS) for programming. Install a *programming* text editor, which does syntax color highlighting. For example,

- For Windows: Sublime Text, Atom, NotePad++, TextPad.
- For macOS: Sublime Text, Atom, jEdit, gEdit.
- For Ubuntu: gEdit.

1. Getting Started - Your First Java Program

Let us revisit the "Hello-world" program that prints a message "`Hello, world!`" to the display console.

Step 1: Write the Source Code: Enter the following source codes, which defines a *class* called "`Hello`", using a programming text editor. Do not enter the line numbers (on the left pane), which were added to aid in the explanation.

Save the source file as "`Hello.java`". A Java source file should be saved with a file extension of "`.java`". The filename shall be the same as the classname - in this case "`Hello`". Filename and classname are *case-sensitive*.

```
1   /*
2    * First Java program, which says hello.
3    */
4   public class Hello {   // Save as "Hello.java"
5      public static void main(String[] args) {  // Program entry point
6         System.out.println("Hello, world!");   // Print text message
7      }
8   }
```

Step 2: Compile the Source Code: Compile the source code "`Hello.java`" into Java bytecode (or machine code) "`Hello.class`" using JDK's Java Compiler "`javac`".

Start a CMD Shell (Windows) or Terminal (UNIX/Linux/macOS) and issue these commands:

```
// Change directory (cd) to the directory (folder) containing the source file "Hello.java"
javac Hello.java
```

Step 3: Run the Program: Run the machine code using JDK's Java Runtime "`java`", by issuing this command:

```
java Hello
Hello, world!
```

How it Works

`/* ...... */`
`// ... until the end of the current line`

These are called *comments*. Comments are NOT executable and are ignored by the compiler. But they provide useful explanation and documentation to your readers (and to yourself three days later). There are two kinds of comments:

1. *Multi-Line Comment*: begins with `/*` and ends with `*/`, and may span more than one lines (as in Lines 1-3).
2. *End-of-Line (Single-Line) Comment*: begins with `//` and lasts until the end of the current line (as in Lines 4, 5, and 6).

```
public class Hello {
   ......
}
```

The basic unit of a Java program is a *class*. A class called "`Hello`" is defined via the keyword "`class`" in Lines 4-8. The braces `{......}` encloses the *body* of the class.

In Java, the name of the source file must be the same as the name of the class with a mandatory file extension of "`.java`". Hence, this file MUST be saved as "`Hello.java`" - case-sensitive.

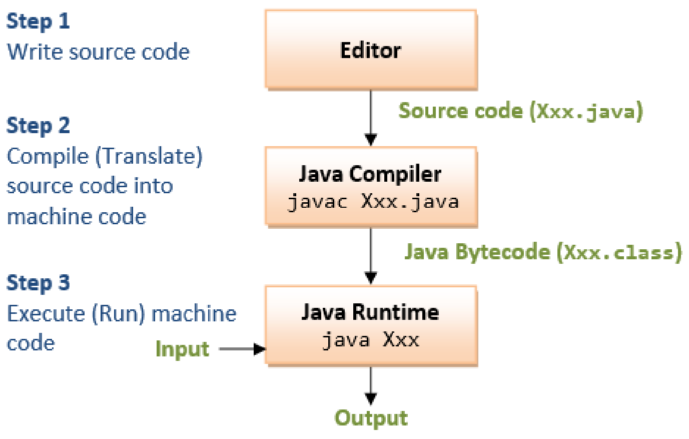
```
public static void main(String[] args) {
   ......
}
```

Lines 5-7 defines the so-called `main()` *method*, which is the *entry point* for program execution. Again, the braces `{......}` encloses the *body* of the method, which contains programming statements.

```
System.out.println("Hello, world!");
```

In Line 6, the programming statement `System.out.println("Hello, world!")` is used to print the string "`Hello, world!`" to the display console. A *string* is surrounded by a pair of double quotes and contain texts. The text will be printed as it is, without the double quotes. A programming statement ends with a semi-colon (`;`).

2. Java Programming Steps



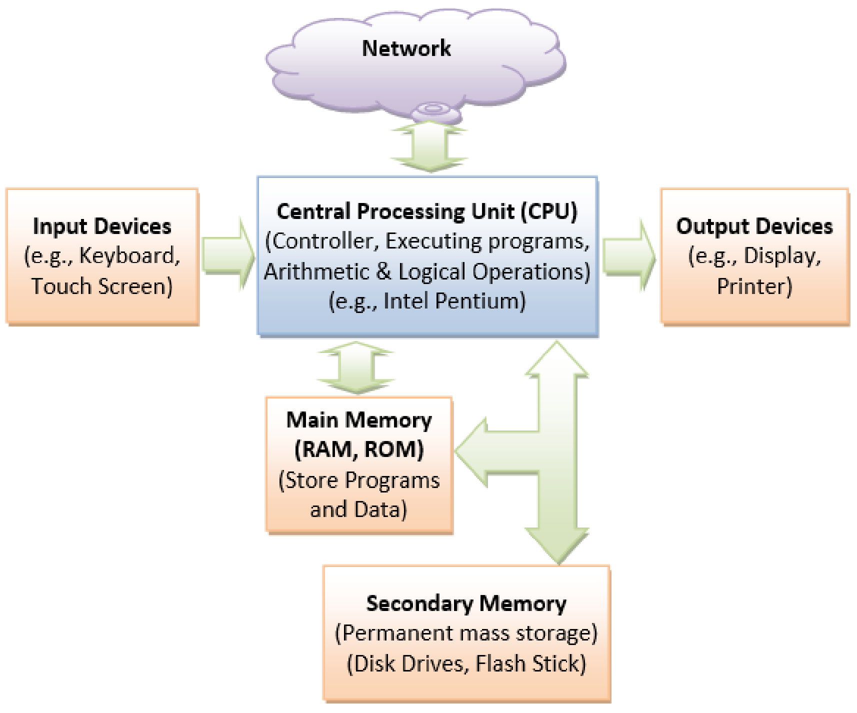
The steps in writing a Java program is illustrated as above:

Step 1: Write the source code "`Xxx.java`".

Step 2: Compile the source code "`Xxx.java`" into Java portable bytecode (or machine code) "`Xxx.class`" using the JDK's Java compiler by issuing the command "`javac Xxx.java`".

Step 3: Run the compiled bytecode "`Xxx.class`", using the JDK's Java Runtime by issuing the command "`java Xxx`".

3. Computer Architecture


Network
Central Processing Unit (CPU)
(Controller, Executing programs, Arithmetic & Logical Operations)
(e.g., Intel Pentium)
Input Devices
(e.g., Keyboard, Touch Screen)
Output Devices
(e.g., Display, Printer)
Main Memory
(RAM, ROM)
(Store Programs and Data)
Secondary Memory
(Permanent mass storage)
(Disk Drives, Flash Stick)

The *Central Processing Unit* (CPU) is the *heart* of a computer, which serves as the overall controller of the computer system. It fetches programs/data from main memory and executes the programs. It performs the arithmetic and logical operations (such as addition and multiplication).

The *Main Memory* stores the programs and data for execution by the CPU. It consists of RAM (Random Access Memory) and ROM (Read-Only Memory). RAM is volatile, which losses all its contents when the power is turned off. ROM is non-volatile, which retains its contents when the power is turned off. ROM is read-only and its contents cannot be changed once initialized. RAM is read-write. RAM and ROM are expensive. Hence, their amount is quite limited.

The *Secondary Memory*, such as disk drives and flash sticks, is less expensive and is used for *mass* and *permanent* storage of programs and data (including texts, images and video). However, the CPU can only run programs from the main memory, not the secondary memory.

When the power is turned on, a small program stored in ROM is executed to fetch the essential programs (called operating system) from the secondary memory to the main memory, in a process known as *booting*. Once the operating system is loaded into the main memory, the computer is ready for use. This is, it is ready to fetch the desired program from the secondary memory to the main memory for execution upon user's command.

The CPU can read data from the Input devices (such as keyboard or touch pad) and write data to the Output devices (such as display or printer). It can also read/write data through the network interfaces (wired or wireless).

You job as a programmer is to write programs, to be executed by the CPU to accomplish a specific task.

4. Java Terminology and Syntax

Comments: A *multi-line comment* begins with `/*` and ends with `*/`, and may span multiple lines. An *end-of-line (single-line) comment* begins with `//` and lasts till the end of the current line. Comments are NOT executable statements and are ignored by the compiler. But they provide useful explanation and documentation. I strongly suggest that you write comments *liberally* to explain your thought and logic.

Statement: A programming *statement* performs a single piece of programming action. It is terminated by a semi-colon (`;`), just like an English sentence is ended with a period, as in Lines 6.

Block: A *block* is a group of programming statements enclosed by a pair of braces `{}`. This group of statements is treated as one single unit. There are two blocks in the above program. One contains the *body* of the class `Hello`. The other contains the *body* of the `main()` method. There is no need to put a semi-colon after the closing brace.

Whitespaces: Blank, tab, and newline are collectively called *whitespace*. Extra whitespaces are ignored, i.e., only one whitespace is needed to separate the tokens. Nonetheless, extra whitespaces improve the readability, and I strongly suggest you use extra spaces and newlines to improve the readability of your code.

Case Sensitivity: Java is *case sensitive* - a *ROSE* is NOT a *Rose*, and is NOT a *rose*. The *filename*, which is the same as the class name, is also case-sensitive.

5. Java Program Template

You can use the following *template* to write your Java programs. Choose a meaningful "*Classname*" that reflects the *purpose* of your program, and write your programming statements inside the body of the `main()` method. Don't worry about the other terms and keywords now. I will explain them in due course. Provide comments in your program!

```java
/*
 * Comment to state the purpose of the program
 */
public class Classname {   // Choose a meaningful Classname. Save as "Classname.java"
   public static void main(String[] args) {  // Entry point of the program
      // Your programming statements here!!!
   }
}
```

6. Output via `System.out.println()` and `System.out.print()`

You can use `System.out.println()` (print-line) or `System.out.print()` to print text messages to the display console:

- `System.out.println(aString)` (print-line) prints *aString*, and advances the *cursor* to the beginning of the next line.
- `System.out.print(aString)` prints *aString* but places the cursor after the printed string.
- `System.out.println()` without parameter prints a *newline*.

Try the following program and explain the output produced:

```java
/*
 * Test System.out.println() (print-line) and System.out.print().
 */
public class PrintTest {   // Save as "PrintTest.java"
   public static void main(String[] args) {
      System.out.println("Hello world!");       // Advance the cursor to the beginning of next line after printing
      System.out.println("Hello world again!"); // Advance the cursor to the beginning of next line after printing
      System.out.println();                     // Print an empty line
      System.out.print("Hello world!");         // Cursor stayed after the printed string
      System.out.print("Hello world again!");   // Cursor stayed after the printed string
      System.out.println();                     // Print an empty line
      System.out.print("Hello,");
      System.out.print(" ");                    // Print a space
      System.out.println("world!");
      System.out.println("Hello, world!");
   }
}
```

Save the source code as "`PrintTest.java`" (which is the same as the classname). Compile and run the program.

The expected outputs are:

```
Hello world!
Hello world again!

Hello world!Hello world again!
Hello, world!
Hello, world!
```

Exercises using `System.out.println()`

1. Write 4 programs, called `PrintCheckerPattern`, `PrintSquarePattern`, `PrintTriangularPattern` and `PrintStarPattern` to print each of the following patterns. Use ONE `System.out.println(...)` (print-line) statement for EACH LINE of outputs. Take note that you need to print the preceding blanks.

```
* * * * *      * * * * *    * * * * *       *
 * * * * *     *       *     *     *     * *   * *
* * * * *      *       *      *   *         * *
 * * * * *     *       *       * *         *   *
* * * * *      * * * * *        *         *     *
   (a)            (b)          (c)           (d)
```

2. Write a program called `PrintSheepPattern` to print the following pattern:

```
          '__'
          (oo)
  /========//
 / || @@ ||
*  ||----||
   VV    VV
   ''    ''
```

7. Let's Write a Program to Add a Few Numbers

Let us write a program to add FIVE integers and display their sum, as follows:

```
 1  /*
 2   * Add five integers and display their sum.
 3   */
 4  public class FiveIntegerSum {   // Save as "FiveIntegerSum.java"
 5     public static void main(String[] args) {
 6        int number1 = 11;  // Declare 5 integer variables and assign a value
 7        int number2 = 22;
 8        int number3 = 33;
 9        int number4 = 44;
10        int number5 = 55;
11        int sum;  // Declare an integer variable called sum to hold the sum
12        sum = number1 + number2 + number3 + number4 + number5;  // Compute sum
13        System.out.print("The sum is ");  // Print a descriptive string
14                                          // Cursor stays after the printed string
15        System.out.println(sum);  // Print the value stored in variable sum
16                                  // Cursor advances to the beginning of next line
17     }
18  }
```

Save the source code as "`FiveIntegerSum.java`" (which is the same as the classname). Compile and run the program.

The expected output is:

```
The sum is 165
```

How It Works?

```
int number1 = 11;
int number2 = 22;
int number3 = 33;
int number4 = 44;
int number5 = 55;
```

These five statements declare five `int` (integer) *variables* called `number1`, `number2`, `number3`, `number4`, and `number5`; and *assign* values of 11, 22, 33, 44 and 55 to the variables respectively, via the so-called *assignment operator* `'='`.

Alternatively, you could declare many variables in one statement separated by commas, e.g.,

```
int number1 = 11, number2 = 22, number3 = 33, number4 = 44, number5 = 55;
```

```
int sum;
```

declares an `int` (integer) variable called `sum`, without assigning an initial value - its value is to be computed and assigned later.

```
sum = number1 + number2 + number3 + number4 + number5;
```

computes the sum of `number1` to `number5` and assign the result to the variable `sum`. The symbol '+' denotes *arithmetic addition*, just like Mathematics.

```
System.out.print("The sum is ");
System.out.println(sum);
```

Line 13 prints a descriptive string. A `String` is surrounded by double quotes, and will be printed *as it is* (without the double quotes). The cursor stays after the printed string. Try using `println()` instead of `print()` and study the output.

Line 15 prints the *value* stored in the variable `sum` (in this case, the sum of the five integers). You should not surround a variable to be printed by double quotes; otherwise, the text will get printed instead of the value stored in the variable. The cursor advances to the beginning of next line after printing. Try using `print()` instead of `println()` and study the output.

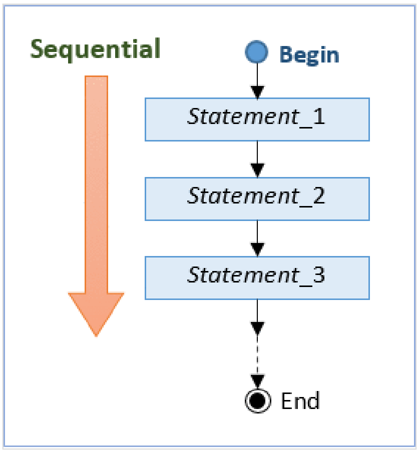
Exercise

1. Follow the above example, write a program called `SixIntegerSum` which includes a new variable called `number6` with a value of 66 and prints their sum.
2. Follow the above example, write a program called `SevenIntegerSum` which includes a new variable called `number7` with a value of 77 and prints their sum.
3. Follow the above example, write a program called `FiveIntegerProduct` to print the product of 5 integers. You should use a variable called `product` (instead of `sum`) to hold the product. Use symbol `*` for multiplication.

8. What is a Program?

A *program* is *a sequence of instructions* (called *programming statements*), executing one after another in a *predictable* manner.

Sequential flow is the most common and straight-forward, where programming statements are executed in the order that they are written - from top to bottom in a *sequential* manner, as illustrated in the following flow chart.



Example

The following program prints the area and circumference of a circle, given its radius. Take note that the programming statements are executed sequentially - one after another in the order that they were written.

In this example, we use "`double`" which hold floating-point number (or real number with an optional fractional part) instead of "`int`" which holds *integer*.

```java
/*
 * Print the area and circumference of a circle, given its radius.
 */
public class CircleComputation {  // Save as "CircleComputation.java"
   public static void main(String[] args) {
      // Declare 3 double variables to hold radius, area and circumference.
      // A "double" holds floating-point number with an optional fractional part.
      double radius, area, circumference;
      // Declare a double to hold PI.
      // Declare as "final" to specify that its value cannot be changed (i.e. constant).
      final double PI = 3.14159265;

      // Assign a value to radius. (We shall read in the value from the keyboard later.)
      radius = 1.2;
      // Compute area and circumference
      area = radius * radius * PI;
      circumference = 2.0 * radius * PI;

      // Print results
      System.out.print("The radius is ");  // Print description
      System.out.println(radius);          // Print the value stored in the variable
      System.out.print("The area is ");
      System.out.println(area);
      System.out.print("The circumference is ");
      System.out.println(circumference);
   }
}
```

The expected outputs are:

```
The radius is 1.2
The area is 4.523893416
The circumference is 7.5398223600000005
```

How It Works?

`double radius, area, circumference;`
declare three `double` variables `radius`, `area` and `circumference`. A `double` variable can hold a real number or floating-point number with an optional fractional part. (In the previous example, we use `int`, which holds integer.)

`final double PI = 3.14159265;`
declare a `double` variables called `PI` and assign a value. `PI` is declared `final` to specify that its value cannot be changed, i.e., a constant.

`radius = 1.2;`
assigns a value (real number) to the `double` variable `radius`.

```
area = radius * radius * PI;
circumference = 2.0 * radius * PI;
```
compute the `area` and `circumference`, based on the value of `radius` and `PI`.

```
System.out.print("The radius is ");
System.out.println(radius);
System.out.print("The area is ");
System.out.println(area);
System.out.print("The circumference is ");
System.out.println(circumference);
```
print the results with proper descriptions.

Take note that the programming statements inside the `main()` method are executed one after another, in a *sequential* manner.

Exercises

1. Follow the above example, write a program called `RectangleComputation` to print the area and perimeter of a rectangle, given its length and width (in `double`s). You should use 4 `double` variables called `length`, `width`, `area` and `perimeter`.
2. Follow the above example, write a program called `CylinderComputation` to print the surface area, base area, and volume of a cylinder, given its radius and height (in `double`s). You should use 5 `double` variables called `radius`, `height`, `surfaceArea`, `baseArea` and `volume`. Take note that space (blank) is not allowed in variable names.

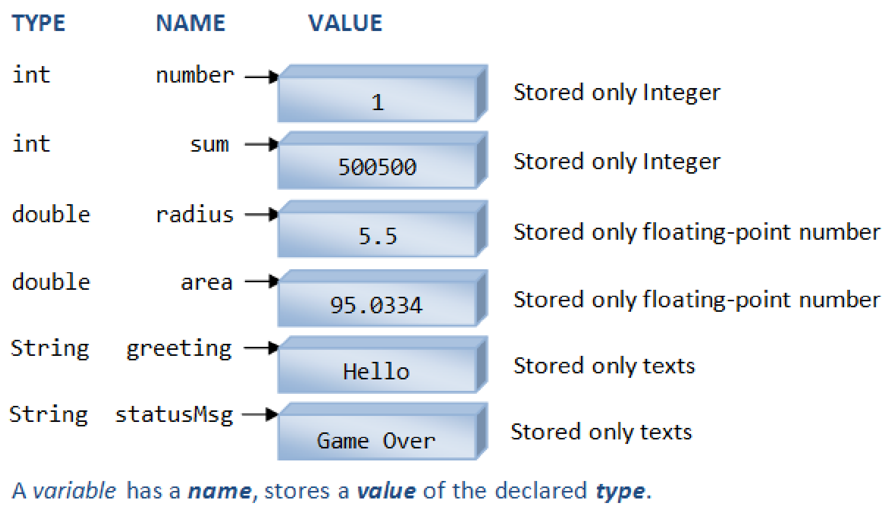
9. What is a Variable?

A computer program manipulates (or processes) data. A *variable* is a storage location (like a house, a pigeon hole, a letter box) that stores a piece of data for processing. It is called *variable* because you can change the value stored inside.

More precisely, a *variable* is a *named* storage location, that stores a *value* of a particular data *type*. In other words, a *variable* has a *name*, a *type* and stores a *value* of that particular type.

- A variable has a *name* (aka *identifier*), e.g., `radius`, `area`, `age`, `height`, `numStudnets`. The name is needed to uniquely identify each variable, so as to assign a value to the variable (e.g., `radius = 1.2`), as well as to retrieve the value stored (e.g., `radius * radius * 3.14159265`).
- A variable has a *type*. Examples of *type* are:
  - `int`: meant for integers (or whole numbers or fixed-point numbers) including zero, positive and negative integers, such as `123`, `-456`, and `0`;
  - `double`: meant for floating-point numbers or real numbers, such as `3.1416`, `-55.66`, having an optional decimal point and fractional part.
  - `String`: meant for texts such as `"Hello"`, `"Good Morning!"`. Strings shall be enclosed with a pair of double quotes.
- A variable can store a *value* of the declared *type*. It is important to take note that a variable in most programming languages is associated with a *type*, and can only store value of that particular type. For example, a `int` variable can store an integer value such as `123`, but NOT a real number such as `12.34`, nor texts such as `"Hello"`. The concept of *type* was introduced into the early programming languages to simplify interpretation of data.

The following diagram illustrates three types of variables: `int`, `double` and `String`. An `int` variable stores an integer (whole number); a `double` variable stores a real number (which includes integer as a special form of real number); a `String` variable stores texts.



Declaring and Using Variables

To use a variable, you need to first *declare* its *name* and *type*, and an optional *initial value*, in one of the following syntaxes:

```
type varName;                // Declare a variable of a type
type varName1, varName2,...; // Declare multiple variables of the SAME type
type varName = initialValue; // Declare a variable of a type, and assign an initial value
type varName1 = initialValue1, varName2 = initialValue2,... ;  // Declare variables with initial values
```

For examples,

```
int sum;            // Declare a variable named "sum" of the type "int" for storing an integer.
                    // Terminate the statement with a semi-colon.
double average;     // Declare a variable named "average" of the type "double" for storing a real number.
int number1, number2; // Declare 2 "int" variables named "number1" and "number2", separated by a comma.
int height = 20;    // Declare an "int" variable, and assign an initial value.
String msg = "Hello"; // Declare a "String" variable, and assign an initial value.
```

Take note that:

- Each *variable declaration statement* begins with a *type*, and applicable for only that type. That is, you cannot mix 2 types in one variable declaration statement.
- Each *statement* is terminated with a semi-colon (`;`).
- In multiple-variable declaration, the variable names are separated by commas (`,`).
- The symbol `'='`, known as the *assignment operator*, can be used to assign an initial value to a variable, in a declaration statement.

More examples,

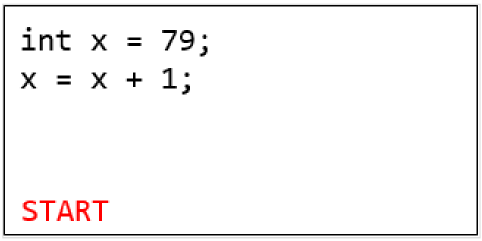
```
int number;           // Declare a variable named "number" of the type "int" (integer).
number = 99;          // Assign an integer value of 99 to the variable "number".
number = 88;          // Re-assign a value of 88 to "number".
number = number + 1;  // Evaluate "number + 1", and assign the result back to "number".
int sum = 0;          // Declare an int variable named "sum" and assign an initial value of 0.
sum = sum + number;   // Evaluate "sum + number", and assign the result back to "sum", i.e. add number into sum.
int num1 = 5, num2 = 6;  // Declare and initialize 2 int variables in one statement, separated by a comma.
double radius = 1.5;  // Declare a variable named "radius", and initialize to 1.5.
String msg;           // Declare a variable named msg of the type "String".
msg = "Hello";        // Assign a double-quoted text string to the String variable.
int number;           // ERROR: The variable named "number" has already been declared.
sum = 55.66;          // ERROR: The variable "sum" is an int. It cannot be assigned a double.
sum = "Hello";        // ERROR: The variable "sum" is an int. It cannot be assigned a string.
```

Take note that:

- Each variable can only be declared once. (You cannot have two houses with the same address.)
- In Java, you can declare a variable *anywhere* inside your program, as long as it is declared before it is being used. (Some older languages require you to declare all the variables at the *beginning* of the program.)
- Once a variable is declared, you can *assign* and *re-assign* a value to that variable, via the *assignment operator* `'='`.
- Once the *type* of a variable is declared, it can only store a value of that particular *type*. For example, an `int` variable can hold only integer such as `123`, and NOT floating-point number such as `-2.17` or text string such as `"Hello"`.
- Once declared, the *type* of a variable CANNOT be changed.

`x=x+1`?

Assignment in programming (denoted as `'='`) is different from equality in Mathematics (also denoted as `'='`). For example, "x=x+1" is invalid in Mathematics. However, in programming, it means compute the value of x plus 1, and *assign* the result back to variable x.



```
int x = 79;
x = x + 1;
```

"x+y=1" is valid in Mathematics, but is invalid in programming. In programming, the RHS (Right-Hand Side) of `'='` has to be evaluated to a value; while the LHS (Left-Hand Side) shall be a variable. That is, evaluate the RHS first, then assign the result to LHS.

Some languages uses `:=` or `->` as the assignment operator to avoid confusion with equality.

10. Basic Arithmetic Operations

The basic *arithmetic operations* are:

Operator	Mode	Usage	Meaning	Example `x=5; y=2`

`+`	Binary
	Unary
		`x + y`
		`+x`
			Addition	`x + y returns 7`

`-`	Binary
	Unary
		`x - y`
		`-x`
			Subtraction	`x - y returns 3`

`*`	Binary	`x * y`	Multiplication	`x * y returns 10`
`/`	Binary	`x / y`	Division	`x / y returns 2`
`%`	Binary	`x % y`	Modulus (Remainder)	`x % y returns 1`

`++`	Unary Prefix
	Unary Postfix
		`++x`
		`x++`
			Increment by 1	`++x or x++ (x is 6)`
				`Same as x = x + 1`

`--`	Unary Prefix
	Unary Postfix
		`--x`
		`x--`
			Decrement by 1	`--y or y-- (y is 1)`
				`Same as y = y - 1`

Addition, subtraction, multiplication, division and remainder are *binary operators* that take two operands (e.g., `x + y`); while negation (e.g., `-x`), increment and decrement (e.g., `++x`, `--y`) are *unary operators* that take only one operand.

Example

The following program illustrates these arithmetic operations:

```java
/*
 * Test Arithmetic Operations
 */
public class ArithmeticTest {     // Save as "ArithmeticTest.java"
   public static void main(String[] args) {
      int number1 = 98; // Declare an int variable number1 and initialize it to 98
      int number2 = 5;  // Declare an int variable number2 and initialize it to 5
      int sum, difference, product, quotient, remainder;  // Declare 5 int variables to hold results

      // Perform arithmetic Operations
      sum = number1 + number2;
      difference = number1 - number2;
      product = number1 * number2;
      quotient = number1 / number2;
      remainder = number1 % number2;

      // Print results
      System.out.print("The sum, difference, product, quotient and remainder of ");  // Print description
      System.out.print(number1);      // Print the value of the variable
      System.out.print(" and ");
      System.out.print(number2);
      System.out.print(" are ");
      System.out.print(sum);
      System.out.print(", ");
      System.out.print(difference);
      System.out.print(", ");
      System.out.print(product);
      System.out.print(", ");
      System.out.print(quotient);
      System.out.print(", and ");
      System.out.println(remainder);

      ++number1;  // Increment the value stored in the variable "number1" by 1
                  // Same as "number1 = number1 + 1"
      --number2;  // Decrement the value stored in the variable "number2" by 1
                  // Same as "number2 = number2 - 1"
      System.out.println("number1 after increment is " + number1);  // Print description and variable
      System.out.println("number2 after decrement is " + number2);
      quotient = number1 / number2;
      System.out.println("The new quotient of " + number1 + " and " + number2
            + " is " + quotient);
   }
}
```

The expected outputs are:

```
The sum, difference, product, quotient and remainder of 98 and 5 are 103, 93, 490, 19, and 3
number1 after increment is 99
number2 after decrement is 4
The new quotient of 99 and 4 is 24
```

How It Works?

```java
int number1 = 98;
int number2 = 5;
int sum, difference, product, quotient, remainder;
```

declare all the variables `number1`, `number2`, `sum`, `difference`, `product`, `quotient` and `remainder` needed in this program. All variables are of the type `int` (integer).

```java
sum = number1 + number2;
difference = number1 - number2;
product = number1 * number2;
quotient = number1 / number2;
remainder = number1 % number2;
```

carry out the arithmetic operations on `number1` and `number2`. Take note that division of two integers produces a *truncated* integer, e.g., `98/5 → 19`, `99/4 → 24`, and `1/2 → 0`.

```java
System.out.print("The sum, difference, product, quotient and remainder of ");
......
```

prints the results of the arithmetic operations, with the appropriate string descriptions in between. Take note that text strings are enclosed within double-quotes, and will get printed as they are, including the white spaces but without the double quotes. To print the *value* stored in a variable, no double quotes should be used. For example,

```
System.out.println("sum");    // Print text string "sum" - as it is
System.out.println(sum);      // Print the value stored in variable sum, e.g., 98
```

```
++number1;
--number2;
```

illustrate the increment and decrement operations. Unlike `'+'`, `'-'`, `'*'`, `'/'` and `'%'`, which work on two operands (*binary operators*), `'++'` and `'--'` operate on only one operand (*unary operators*). ++x is equivalent to `x = x + 1`, i.e., increment x by 1.

```
System.out.println("number1 after increment is " + number1);
System.out.println("number2 after decrement is " + number2);
```

print the new values stored after the increment/decrement operations. Take note that instead of using many `print()` statements as in Lines 18-31, we could simply place all the items (text strings and variables) into one `println()`, with the items separated by `'+'`. In this case, `'+'` does not perform *addition*. Instead, it *concatenates* or *joins* all the items together.

Exercises

1. Combining Lines 18-31 into one single `println()` statement, using `'+'` to *concatenate* all the items together.
2. In Mathematics, we could omit the multiplication sign in an arithmetic expression, e.g., `x = 5a + 4b`. In programming, you need to explicitly provide all the operators, i.e., `x = 5*a + 4*b`. Try printing the sum of `31` times of `number1` and `17` times of `number2`.
3. Based on the above example, write a program called `SumProduct3Numbers`, which introduces one more `int` variable called `number3`, and assign it an integer value of 77. Compute and print the *sum* and *product* of all the three numbers.

11. What If Your Need To Add a Thousand Numbers? Use a Loop

Suppose that you want to add all the integers from `1` to `1000`. If you follow the previous example, you would require a thousand-line program! Instead, you could use a so-called *loop* in your program to perform a *repetitive* task, that is what the computer is good at.

Example

Try the following program, which sums all the integers from a lowerbound (=`1`) to an upperbound (=`1000`) using a so-called *while-loop*.

```
/*
 * Sum from a lowerbound to an upperbound using a while-loop
 */
public class RunningNumberSum {  // Save as "RunningNumberSum.java"
   public static void main(String[] args) {
      final int LOWERBOUND = 1;      // Store the lowerbound
      final int UPPERBOUND = 1000;   // Store the upperbound
      int sum = 0;   // Declare an int variable "sum" to accumulate the numbers
                     // Set the initial sum to 0
      // Use a while-loop to repeatedly sum from the lowerbound to the upperbound
      int number = LOWERBOUND;
      while (number <= UPPERBOUND) {
            // number = LOWERBOUND, LOWERBOUND+1, LOWERBOUND+2, ..., UPPERBOUND for each iteration
         sum = sum + number;  // Accumulate number into sum
         ++number;            // increment number
      }
      // Print the result
      System.out.println("The sum from " + LOWERBOUND + " to " + UPPERBOUND + " is " + sum);
   }
}
```

The expected output is:

```
The sum from 1 to 1000 is 500500
```

How It Works?

```
final int LOWERBOUND = 1;
final int UPPERBOUND = 1000;
```

declare two `int` constants to hold the upperbound and lowerbound, respectively.

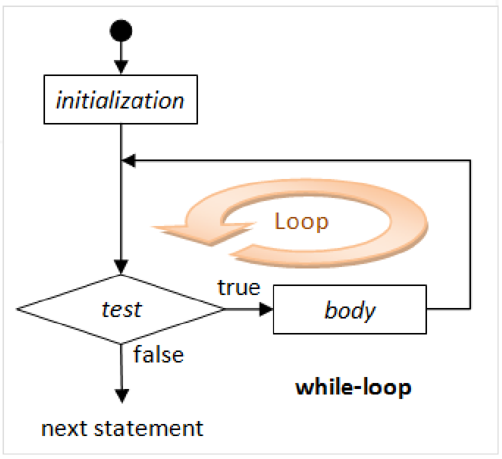
```
int sum = 0;
```

declares an `int` variable to hold the sum. This variable will be used to *accumulate* over the steps in the repetitive loop, and thus initialized to 0.

```
int number = LOWERBOUND;
while (number <= UPPERBOUND) {
   sum = sum + number;
   ++number;
}
```

This is the so-called *while-loop*. A *while-loop* takes the following syntax:

```
initialization-statement;
while (test) {
   loop-body;
}
next-statement;
```



As illustrated in the flow chart, the *initialization* statement is first executed. The *test* is then checked. If *test* is true, the *body* is executed. The *test* is checked again and the process repeats until the *test* is false. When the *test* is false, the loop completes and program execution continues to the *next statement* after the loop.

In our example, the *initialization* statement declares an `int` variable named `number` and initializes it to `LOWERBOUND`. The *test* checks if `number` is equal to or less than the `UPPERBOUND`. If it is true, the current value of `number` is added into the `sum`, and the statement `++number` increases the value of `number` by 1. The *test* is then checked again and the process repeats until the *test* is false (i.e., `number` increases to `UPPERBOUND+1`), which causes the loop to terminate. Execution then continues to the next statement (in Line 18).

A loop is typically controlled by an index variable. In this example, the index variable `number` takes the value `LOWERBOUND`, `LOWERBOUND+1`, `LOWERBOUND+2`, ..., `UPPERBOUND`, for each iteration of the loop.

In this example, the loop repeats `UPPERBOUND-LOWERBOUND+1` times. After the loop is completed, Line 18 prints the result with a proper description.

`System.out.println("The sum from " + LOWERBOUND + " to " + UPPERBOUND + " is " + sum);`
prints the results.

Exercises

1. Modify the above program (called `RunningNumberSum1`) to sum all the numbers from 9 to 899. (*Ans*: `404514`)
2. Modify the above program (called `RunningNumberOddSum`) to sum all the *odd* numbers between `1` to `1000`. (*Hint*: Change the *post-processing* statement to "`number = number + 2`". *Ans*: `250000`)
3. Modify the above program (called `RunningNumberMod7Sum`) to sum all the numbers between `1` to `1000` that are divisible by `7`. (*Hint*: Modify the initialization statement to begin from 7 and post-processing statement to increment by 7. *Ans*: `71071`)
4. Modify the above program (called `RunningNumberSquareSum`) to find the sum of the *square* of all the numbers from `1` to `100`, i.e. `1*1 + 2*2 + 3*3 +...` (*Hint*: Modify the `sum = sum + number` statement. *Ans*: `338350`)
5. Modify the above program (called `RunningNumberProduct`) to compute the *product* of all the numbers from `1` to `10`. (*Hint*: Use a variable called `product` instead of `sum` and initialize `product` to 1. Modify the `sum = sum + number` statement to do multiplication on variable `product`. *Ans*: `3628800`)

12. Conditional (or Decision)

What if you want to sum all the odd numbers and also all the even numbers between `1` and `1000`? You could declare two variables, `sumOdd` and `sumEven`, to keep the two sums. You can then use a *conditional* statement to check whether the number is odd or even, and accumulate the number into the respective sums. The program is as follows:

```
/*
 * Sum the odd numbers and the even numbers from a lowerbound to an upperbound
 */
public class OddEvenSum {  // Save as "OddEvenSum.java"
   public static void main(String[] args) {
      final int LOWERBOUND = 1;
      final int UPPERBOUND = 1000;
      int sumOdd  = 0;    // For accumulating odd numbers, init to 0
      int sumEven = 0;    // For accumulating even numbers, init to 0
      int number = LOWERBOUND;
      while (number <= UPPERBOUND) {
            // number = LOWERBOUND, LOWERBOUND+1, LOWERBOUND+2, ..., UPPERBOUND for each iteration
         if (number % 2 == 0) {  // Even
            sumEven += number;   // Same as sumEven = sumEven + number
         } else {                // Odd
            sumOdd += number;    // Same as sumOdd = sumOdd + number
         }
         ++number;  // Next number
      }
      // Print the result
      System.out.println("The sum of odd numbers from " + LOWERBOUND + " to " + UPPERBOUND + " is " + sumOdd);
      System.out.println("The sum of even numbers from " + LOWERBOUND + " to " + UPPERBOUND + "  is " + sumEven);
      System.out.println("The difference between the two sums is " + (sumOdd - sumEven));
   }
}
```

The expected outputs are:

```
The sum of odd numbers from 1 to 1000 is 250000
The sum of even numbers from 1 to 1000  is 250500
The difference between the two sums is -500
```

How It Works?

```
final int LOWERBOUND = 1;
final int UPPERBOUND = 1000;
```

declares and initializes the upperbound and lowerbound constants.

```
int sumOdd = 0;
int sumEven = 0;
```

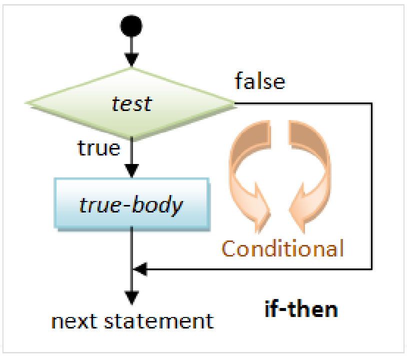
declare two `int` variables named `sumOdd` and `sumEven` and initialize them to 0, for accumulating the odd and even numbers, respectively.

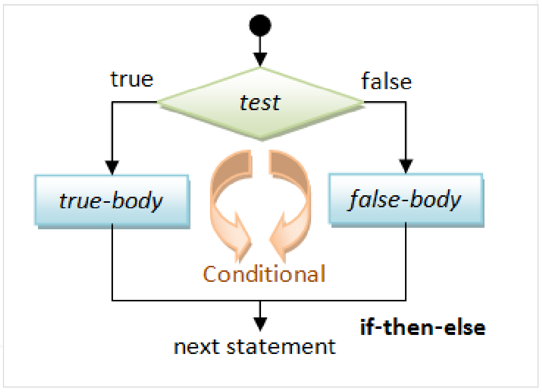
```
if (number % 2 == 0) {
   sumEven += number;
} else {
   sumOdd += number;
}
```

This is a *conditional* statement. The conditional statement can take one these forms: *if-then* or *if-then-else*.

```
// if-then
if ( test ) {
   true-body;
}

// if-then-else
if ( test ) {
   true-body;
} else {
   false-body;
}
```





For a *if-then* statement, the *true-body* is executed if the *test* is true. Otherwise, nothing is done and the execution continues to the next statement. For a *if-then-else* statement, the *true-body* is executed if the *test* is true; otherwise, the *false-body* is executed. Execution is then continued to the next statement.

In our program, we use the *remainder* or *modulus* operator (`%`) to compute the remainder of `number` divides by `2`. We then compare the remainder with `0` to test for even number.

Furthermore, `sumEven += number` is a *shorthand* for `sumEven = sumEven + number`.

Comparison Operators

There are six comparison (or relational) operators:

Operator	Mode	Usage	Meaning	Example
`==`	Binary	`x == y`	Equal to	
`!=`	Binary	`x != y`	Not equal to	
`>`	Binary	`x > y`	Greater than	
`>=`	Binary	`x >= y`	Greater than or equal to	
`<`	Binary	`x < y`	Less than	
`<=`	Binary	`x <= y`	Less than or equal to	

Take note that the comparison operator for equality is a double-equal sign (`==`); whereas a single-equal sign (`=`) is the assignment operator.

Combining Simple Conditions

Suppose that you want to check whether a number `x` is between `1` and `100` (inclusive), i.e., `1 <= x <= 100`. There are two *simple conditions* here, `(x >= 1) AND (x <= 100)`. In Java, you cannot write `1 <= x <= 100`, but need to write `(x >= 1) && (x <= 100)`, where "`&&`" denotes the "AND" operator. Similarly, suppose that you want to check whether a number `x` is divisible by 2 OR by 3, you have to write `(x % 2 == 0) || (x % 3 == 0)` where "`||`" denotes the "OR" operator.

There are three so-called *logical operators* that operate on the *boolean* conditions:

Operator	Mode	Usage	Meaning	Example

&&	Binary	`x && y`	Logical AND	`(x >= 1) && (x <= 100)`
||	Binary	`x || y`	Logical OR	`(x < 1) || (x > 100)`
!	Unary Prefix	`!x`	Logical NOT	`!(x == 8)`

For examples:

```
// Return true if x is between 0 and 100 (inclusive)
(x >= 0) && (x <= 100)  // AND (&&)
// Incorrect to use 0 <= x <= 100

// Return true if x is outside 0 and 100 (inclusive)
(x < 0) || (x > 100)       // OR (||)
!((x >= 0) && (x <= 100))  // NOT (!), AND (&&)

// Return true if "year" is a leap year
// A year is a leap year if it is divisible by 4 but not by 100, or it is divisible by 400.
((year % 4 == 0) && (year % 100 != 0)) || (year % 400 == 0)
```

Exercises

1. Write a program called **`ThreeFiveSevenSum`** to sum all the running integers from 1 and 1000, that are divisible by 3, 5 or 7, but NOT by 15, 21, 35 or 105.
2. Write a program called **`PrintLeapYears`** to print all the leap years between AD999 and AD2010. Also print the total number of leap years. (Hints: use a `int` variable called `count`, which is initialized to zero. Increment the `count` whenever a leap year is found.)

13. Summary

I have presented the basics for you to get start in programming. To learn programming, you need to understand the syntaxes and features involved in the programming language that you chosen, and you have to practice, practice and practice, on as many problems as you could.

Link TO "Java References & Resources"

Latest version tested: JDK 15.0.2
Last modified: Feb 2021

Feedback, comments, corrections, and errata can be sent to Chua Hock-Chuan (ehchua@ntu.edu.sg) | HOME