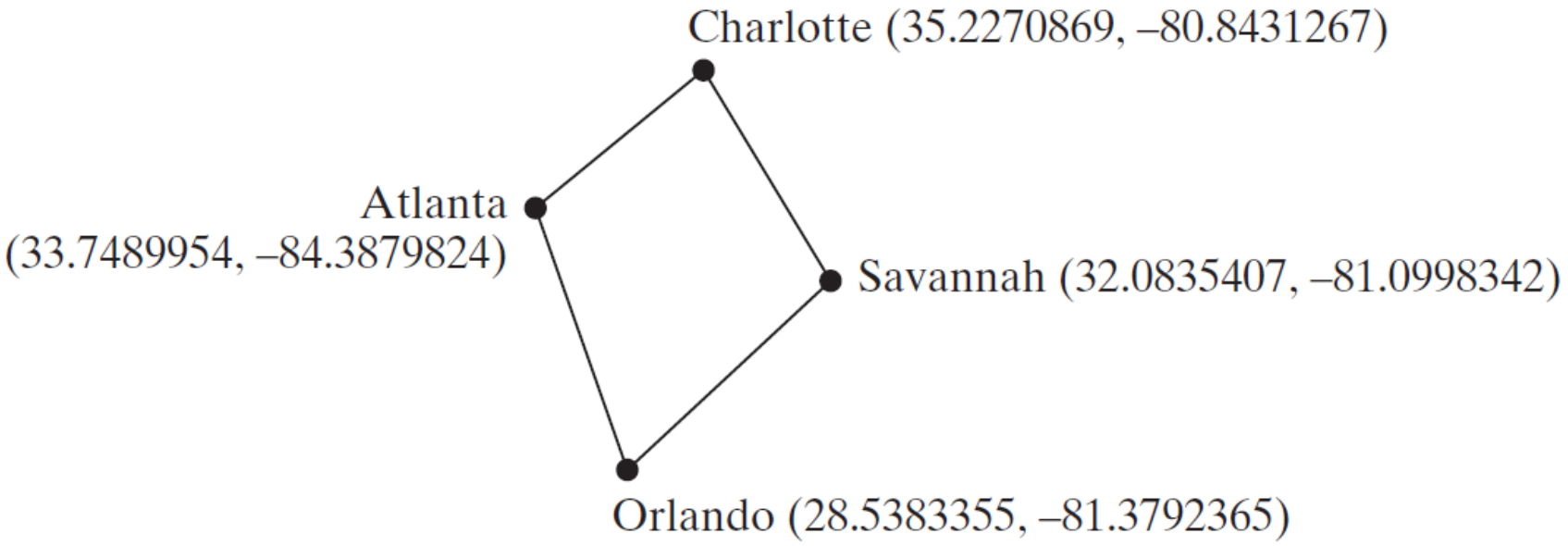
Chapter 4 Mathematical Functions, Characters, and Strings

Motivations

Suppose you need to estimate the area enclosed by four cities, given the GPS locations (latitude and longitude) of these cities, as shown in the following diagram. How would you write a program to solve this problem? You will be able to write such a program after completing this chapter.



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:
  - `PI`
  - `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)`
- `acos(double a)`
- `asin(double a)`
- `atan(double a)`

Radians $pi = 3.14159$

toRadians(180)

```
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
```

static methods

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 <= Math.random() < 1.0).

Examples:

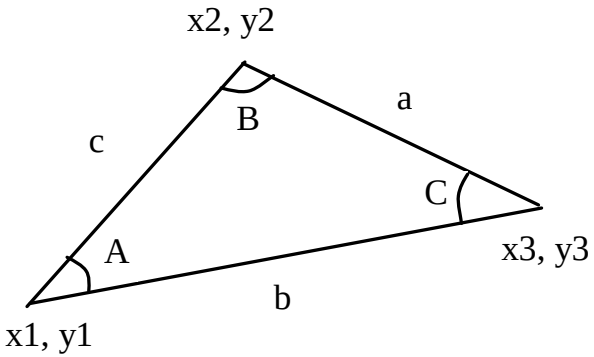
```
(int)(Math.random() * 10)
```
→ Returns a random integer between 0 and 9.

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

In general,

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

Case Study: Computing Angles of a Triangle




```
A = acos((a * a - b * b - c * c) / (-2 * b * c))
B = acos((b * b - a * a - c * c) / (-2 * a * c))
C = acos((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.

ComputeAngles

Run

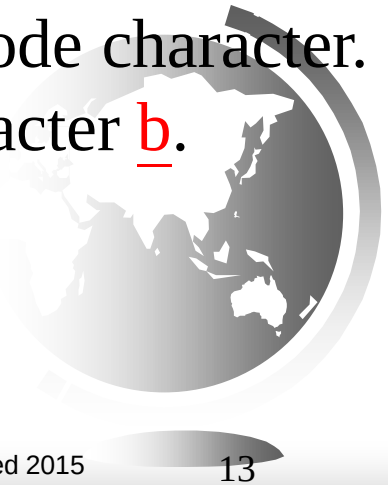
Character Data Type

Four hexadecimal digits = 2 bytes

```
char letter = 'A'; (ASCII)
char numChar = '4'; (ASCII)
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. For example, the following statements display character b.

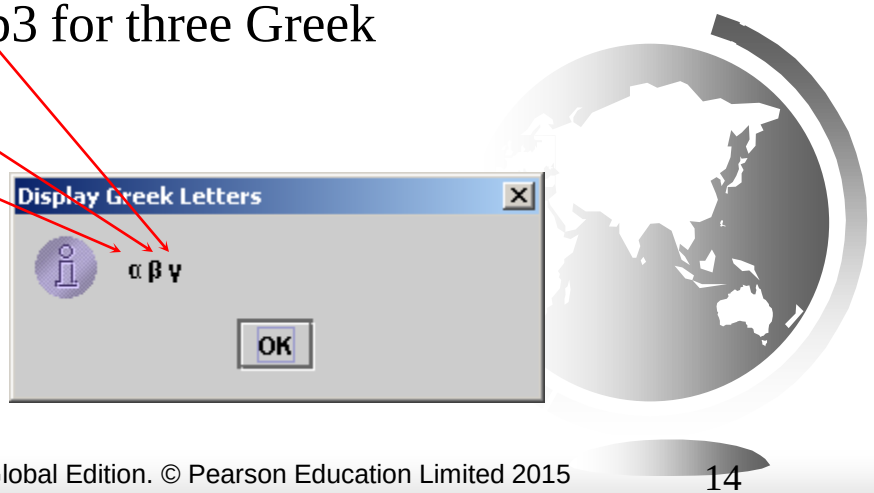
```
char ch = 'a';
System.out.println(++ch);
```



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

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

	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*A*	*B*	*C*	*D*	*E*	*F*
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
`isDigit(ch)`	Returns true if the specified character is a digit.
`isLetter(ch)`	Returns true if the specified character is a letter.
`isLetterOfDigit(ch)`	Returns true if the specified character is a letter or digit.
`isLowerCase(ch)`	Returns true if the specified character is a lowercase letter.
`isUpperCase(ch)`	Returns true if the specified character is an uppercase letter.
`toLowerCase(ch)`	Returns the lowercase of the specified character.
`toUpperCase(ch)`	Returns the uppercase of the specified character.

The String Type

The char type only represents one character. To represent a string of characters, use the data type called String. For example,

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

String is a class

String is actually a predefined class in the Java library just like the System class and Scanner class. The String type is not a **primitive type**. It is known as a ***reference type***. Any Java class can be used as a reference type for a variable. Reference data types will be thoroughly discussed in Chapter 9, "Objects and Classes." For the time being, you just need to know how to declare a String variable, how to assign a string to the variable, how to concatenate strings, and to perform simple operations for strings.

Simple Methods for **String** Objects

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

*All are **instance methods**, depending on **objects** created*

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).

Non-instance method (*static method*)

```
Math.rint(2.5)
```

Not for a particular object

Getting String Length

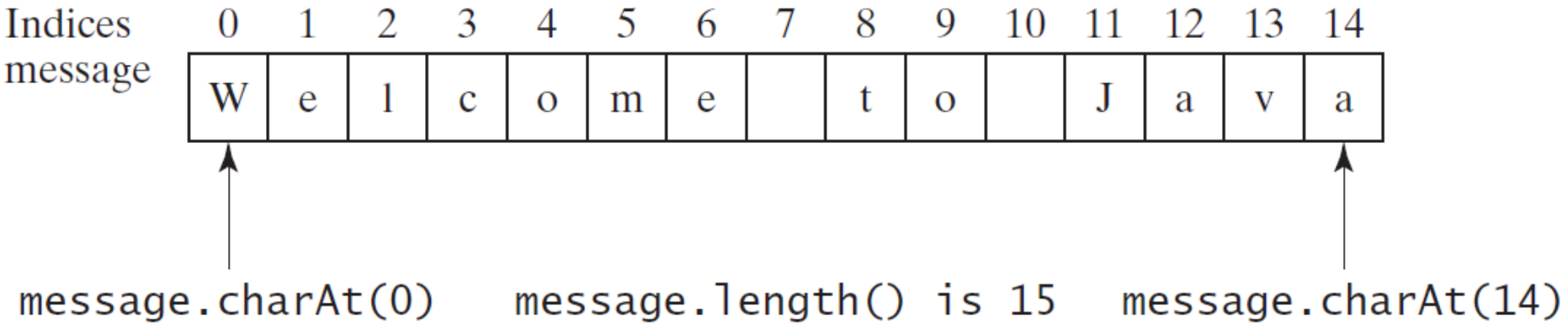
```
String message = "Welcome to Java";
System.out.println("The length of " + message + " is "
  + message.length());
```

referenceVariable

referenceVariable.methodName(arguments)

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.

"Welcome".toLowerCase()

message.charAt(0)

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"

Type conversion before concatenation

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);
```

input.next() knows the next input should be read as a string.

Reading a Character from the Console

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

Comparing Strings

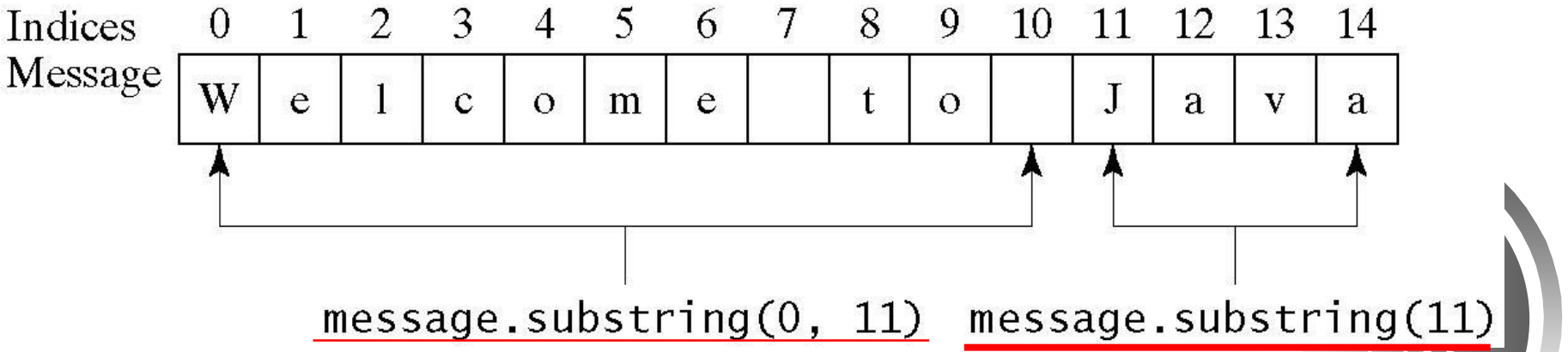
Method	Description
`equals(s1)`	Returns true if this string is equal to string `s1`.
`equalsIgnoreCase(s1)`	Returns true if this string is equal to string `s1`; it is case insensitive.
`compareTo(s1)`	Returns an integer greater than `0`, equal to `0`, or less than `0` to indicate whether this string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

OrderTwoCities

Run

Obtaining Substrings

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



Finding a Character or a Substring in a String

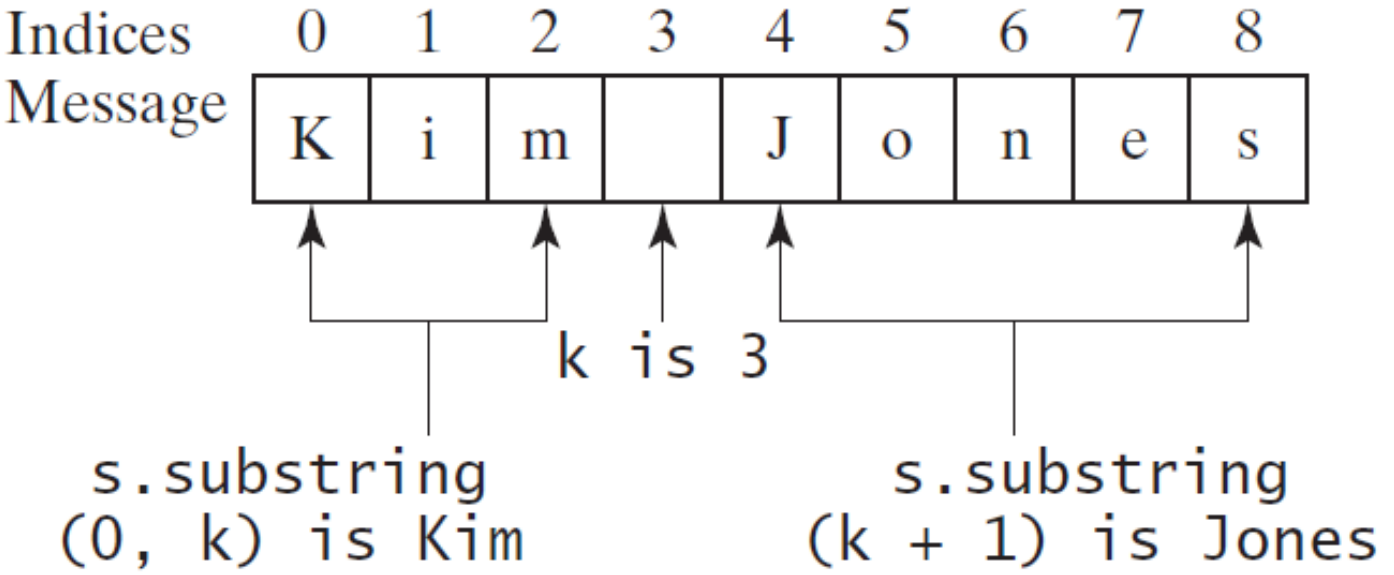
Method	Description
`indexOf(ch)`	Returns the index of the first occurrence of `ch` in the string. Returns `-1` if not matched.
`indexOf(ch, fromIndex)`	Returns the index of the first occurrence of `ch` after `fromIndex` in the string. Returns `-1` if not matched.
`indexOf(s)`	Returns the index of the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

Finding a Character or a Substring in a String

3

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

0 ~ 3-1



Conversion between Strings and Numbers

"123"
"12.34"

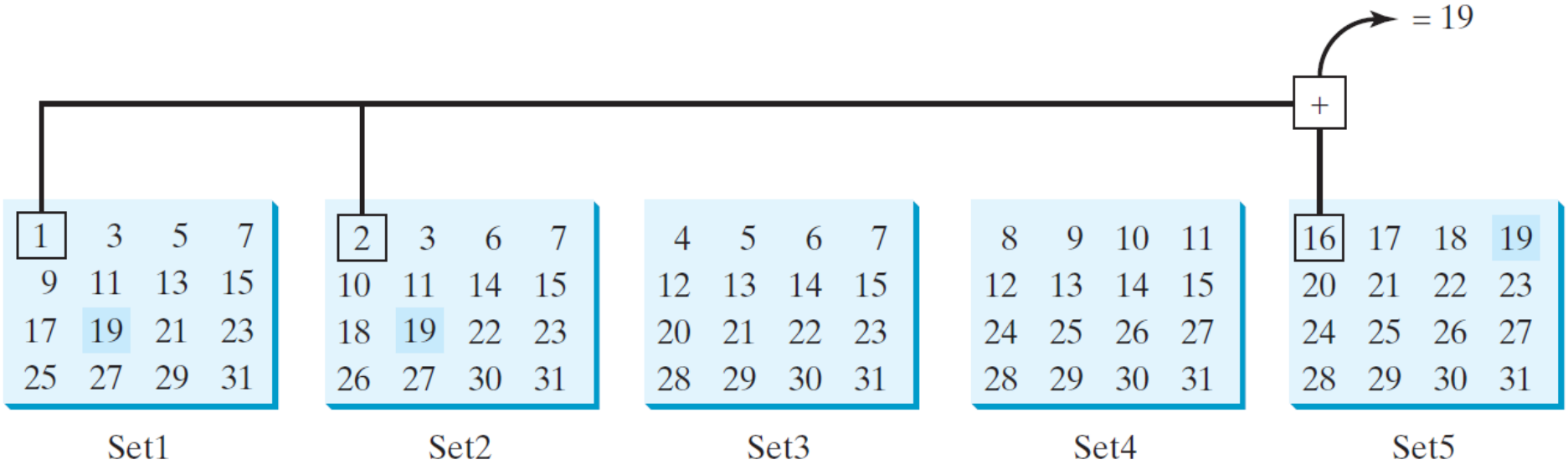
```
int intValue = Integer.parseInt(intString);
double doubleValue = Double.parseDouble(doubleString);
```

```
String s = number + "";
```

number is converted to String before "+"

Problem: Guessing Birthday

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



GuessBirthday

Run

Mathematics Basis for the Game

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

```
  10000          00110          10000
     10             10           1000
+     1        +     1            100
  -----          -----       +     1
  10011          00111          -----
                                11101

    19             7              23
```

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

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

Case Study: Converting a Hexadecimal Digit to a Decimal Value

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

HexDigit2Dec

Run

Case Study: Revising the Lottery Program Using Strings

A problem can be solved using many different approaches. This section rewrites the lottery program in Listing 3.7 using strings. Using strings simplifies this program.

LotteryUsingStrings

Run

Formatting Output

Use the printf statement.

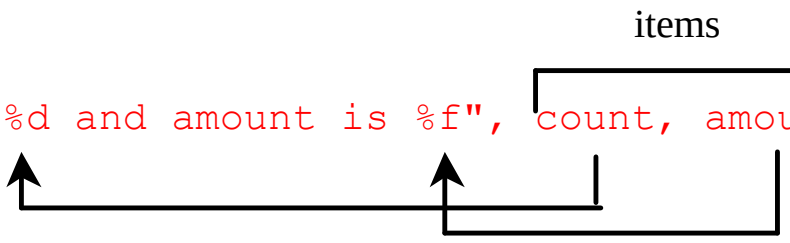
System.out.**printf**(format, items);

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
%b	a boolean value	true or false
%c	a character	'a'
%d	a decimal integer	200
%f	a floating-point number	45.460000
%e	a number in standard scientific notation	4.556000e+01
%s	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.

FormatDemo

Run