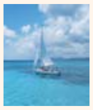
Numerical Data



Objectives

After you have read and studied this chapter, you should be able to

- Select proper types for numerical data.
- Write arithmetic expressions in Java.
- Evaluate arithmetic expressions using the precedence rules.
- Describe how the memory allocation works for objects and primitive data values.
- Write mathematical expressions, using methods in the Math class.
- Generate pseudo random numbers.
- Use the GregorianCalendar class in manipulating date information such as year, month, and day.
- Use the DecimalFormat class to format numerical data
- Input and output numerical data by using System.in and System.out

Manipulating Numbers

- In Java, to add two numbers x and y, we write

```
x + y
```

- But before the actual addition of the two numbers takes place, we must declare their data type. If x and y are integers, we write

```
int x, y;
```

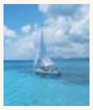
or

```
int x;
int y;
```

Variables

- When the declaration is made, memory space is allocated to store the values of x and y.
- x and y are called *variables*. A variable has three properties:
  - A memory location to store the value,
  - The type of data stored in the memory location, and
  - The name used to refer to the memory location.
- Sample variable declarations:

```
int x;
int v, w, y;
```



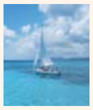
Numerical Data Types

- There are six numerical data types: byte, short, int, long, float, and double.
- Sample variable declarations:

```
int      i, j, k;
float    numberOne, numberTwo;
long     bigInteger;
double   bigNumber;
```

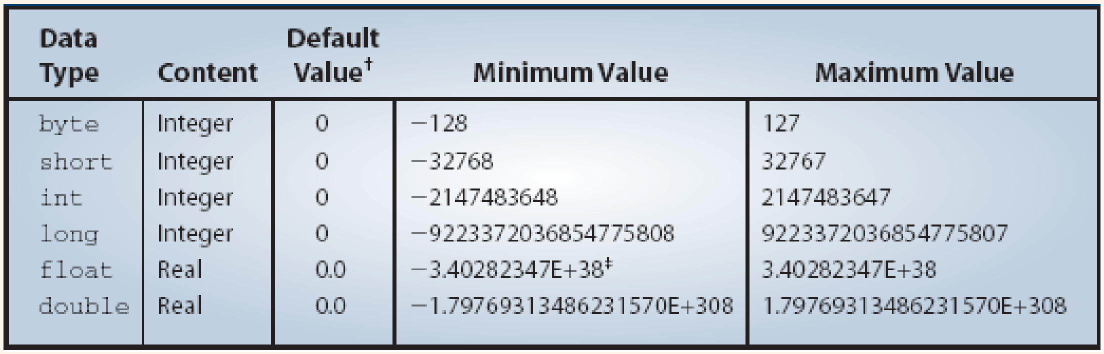
- At the time a variable is declared, it also can be initialized. For example, we may initialize the integer variables count and height to 10 and 34 as

```
int count = 10, height = 34;
```

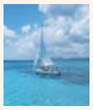


Data Type Precisions

The six data types differ in the precision of values they can store in memory.



Data Type	Content	Default Value[†]	Minimum Value	Maximum Value
byte	Integer	0	−128	127
short	Integer	0	−32768	32767
int	Integer	0	−2147483648	2147483647
long	Integer	0	−9223372036854775808	9223372036854775807
float	Real	0.0	−3.40282347E+38[‡]	3.40282347E+38
double	Real	0.0	−1.79769313486231570E+308	1.79769313486231570E+308



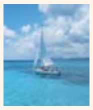
Assignment Statements

- We assign a value to a variable using an *assignment statements*.
- The syntax is

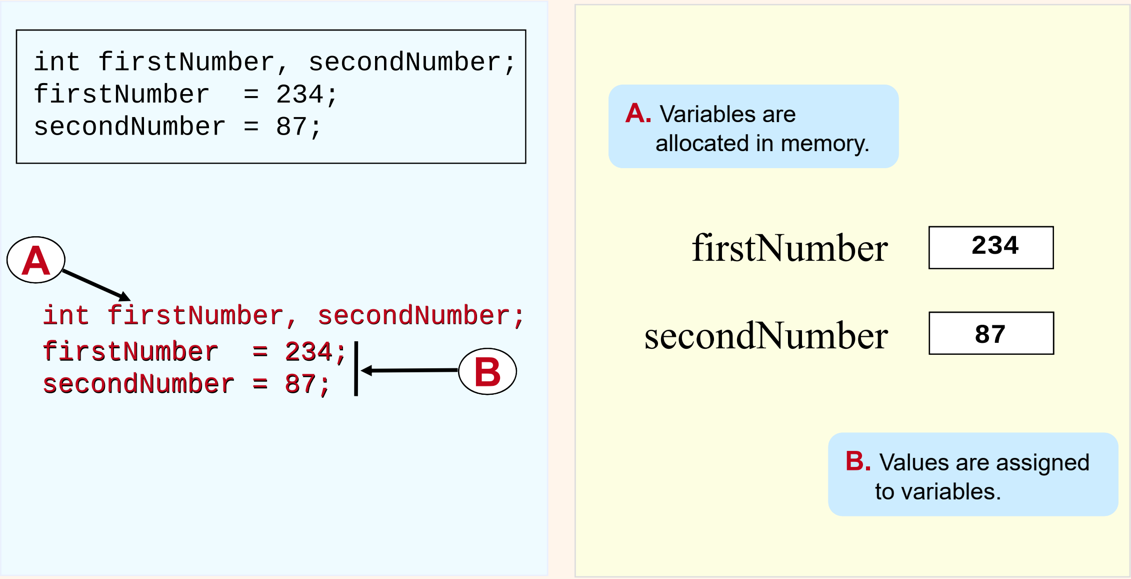
```
<variable> = <expression> ;
```

- Examples:

```
sum = firstNumber + secondNumber;
avg = (one + two + three) / 3.0;
```



Primitive Data Declaration and Assignments



```
int firstNumber, secondNumber;
firstNumber  = 234;
secondNumber = 87;
```

A. Variables are allocated in memory.

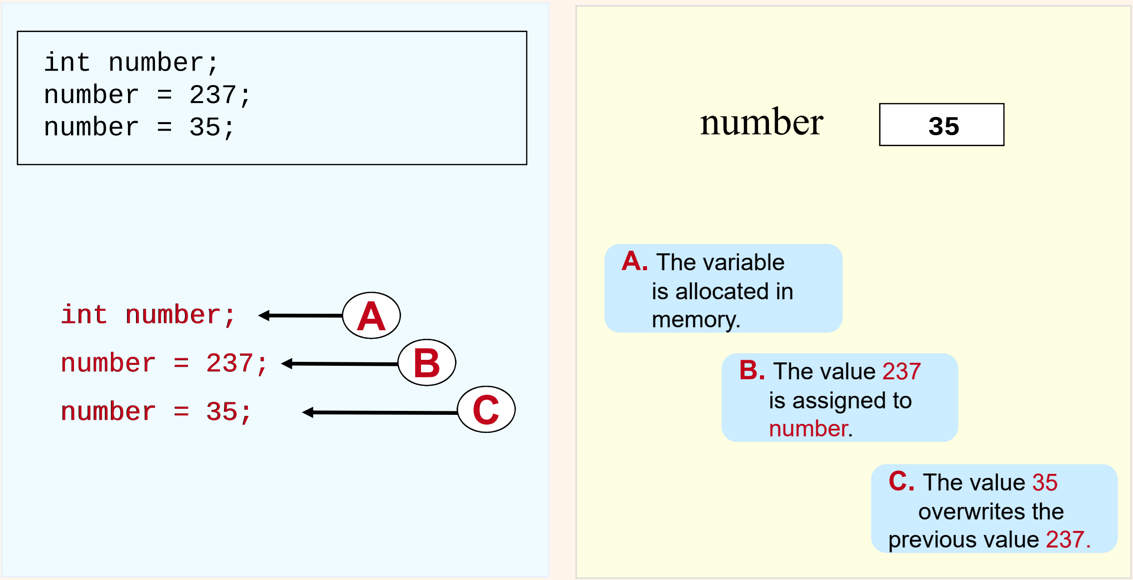
B. Values are assigned to variables.

Code

State of Memory

Assigning Numerical Data

```
int number;
number = 237;
number = 35;
```



```
int number;
number = 237;
number = 35;
```

A. The variable is allocated in memory.

B. The value 237 is assigned to number.

C. The value 35 overwrites the previous value 237.

Code

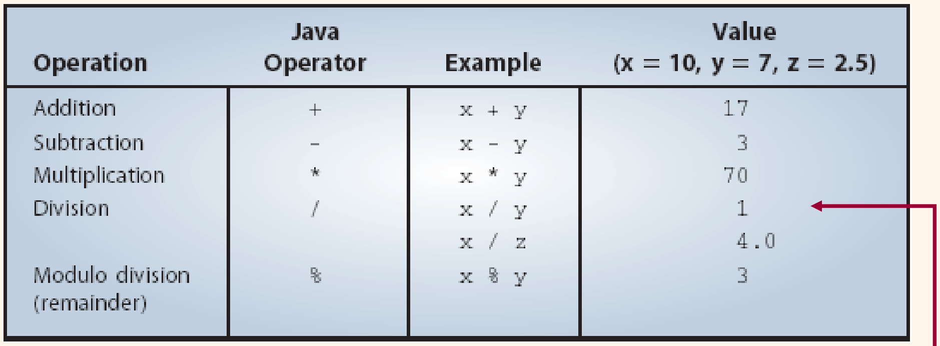
State of Memory

Primitive vs. Reference

- Numerical data are called *primitive data types*.
- Objects are called *reference data types*, because the contents are addresses that refer to memory locations where the objects are actually stored.

Arithmetic Operators

- The following table summarizes the arithmetic operators available in Java.



Operation	Java Operator	Example	Value (x = 10, y = 7, z = 2.5)
Addition	+	x + y	17
Subtraction	-	x - y	3
Multiplication	*	x * y	70
Division	/	x / y	1
		x / z	4.0
Modulo division (remainder)	%	x % y	3

This is an integer division where the fractional part is truncated.

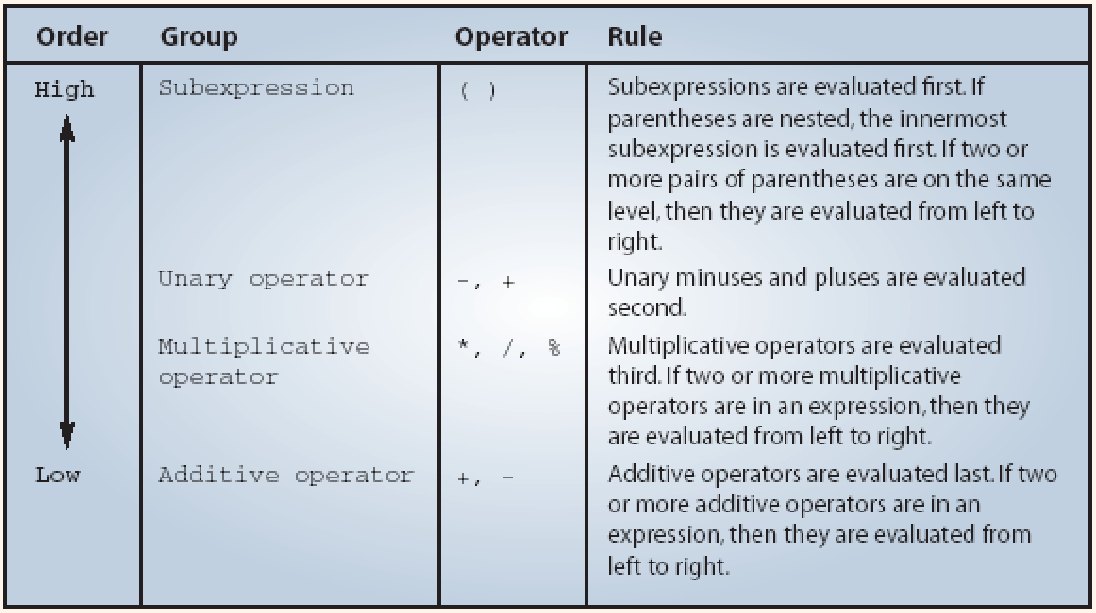
Arithmetic Expression

- How does the expression

  x + 3 * y

  get evaluated? Answer: x is added to 3*y.
- We determine the order of evaluation by following the *precedence rules*.
- A higher precedence operator is evaluated before the lower one. If two operators are the same precedence, then they are evaluated left to right for most operators.

Precedence Rules



Order	Group	Operator	Rule
High	Subexpression	( )	Subexpressions are evaluated first. If parentheses are nested, the innermost subexpression is evaluated first. If two or more pairs of parentheses are on the same level, then they are evaluated from left to right.
	Unary operator	-, +	Unary minuses and pluses are evaluated second.
	Multiplicative operator	*, /, %	Multiplicative operators are evaluated third. If two or more multiplicative operators are in an expression, then they are evaluated from left to right.
Low	Additive operator	+, -	Additive operators are evaluated last. If two or more additive operators are in an expression, then they are evaluated from left to right.

Type Casting

- If **x** is a **float** and **y** is an **int**, what will be the data type of the following expression?

  x * y

  The answer is **float**.
- The above expression is called a *mixed expression*.
- The data types of the operands in mixed expressions are converted based on the *promotion rules*. The promotion rules ensure that the data type of the expression will be the same as the data type of an operand whose type has the highest precision.

Explicit Type Casting

- Instead of relying on the promotion rules, we can make an explicit type cast by prefixing the operand with the data type using the following syntax:

```
( <data type> ) <expression>
```

- Example

```
(float) x / 3
```

Type case **x** to **float** and then divide it by 3.

```
(int) (x / y * 3.0)
```

Type cast the result of the expression **x / y * 3.0** to **int**.

Implicit Type Casting

- Consider the following expression:

```
double x = 3 + 5;
```

- The result of 3 + 5 is of type **int**. However, since the variable **x** is **double**, the value 8 (type **int**) is promoted to 8.0 (type **double**) before being assigned to **x**.
- Notice that it is a promotion. Demotion is not allowed.

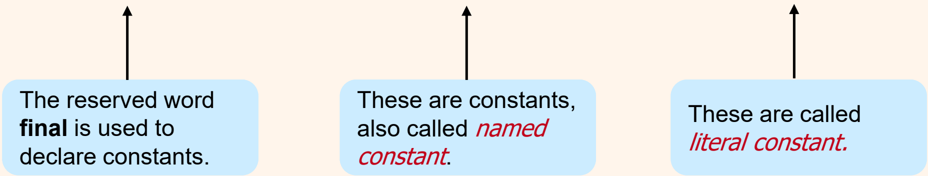
```
int x = 3.5;
```

A higher precision value cannot be assigned to a lower precision variable.

Constants

- We can change the value of a variable. If we want the value to remain the same, we use a *constant*.

```
final double PI                = 3.14159;
final int    MONTH_IN_YEAR     = 12;
final short  FARADAY_CONSTANT = 23060;
```



The reserved word **final** is used to declare constants.

These are constants, also called *named constant*.

These are called *literal constant.*

Displaying Numerical Values

- In Chapter 2, we showed how to output text (String) to the standard output
- We use the same print and println methods to output numerical data to the standard output.

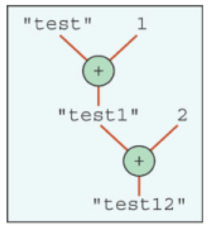
```
int num = 15;
System.out.print(num); //print a variable
System.out.print(" "); //print a string
System.out.print(10);  //print a constant
```

```
15 10
```

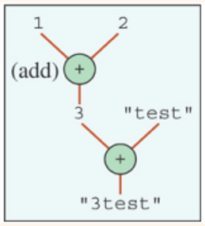
Overloaded Operator +

- The plus operator + can mean two different operations, depending on the context.
- <val1> + <val2> is an addition if both are numbers. If either one of them is a String, the it is a concatenation.
- Evaluation goes from left to right.

output = “test” + 1 + 2;

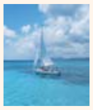


output = 1 + 2 + “test”;



Sample Code Fragment

```
//code fragment to input radius and output
//area and circumference
final double PI = 3.14159;

double radius, area, circumference;

//compute area and circumference
area = PI * radius * radius;
circumference = 2.0 * PI * radius;

System.out.println("Given Radius:   " + radius);
System.out.println("Area: " + area);
System.out.println(" Circumference: “ + circumference);
```

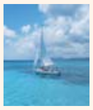


The DecimalFormat Class

- Use a DecimalFormat object to format the numerical output.

```
double num = 123.45789345;

DecimalFormat df = new DecimalFormat(“0.000”);
            //three decimal places
```

```
System.out.print(num);          ——→  123.45789345

System.out.print(df.format(num));
                                ——→  123.458
```



Getting Numerical Input

- In Chapter 2, we learned how to input strings using the Scanner class.
- We can use the same Scanner class to input numerical values

```
Scanner scanner = new Scanner(System.in);
int age;
System.out.print( “Enter your age: “ );
age = scanner.nextInt();
```

Scanner Methods

Method	Example
nextByte( )	byte b = scanner.nextByte( );
nextDouble( )	double d = scanner.nextDouble( );
nextFloat( )	float f = scanner.nextFloat( );
nextInt( )	int i = scanner.nextInt( );
nextLong( )	long l = scanner.nextLong( );
nextShort( )	short s = scanner.nextShort( );
next()	String str = scanner.next();

The Math class

- The **Math** class in the **java.lang** package contains class methods for commonly used mathematical functions.

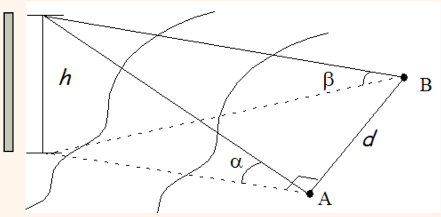
```
double     num, x, y;

x = …;
y = …;

num = Math.sqrt(Math.max(x, y) + 12.4);
```

Some Math Class Methods

Method	Description
exp(a)	Natural number **e** raised to the power of **a**.
log(a)	Natural logarithm (base **e**) of **a**.
floor(a)	The largest whole number less than or equal to **a**.
max(a,b)	The larger of a and b.
pow(a,b)	The number **a** raised to the power of **b**.
sqrt(a)	The square root of **a**.
sin(a)	The sine of **a**. (Note: all trigonometric functions are computed in radians)

Table 3.7 page 113 in the textbook contains a list of class methods defined in the **Math** class.

Computing the Height of a Pole



$$h = \frac{d \sin\alpha \sin\beta}{\sqrt{\sin(\alpha+\beta)\sin(\alpha-\beta)}}$$

```
alphaRad = Math.toRadians(alpha);
betaRad  = Math.toRadians(beta);

height = ( distance * Math.sin(alphaRad) * Math.sin(betaRad) )
                          /
          Math.sqrt( Math.sin(alphaRad + betaRad) *
                                Math.sin(alphaRad - betaRad) );
```

Random Number Generation

- We can use the nextInt(n) method of the Random class to generate a random number between 0 and n-1, inclusive.

```
import java.util.Random;
. . .
Random random = new Random();
. . .
int number = random.nextInt(11); //return x, 0 <= x <= 10
```

- To return a random integer in [min, max] inclusively, where min <= max

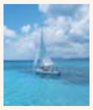
```
. . .

int number = random.nextInt(max – min + 1) + min;
```

Random Number Generation - 2

- The Math.random method is called a pseudo random number generator and returns a number (double) X, where 0.0 <= X < 1.0
- To return a pseudo random integer in [min, max] inclusively, where min <= max, use the formula

$$\lfloor X \times (\max - \min + 1) \rfloor + \min$$

```
int randomNumber = (int) (Math.floor(Math.random()
                          * (max – min + 1)) + min);
```



Problem Statement

- Problem statement:

  Write a loan calculator program that computes both monthly and total payments for a given loan amount, annual interest rate, and loan period.

- *This will be one of your homework problem*