

Chapter 4 Mathematical Functions, Characters, and Strings

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Objectives

- ✦ To solve mathematics problems by using the methods in the **Math** class (§4.2).
- ✦ To represent characters using the **char** type (§4.3).
- ✦ To encode characters using ASCII and Unicode (§4.3.1).
- ✦ To represent special characters using the escape sequences (§4.4.2).
- ✦ To cast a numeric value to a character and cast a character to an integer (§4.3.3).
- ✦ To compare and test characters using the static methods in the **Character** class (§4.3.4).
- ✦ To introduce objects and instance methods (§4.4).
- ✦ To represent strings using the **String** objects (§4.4).
- ✦ To return the string length using the **length()** method (§4.4.1).
- ✦ To return a character in the string using the **charAt(i)** method (§4.4.2).
- ✦ To use the + operator to concatenate strings (§4.4.3).
- ✦ To read strings from the console (§4.4.4).
- ✦ To read a character from the console (§4.4.5).
- ✦ To compare strings using the **equals** method and the **compareTo** methods (§4.4.6).
- ✦ To obtain substrings (§4.4.7).
- ✦ To find a character or a substring in a string using the **indexOf** method (§4.4.8).
- ✦ To program using characters and strings (**GuessBirthday**) (§4.5.1).
- ✦ To convert a hexadecimal character to a decimal value (**HexDigit2Dec**) (§4.5.2).
- ✦ To revise the lottery program using strings (**LotteryUsingStrings**) (§4.5.3).
- ✦ To format output using the **System.out.printf** method (§4.6).

Mathematical Functions

Java provides many useful methods in the **Math** class for performing common mathematical functions.

The Math Class

- ♦ Class constants:

- π
- e

- ♦ Class methods:

- Trigonometric Methods
- Exponent Methods
- Rounding Methods
- min, max, abs, and random Methods

Trigonometric Methods

✦ `sin(double a)`

✦ `cos(double a)`

✦ `tan(double a)`

a: Radians 弧度

✦ `acos(double b)`

✦ `asin(double b)`

✦ `atan(double b)`

✦ `toRadians(90)`

✦ `toDegrees(Math.PI/2)`

Examples:

`Math.sin(0)` returns 0.0

`Math.sin(Math.PI / 6)`
returns 0.5

`Math.sin(Math.PI / 2)`
returns 1.0

`Math.cos(0)` returns 1.0

`Math.cos(Math.PI / 6)`
returns 0.866

`Math.cos(Math.PI / 2)`
returns 0

Exponent Methods

- ✦ **`exp(double a)`**
Returns e raised to the power of a .
- ✦ **`log(double a)`**
Returns the natural logarithm of a .
- ✦ **`log10(double a)`**
Returns the 10-based logarithm of a .
- ✦ **`pow(double a, double b)`**
Returns a raised to the power of b .
- ✦ **`sqrt(double a)`**
Returns the square root of a .

Examples:

`Math.exp(1)` returns 2.71

`Math.log(2.71)` returns 1.0

`Math.pow(2, 3)` returns 8.0

`Math.pow(3, 2)` returns 9.0

**`Math.pow(3.5, 2.5)` returns
22.91765**

`Math.sqrt(4)` returns 2.0

`Math.sqrt(10.5)` returns 3.24

Rounding Methods

- ♦ **double ceil(double x)**

x rounded up to its nearest integer. This integer is returned as a double value.

- ♦ **double floor(double x)**

x is rounded down to its nearest integer. This integer is returned as a double value.

- ♦ **double rint(double x)**

x is rounded to its nearest integer. If x is equally close to two integers, the even one is returned as a double.

- ♦ **int round(float x)**

Return (int)Math.floor(x+0.5).

- ♦ **long round(double x)**

Return (long)Math.floor(x+0.5).

Rounding Methods Examples

```
Math.ceil(2.1) returns 3.0
Math.ceil(2.0) returns 2.0
Math.ceil(-2.0) returns -2.0
Math.ceil(-2.1) returns -2.0
Math.floor(2.1) returns 2.0
Math.floor(2.0) returns 2.0
Math.floor(-2.0) returns -2.0
Math.floor(-2.1) returns -3.0
Math rint(2.1) returns 2.0
Math rint(2.0) returns 2.0
Math rint(-2.0) returns -2.0
Math rint(-2.1) returns -2.0
Math rint(2.5) returns 2.0
Math rint(-2.5) returns -2.0
Math.round(2.6f) returns 3
Math.round(2.0) returns 2
Math.round(-2.0f) returns -2
Math.round(-2.6) returns -3
```


min, max, and abs

- ◆ `max(a, b)` and `min(a, b)`
Returns the maximum or minimum of two parameters.
- ◆ `abs(a)`
Returns the absolute value of the parameter.
- ◆ `random()`
Returns a random double value in the range [0.0, 1.0).

Examples:

`Math.max(2, 3)` returns 3

**`Math.max(2.5, 3)` returns
3.0**

**`Math.min(2.5, 3.6)`
returns 2.5**

`Math.abs(-2)` returns 2

**`Math.abs(-2.1)` returns
2.1**

The random Method

Generates a random double value greater than or equal to 0.0 and less than 1.0 ($0 \leq \text{Math.random()} < 1.0$).

Examples:

`(int) (Math.random() * 10)` \longrightarrow Returns a random integer between 0 and 9.

`50 + (int) (Math.random() * 50)` \longrightarrow Returns a random integer between 50 and 99.

In general,

`a + Math.random() * b` \longrightarrow Returns a random number between a and a + b, excluding a + b.

Examples

♦ MathTest.java

♦ ComputeAngles.java

Character Data Type

```
char letter = 'A'; (ASCII)    // literals
```

```
char numChar = '4'; (ASCII)
```

Four hexadecimal digits.



```
char letter = '\u0041'; (Unicode)
```

```
char numChar = '\u0034'; (Unicode)
```

NOTE: The increment and decrement operators can also be used on char variables to get the next or preceding Unicode character.

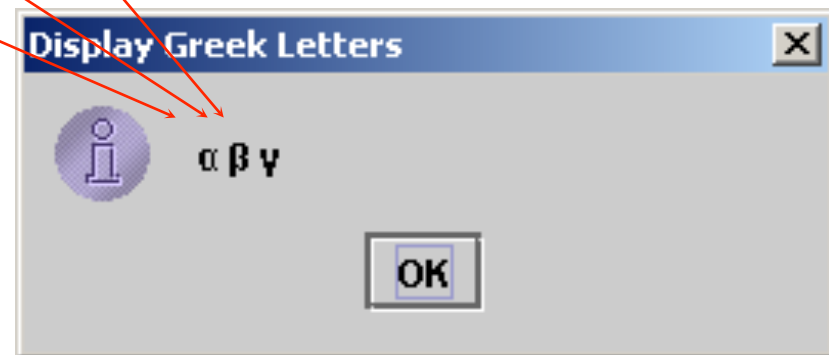
```
char ch = 'a';
```

```
System.out.println(++ch);
```

Unicode Format

Java characters use *Unicode*, a 16-bit encoding scheme established by the Unicode Consortium to support the interchange, processing, and display of written texts in the world's diverse languages. Unicode takes two bytes, preceded by `\u`, expressed in four hexadecimal numbers that run from `\u0000` to `\uFFFF`. So, Unicode can represent $65535 + 1$ characters.

Unicode `\u03b1` `\u03b2` `\u03b3` for three Greek letters



ASCII Code for Commonly Used Characters

Characters	Code Value in Decimal	Unicode Value
'0' to '9'	48 to 57	\u0030 to \u0039
'A' to 'Z'	65 to 90	\u0041 to \u005A
'a' to 'z'	97 to 122	\u0061 to \u007A

Escape Sequences for Special Characters

<i>Escape Sequence</i>	<i>Name</i>	<i>Unicode Code</i>	<i>Decimal Value</i>
<code>\b</code>	Backspace	<code>\u0008</code>	8
<code>\t</code>	Tab	<code>\u0009</code>	9
<code>\n</code>	Linefeed	<code>\u000A</code>	10
<code>\f</code>	Formfeed	<code>\u000C</code>	12
<code>\r</code>	Carriage Return	<code>\u000D</code>	13
<code>\\</code>	Backslash	<code>\u005C</code>	92
<code>\"</code>	Double Quote	<code>\u0022</code>	34

Appendix B: ASCII Character Set

ASCII Character Set is a subset of the Unicode from \u0000 to \u007f

TABLE B.1 ASCII Character Set in the Decimal Index

	0	1	2	3	4	5	6	7	8	9
0	nul	soh	stx	etx	eot	enq	ack	bel	bs	ht
1	nl	vt	ff	cr	so	si	dle	dcl	dc2	dc3
2	dc4	nak	syn	etb	can	em	sub	esc	fs	gs
3	rs	us	sp	!	"	#	\$	%	&	'
4	()	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[\]	^	_	`	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{		}	~	del		

ASCII Character Set, cont.

ASCII Character Set is a subset of the Unicode from \u0000 to \u007f

TABLE B.2 ASCII Character Set in the Hexadecimal Index

	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>
0	nul	soh	stx	etx	eot	enq	ack	bel	bs	ht	nl	vt	ff	cr	so	si
1	dle	dcl	dc2	dc3	dc4	nak	syn	etb	can	em	sub	esc	fs	gs	rs	us
2	sp	!	“	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_
6	‘	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{		}	~	del

Casting between char and Numeric Types

```
int i = 'a'; // Same as int i = (int) 'a';
```

```
char c = 97; // Same as char c = (char) 97;
```

Comparing and Testing Characters

```
if (ch >= 'A' && ch <= 'Z')
```

```
    System.out.println(ch + " is an uppercase letter");
```

```
else if (ch >= 'a' && ch <= 'z')
```

```
    System.out.println(ch + " is a lowercase letter");
```

```
else if (ch >= '0' && ch <= '9')
```

```
    System.out.println(ch + " is a numeric character");
```

Methods in the Character Class

Method	Description
<code>isDigit(ch)</code>	Returns true if the specified character is a digit.
<code>isLetter(ch)</code>	Returns true if the specified character is a letter.
<code>isLetterOrDigit(ch)</code>	Returns true if the specified character is a letter or digit.
<code>isLowerCase(ch)</code>	Returns true if the specified character is a lowercase letter.
<code>isUpperCase(ch)</code>	Returns true if the specified character is an uppercase letter.
<code>toLowerCase(ch)</code>	Returns the lowercase of the specified character.
<code>toUpperCase(ch)</code>	Returns the uppercase of the specified character.

The String Type

To represent a string of characters, use the data type called String (*reference type*, not primitive type)

```
String message = "Welcome to Java";
```

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

String is actually a predefined class like the System class and Scanner class.

Any Java class can be used as a reference type for a variable.

Simple Methods for String Objects

Method	Description
<code>length()</code>	Returns the number of characters in this string.
<code>charAt(index)</code>	Returns the character at the specified index from this string.
<code>concat(s1)</code>	Returns a new string that concatenates this string with string s1.
<code>toUpperCase()</code>	Returns a new string with all letters in uppercase.
<code>toLowerCase()</code>	Returns a new string with all letters in lowercase.
<code>trim()</code>	Returns a new string with whitespace characters trimmed on both sides.

Simple Methods for **String** Objects

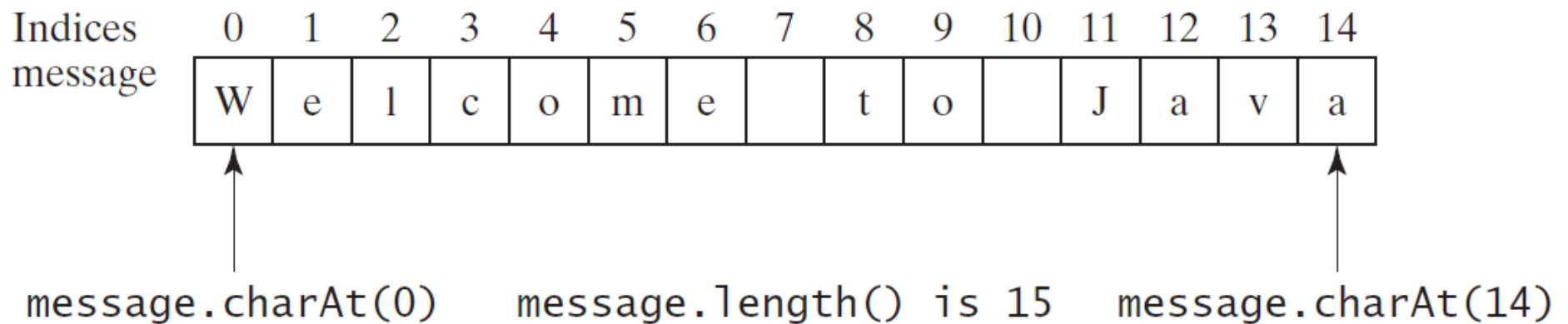
Strings are objects in Java. The methods in the preceding table can only be invoked from a specific string instance. For this reason, these methods are called *instance methods*. A non-instance method is called a *static method*. A static method can be invoked without using an object. All the methods defined in the **Math** class are static methods. They are not tied to a specific object instance. The syntax to invoke an instance method is

referenceVariable.methodName(arguments).

Getting String Length

```
String message = "Welcome to Java";  
System.out.println("The length of " + message  
+ " is "  
+ message.length() );
```


Getting Characters from a String



```
String message = "Welcome to Java";
```

```
System.out.println("The first character in  
message is "
```

```
+ message.charAt(0) );
```

Converting Strings

"Welcome".toLowerCase() returns a new string, welcome.

"Welcome".toUpperCase() returns a new string,
WELCOME.

" Welcome ".trim() returns a new string, Welcome.

String Concatenation

```
String s3 = s1.concat(s2); or String s3 = s1 + s2;
```

```
// Three strings are concatenated
```

```
String message = "Welcome " + "to " + "Java";
```

```
// String Chapter is concatenated with number 2
```

```
String s = "Chapter" + 2; // s becomes Chapter2
```

```
// String Supplement is concatenated with character B
```

```
String s1 = "Supplement" + 'B'; // s1 becomes SupplementB
```

Reading a String from the Console

```
Scanner input = new Scanner(System.in);  
System.out.print("Enter three words separated by spaces:  
");  
String s1 = input.next();  
String s2 = input.next();  
String s3 = input.next();  
System.out.println("s1 is " + s1);  
System.out.println("s2 is " + s2);  
System.out.println("s3 is " + s3);
```

Reading a Character from the Console

```
Scanner input = new Scanner(System.in);  
System.out.print("Enter a character: ");  
String s = input.nextLine();  
char ch = s.charAt(0);  
System.out.println("The character entered is "  
    + ch);
```

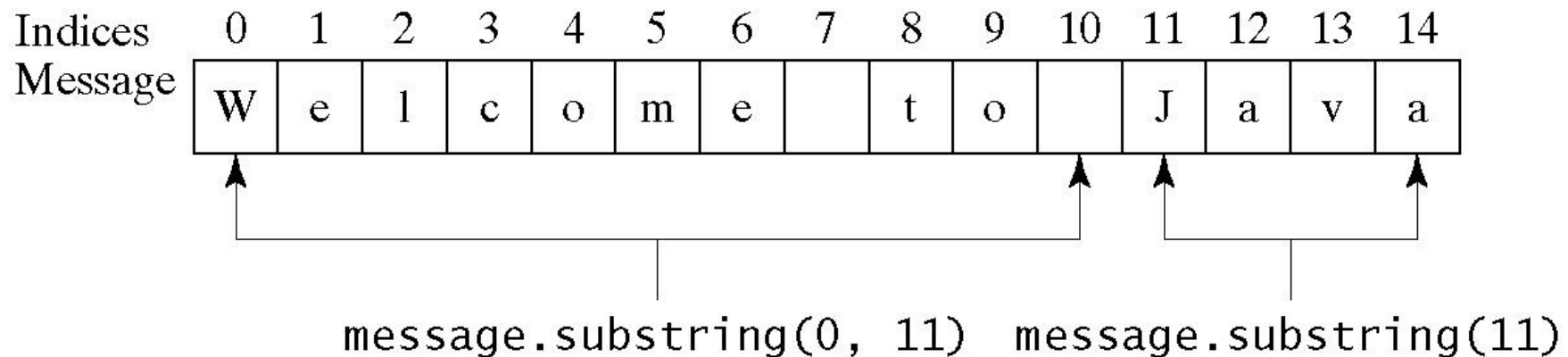
Comparing Strings

Method	Description
<code>equals(s1)</code>	Returns true if this string is equal to string <code>s1</code> .
<code>equalsIgnoreCase(s1)</code>	Returns true if this string is equal to string <code>s1</code> ; it is case insensitive.
<code>compareTo(s1)</code>	Returns an integer greater than 0, equal to 0, or less than 0 to indicate whether this string is greater than, equal to, or less than <code>s1</code> .
<code>compareToIgnoreCase(s1)</code>	Same as <code>compareTo</code> except that the comparison is case insensitive.
<code>startsWith(prefix)</code>	Returns true if this string starts with the specified prefix.
<code>endsWith(suffix)</code>	Returns true if this string ends with the specified suffix.

ch04/OrderTwoCities.java

Obtaining Substrings

Method	Description
<code>substring(beginIndex)</code>	Returns this string's substring that begins with the character at the specified <code>beginIndex</code> and extends to the end of the string, as shown in Figure 4.2.
<code>substring(beginIndex, endIndex)</code>	Returns this string's substring that begins at the specified <code>beginIndex</code> and extends to the character at index <code>endIndex - 1</code> , as shown in Figure 9.6. Note that the character at <code>endIndex</code> is not part of the substring.

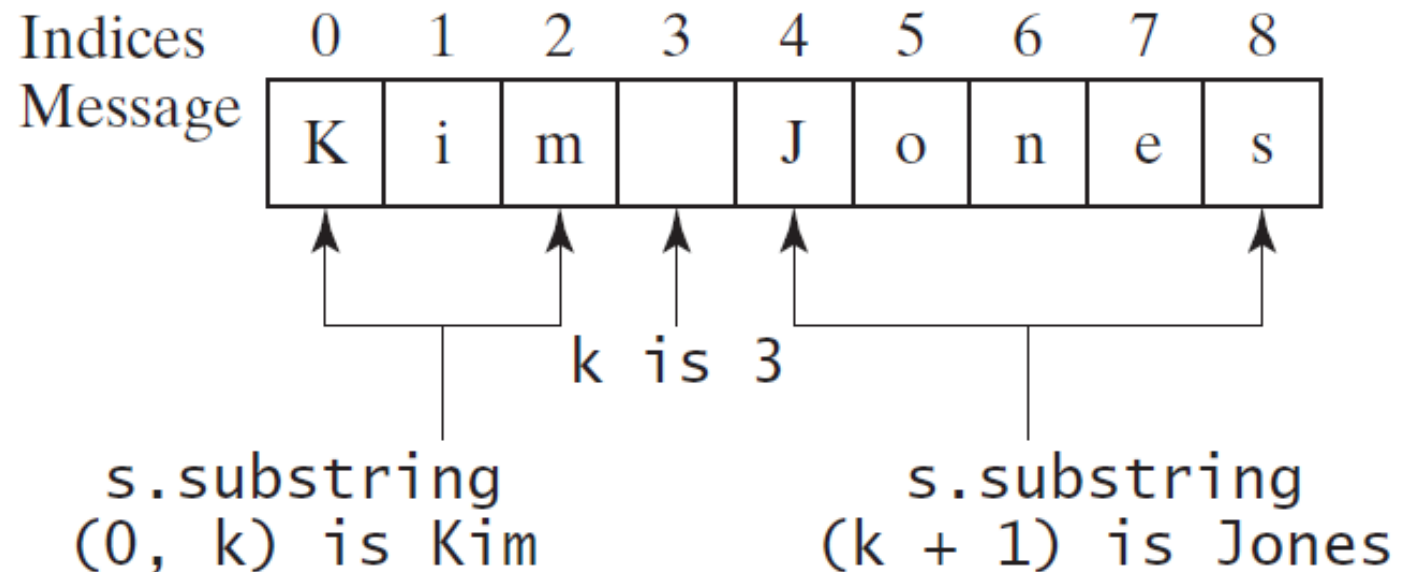


Finding a Character or a Substring in a String

Method	Description
<code>indexOf(ch)</code>	Returns the index of the first occurrence of <code>ch</code> in the string. Returns <code>-1</code> if not matched.
<code>indexOf(ch, fromIndex)</code>	Returns the index of the first occurrence of <code>ch</code> after <code>fromIndex</code> in the string. Returns <code>-1</code> if not matched.
<code>indexOf(s)</code>	Returns the index of the first occurrence of string <code>s</code> in this string. Returns <code>-1</code> if not matched.
<code>indexOf(s, fromIndex)</code>	Returns the index of the first occurrence of string <code>s</code> in this string after <code>fromIndex</code> . Returns <code>-1</code> if not matched.
<code>lastIndexOf(ch)</code>	Returns the index of the last occurrence of <code>ch</code> in the string. Returns <code>-1</code> if not matched.
<code>lastIndexOf(ch, fromIndex)</code>	Returns the index of the last occurrence of <code>ch</code> before <code>fromIndex</code> in this string. Returns <code>-1</code> if not matched.
<code>lastIndexOf(s)</code>	Returns the index of the last occurrence of string <code>s</code> . Returns <code>-1</code> if not matched.
<code>lastIndexOf(s, fromIndex)</code>	Returns the index of the last occurrence of string <code>s</code> before <code>fromIndex</code> . Returns <code>-1</code> if not matched.

Finding a Character or a Substring in a String

```
int k = s.indexOf(' ');  
String firstName = s.substring(0, k);  
String lastName = s.substring(k + 1);
```

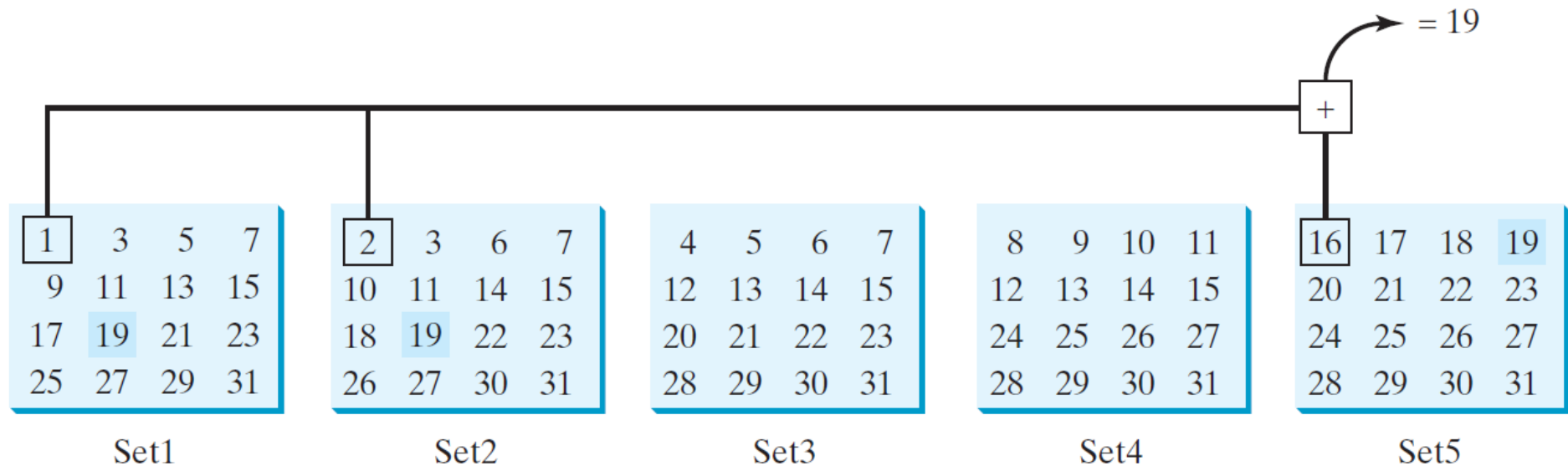


Conversion between Strings and Numbers

```
int intValue = Integer.parseInt(intString);  
double doubleValue =  
    Double.parseDouble(doubleString);  
  
String s = number + "";
```

Problem: Guessing Birthday

The program can guess your birth date. Run to see how it works.



Ch04/GuessBirthday.java

Mathematics Basis for the Game

19 is 10011 in binary. 7 is 111 in binary. 23 is 11101 in binary

$$\begin{array}{r}
 10000 \\
 10 \\
 + 1 \\
 \hline
 10011
 \end{array}
 \qquad
 \begin{array}{r}
 00110 \\
 10 \\
 + 1 \\
 \hline
 00111
 \end{array}
 \qquad
 \begin{array}{r}
 10000 \\
 1000 \\
 100 \\
 + 1 \\
 \hline
 11101
 \end{array}$$

19

7

23

Decimal	Binary
1	00001
2	00010
3	00011
...	
19	10011
...	
31	11111

$ \begin{array}{r} b_5 \ 0 \ 0 \ 0 \ 0 \\ b_4 \ 0 \ 0 \ 0 \\ b_3 \ 0 \ 0 \\ b_2 \ 0 \\ + b_1 \\ \hline b_5 \ b_4 \ b_3 \ b_2 \ b_1 \end{array} $	$ \begin{array}{r} 10000 \\ 1000 \\ 100 \\ 10 \\ + 1 \\ \hline 10011 \end{array} $	$ \begin{array}{r} 10000 \\ 1000 \\ 100 \\ 10 \\ + 1 \\ \hline 11111 \end{array} $
19	19	31

Case Study: Converting a Hexadecimal Digit to a Decimal Value

Write a program that converts a hexadecimal digit into a decimal value.

ch04/HexDigit2Dec.java

Case Study: Revisting the Lottery Program Using Strings

A problem can be solved using many different approaches. This section rewrites the lottery program in ch03 /Lottery.java using strings. Using strings simplifies this program.

ch04/LotteryUsingStrings.java

Formatting Output

Use the printf statement.

```
System.out.printf(format, items);
```

Where format is a string that may consist of substrings and format specifiers.

A format specifier specifies how an item should be displayed.

An item may be a numeric value, character, boolean value, or a string.

Each specifier begins with a percent sign.

Frequently-Used Specifiers

Specifier	Output	Example
<code>%b</code>	a boolean value	true or false
<code>%c</code>	a character	'a'
<code>%d</code>	a decimal integer	200
<code>%f</code>	a floating-point number	45.460000
<code>%e</code>	a number in standard scientific notation	4.556000e+01
<code>%s</code>	a string	"Java is cool"

```
int count = 5;
double amount = 45.56;
System.out.printf("count is %d and amount is %f", count, amount);
```

display count is 5 and amount is 45.560000

FormatDemo

The example gives a program that uses **printf** to display a table.

ch04/FormatDemo.java


编程练习题

下周一交10.30

4.1（检查SSN）

编写一个程序，提示用户输入一个社保号码，它的格式是DDD-DD-DDDD，其中D是一个数字。你的程序应该判断输入是否合法。

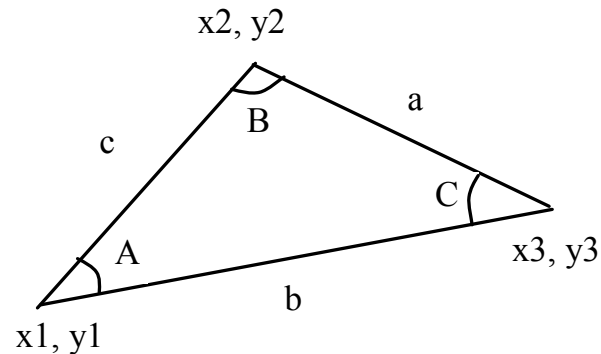
下面是一个运行示例：

```
Enter a SSN: 232-23-5435   
232-23-5435 is a valid social security number
```

```
Enter a SSN: 23-23-5435   
23-23-5435 is an invalid social security number
```

编程练习题 下周一交10.30

4.2 Computing Angles of a Triangle



$$A = \arccos((a * a - b * b - c * c) / (-2 * b * c))$$

$$B = \arccos((b * b - a * a - c * c) / (-2 * a * c))$$

$$C = \arccos((c * c - b * b - a * a) / (-2 * a * b))$$

Write a program that prompts the user to enter the x- and y-coordinates of the three corner points in a triangle and then displays the triangle's angles.

ch04/ComputeAngles.java

编程练习题 下周一交10.30

4.3（选做题）

自己调研深度神经网络的几种激活函数
（Activation Functions）并用 java实现

Sigmoid、Tanh、ReLU 及某些变体
以及最新的“SWISH: A SELF-GATED ACTIVATION FUNCTION”