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Appendix A

Java Keywords and Reserved Words

Keywords have special meaning in Java and are part of the syntax. Reserved words are the words that cannot be used as identifiers. Keywords are reserved words. The following 50 keywords are reserved for use by the Java language:

abstract	double	int	super
assert	else	interface	switch
boolean	enum	long	synchronized
break	extends	native	this
byte	final	new	throw
case	finally	package	throws
catch	float	private	transient
char	for	protected	try
class	goto	public	void
const	if	return	volatile
continue	implements	short	while
default	import	static	
do	instanceof	strictfp*	

The keywords **goto** and **const** are C++ keywords reserved, but not currently used in Java. This enables Java compilers to identify them and to produce better error messages if they appear in Java programs.

The literal values **true**, **false**, and **null** are reserved words, but not keywords. You cannot use them as identifiers.

In the code listing, we use the keyword color for **true**, **false**, and **null** to be consistent with their coloring in Java IDEs.

*The **strictfp** keyword is a modifier for a method or class that enables it to use strict floating-point calculations. Floating-point arithmetic can be executed in one of two modes: *strict* or *nonstrict*. The strict mode guarantees that the evaluation result is the same on all Java Virtual Machine implementations. The nonstrict mode allows intermediate results from calculations to be stored in an extended format different from the standard IEEE floating-point number format. The extended format is machine dependent and enables code to be executed faster. However, when you execute the code using the nonstrict mode on different JVMs, you may not always get precisely the same results. By default, the nonstrict mode is used for floating-point calculations. To use the strict mode in a method or a class, add the **strictfp** keyword in the method or the class declaration. Strict floating-point may give you slightly better precision than nonstrict floating-point, but the distinction will only affect some applications. Strictness is not inherited; that is, the presence of **strictfp** on a class or interface declaration does not cause extended classes or interfaces to be strict.

Appendix B

The ASCII Character Set

Tables B.1 and B.2 show ASCII characters and their respective decimal and hexadecimal codes. The decimal or hexadecimal code of a character is a combination of its row index and column index. For example, in Table B.1, the letter A is at row 6 and column 5, so its decimal equivalent is 65; in Table B.2, letter A is at row 4 and column 1, so its hexadecimal equivalent is 41.

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		

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

APPENDIX C

Operator Precedence Chart

The operators are shown in decreasing order of precedence from top to bottom. Operators in the same group have the same precedence, and their associativity is shown in the table.

Operator	*Name*	*Associativity*
`()`	Parentheses	Left to right
`()`	Function call	Left to right
`[]`	Array subscript	Left to right
`.`	Object member access	Left to right
`++`	Postincrement	Left to right
`--`	Postdecrement	Left to right
`++`	Preincrement	Right to left
`--`	Predecrement	Right to left
`+`	Unary plus	Right to left
`-`	Unary minus	Right to left
`!`	Unary logical negation	Right to left
`(type)`	Unary casting	Right to left
`new`	Creating object	Right to left
`*`	Multiplication	Left to right
`/`	Division	Left to right
`%`	Remainder	Left to right
`+`	Addition	Left to right
`-`	Subtraction	Left to right
`<<`	Left shift	Left to right
`>>`	Right shift with sign extension	Left to right
`>>>`	Right shift with zero extension	Left to right
`<`	Less than	Left to right
`<=`	Less than or equal to	Left to right
`>`	Greater than	Left to right
`>=`	Greater than or equal to	Left to right
`instanceof`	Checking object type	Left to right

Operator	*Name*	*Associativity*
==	Equal comparison	Left to right
!=	Not equal	Left to right
&	(Unconditional AND)	Left to right
^	(Exclusive OR)	Left to right
|	(Unconditional OR)	Left to right
&&	Conditional AND	Left to right
||	Conditional OR	Left to right
?:	Ternary condition	Right to left
=	Assignment	Right to left
+=	Addition assignment	Right to left
-=	Subtraction assignment	Right to left
*=	Multiplication assignment	Right to left
/=	Division assignment	Right to left
%=	Remainder assignment	Right to left

APPENDIX D

Java Modifiers

Modifiers are used on classes and class members (constructors, methods, data, and class-level blocks), but the `final` modifier can also be used on local variables in a method. A modifier that can be applied to a class is called a *class modifier*. A modifier that can be applied to a method is called a *method modifier*. A modifier that can be applied to a data field is called a *data modifier*. A modifier that can be applied to a class-level block is called a *block modifier*. The following table gives a summary of the Java modifiers.

Modifier	*Class*	*Constructor*	*Method*	*Data*	*Block*	*Explanation*
`(blank)`*	√	√	√	√	√	A class, constructor, method, or data field is visible in this package.
`public`	√	√	√	√		A class, constructor, method, or data field is visible to all the programs in any package.
`private`		√	√	√		A constructor, method, or data field is only visible in this class.
`protected`		√	√	√		A constructor, method, or data field is visible in this package and in subclasses of this class in any package.
`static`			√	√	√	Define a class method, a class data field, or a static initialization block.
`final`	√		√	√		A final class cannot be extended. A final method cannot be modified in a subclass. A final data field is a constant.
`abstract`	√		√			An abstract class must be extended. An abstract method must be implemented in a concrete subclass.
`native`			√			A native method indicates that the method is implemented using a language other than Java.

* (blank) means no modifiers are used. For example: `class Test {}`

Modifier	*Class*	*Constructor*	*Method*	*Data*	*Block*	*Explanation*
`synchronized`			√		√	Only one thread at a time can execute this method.
`strictfp`	√		√			Use strict floating-point calculations to guarantee that the evaluation result is the same on all JVMs.
`transient`				√		Mark a nonserializable instance data field.

The modifiers `public`, `private`, and `protected` are known as *visibility* or *accessibility modifiers* because they specify how classes and class members are accessed.

The modifiers `public`, `private`, `protected`, `static`, `final`, and `abstract` can also be applied to inner classes.

Java 8 introduced the `default` modifier for declaring a default method in an interface. A default method provides a default implementation for the method in the interface.

Appendix E

Special Floating-Point Values

Dividing an integer by zero is invalid and throws `ArithmeticException`, but dividing a floating-point value by zero does not cause an exception. Floating-point arithmetic can overflow to infinity if the result of the operation is too large for a `double` or a `float`, or underflow to zero if the result is too small for a `double` or a `float`. Java provides the special floating-point values `POSITIVE_INFINITY`, `NEGATIVE_INFINITY`, and `NaN` (Not a Number) to denote these results. These values are defined as special constants in the `Float` class and the `Double` class.

If a positive floating-point number is divided by zero, the result is `POSITIVE_INFINITY`. If a negative floating-point number is divided by zero, the result is `NEGATIVE_INFINITY`. If a floating-point zero is divided by zero, the result is `NaN`, which means that the result is undefined mathematically. The string representations of these three values are `Infinity`, `-Infinity`, and `NaN`. For example,

```
System.out.print(1.0 / 0); // Print Infinity
System.out.print(–1.0 / 0); // Print –Infinity
System.out.print(0.0 / 0); // Print NaN
```

These special values can also be used as operands in computations. For example, a number divided by `POSITIVE_INFINITY` yields a positive zero. Table E.1 summarizes various combinations of the `/`, `*`, `%`, `+`, and `–` operators.

Table E.1 Special Floating-Point Values

x	*y*	*x/y*	*x*y*	*x%y*	*x + y*	*x − y*
Finite	±0.0	±infinity	±0.0	NaN	Finite	Finite
Finite	±infinity	±0.0	±0.0	x	±infinity	infinity
±0.0	±0.0	NaN	±0.0	NaN	±0.0	±0.0
±infinity	Finite	±infinity	±0.0	NaN	±infinity	±infinity
±infinity	±infinity	NaN	±0.0	NaN	±infinity	infinity
±0.0	±infinity	±0.0	NaN	±0.0	±infinity	±0.0
NaN	Any	NaN	NaN	NaN	NaN	NaN
Any	NaN	NaN	NaN	NaN	NaN	NaN

Note
If one of the operands is NaN, the result is NaN.

APPENDIX F

Number Systems

F.1 Introduction

Computers use binary numbers internally, because computers are made naturally to store and process 0s and 1s. The binary number system has two digits, 0 and 1. A number or character is stored as a sequence of 0s and 1s. Each 0 or 1 is called a *bit* (binary digit). base radix

In our daily life, we use decimal numbers. When we write a number such as 20 in a program, it is assumed to be a decimal number. Internally, computer software is used to convert decimal numbers into binary numbers, and vice versa. decimal numbers

We write computer programs using decimal numbers. However, to deal with an operating system, we need to reach down to the "machine level" by using binary numbers. Binary numbers tend to be very long and cumbersome. Often hexadecimal numbers are used to abbreviate them, with each hexadecimal digit representing four binary digits. The hexadecimal number system has 16 digits: 0–9 and A–F. The letters A, B, C, D, E, and F correspond to the decimal numbers 10, 11, 12, 13, 14, and 15. hexadecimal number

The digits in the decimal number system are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. A decimal number is represented by a sequence of one or more of these digits. The value that each digit represents depends on its position, which denotes an integral power of 10. For example, the digits 7, 4, 2, and 3 in decimal number 7423 represent 7000, 400, 20, and 3, respectively, as shown below:

$$\boxed{7}\boxed{4}\boxed{2}\boxed{3} = 7 \times 10^3 + 4 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

$$10^3\ 10^2\ 10^1\ 10^0 = 7000 + 400 + 20 + 3 = 7423$$

The decimal number system has 10 digits, and the position values are integral powers of 10. We say that 10 is the *base* or *radix* of the decimal number system. Similarly, since the binary number system has two digits, its base is 2, and since the hex number system has 16 digits, its base is 16.

If 1101 is a binary number, the digits 1, 1, 0, and 1 represent 1×2^3, 1×2^2, 0×2^1, and 1×2^0, respectively: binary numbers

$$\boxed{1}\boxed{1}\boxed{0}\boxed{1} = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

$$2^3\ 2^2\ 2^1\ 2^0 = 8 + 4 + 0 + 1 = 13$$

If 7423 is a hex number, the digits 7, 4, 2, and 3 represent 7×16^3, 4×16^2, 2×16^1, and 3×16^0, respectively:

$$\boxed{7}\boxed{4}\boxed{3}\boxed{2} = 7 \times 16^3 + 4 \times 16^2 + 2 \times 16^1 + 3 \times 16^0$$

$$16^3\ 16^2\ 16^1\ 16^0 = 28672 + 1024 + 32 + 3 = 29731$$

F.2 Conversions between Binary and Decimal Numbers

binary to decimal

Given a binary number $b_n b_{n-1} b_{n-2} \ldots b_2 b_1 b_0$, the equivalent decimal value is

$$b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

Here are some examples of converting binary numbers to decimals:

Binary	*Conversion Formula*	*Decimal*
10	$1 \times 2^1 + 0 \times 2^0$	2
1000	$1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$	8
10101011	$1 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$	171

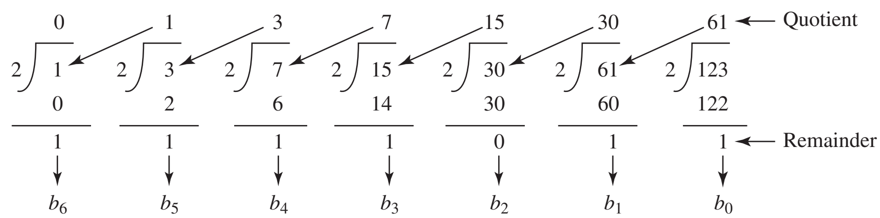
decimal to binary

To convert a decimal number d to a binary number is to find the bits $b_n, b_{n-1}, b_{n-2}, \ldots, b_2, b$ and b_0 such that

$$d = b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

These bits can be found by successively dividing d by 2 until the quotient is 0. The remainders are $b_0, b_1, b_2, \ldots, b_{n-2}, b_{n-1}$, and b_n.

For example, the decimal number 123 is 1111011 in binary. The conversion is done as follows:



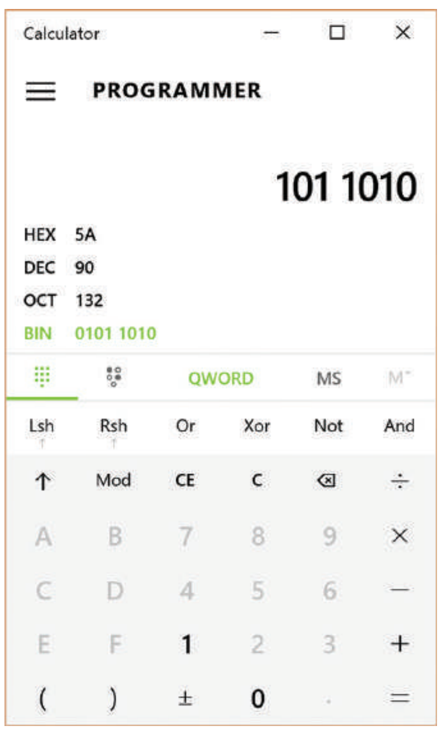


FIGURE F.1 You can perform number conversions using the Windows Calculator.

Tip

The Windows Calculator, as shown in Figure F.1, is a useful tool for performing number conversions. To run it, search for *Calculator* from the *Start* button and launch Calculator, then under *View* select *Scientific*.

F.3 Conversions between Hexadecimal and Decimal Numbers

hex to decimal

Given a hexadecimal number $h_n h_{n-1} h_{n-2} \ldots h_2 h_1 h_0$, the equivalent decimal value is

$$h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + \ldots + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

Here are some examples of converting hexadecimal numbers to decimals:

Hexadecimal	*Conversion Formula*	*Decimal*
7F	$7 \times 16^1 + 15 \times 16^0$	127
FFFF	$15 \times 16^3 + 15 \times 16^2 + 15 \times 16^1 + 15 \times 16^0$	65535
431	$4 \times 16^2 + 3 \times 16^1 + 1 \times 16^0$	1073

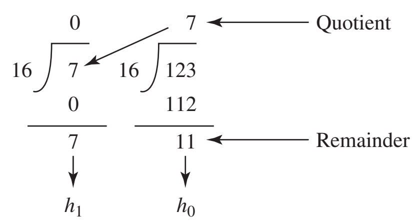
decimal to hex

To convert a decimal number d to a hexadecimal number is to find the hexadecimal digits $h_n, h_{n-1}, h_{n-2}, \ldots, h_2, h_1$, and h_0 such that

$$d = h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + \ldots + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

These numbers can be found by successively dividing d by 16 until the quotient is 0. The remainders are $h_0, h_1, h_2, \ldots, h_{n-2}, h_{n-1}$, and h_n.

For example, the decimal number 123 is 7B in hexadecimal. The conversion is done as follows:



F.4 Conversions between Binary and Hexadecimal Numbers

hex to binary

To convert a hexadecimal number to a binary number, simply convert each digit in the hexadecimal number into a four-digit binary number, using Table F.1.

For example, the hexadecimal number 7B is 01111011, where 7 is 0111 in binary and B is 1011 in binary.

binary to hex

To convert a binary number to a hexadecimal number, convert every four binary digits from right to left in the binary number into a hexadecimal number.

For example, the binary number 001110001101 is 38D, since 1101 is D, 1000 is 8, and 0011 is 3, as shown below.

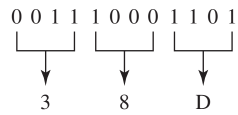


TABLE F.1 Converting Hexadecimal to Binary

Hexadecimal	*Binary*	*Decimal*
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

Note

Octal numbers are also useful. The octal number system has eight digits, 0 to 7. A decimal number 8 is represented in the octal system as 10.

Check Point

F.1 Convert the following decimal numbers into hexadecimal and binary numbers:

`100; 4340; 2000`

F.2 Convert the following binary numbers into hexadecimal and decimal numbers:

`1000011001; 100000000; 100111`

F.3 Convert the following hexadecimal numbers into binary and decimal numbers:

`FEFA9; 93; 2000`

Appendix G

Bitwise Operations

To write programs at the machine-level, often you need to deal with binary numbers directly and perform operations at the bit level. Java provides the bitwise operators and shift operators defined in Table G.1.

The bit operators apply only to integer types (`byte`, `short`, `int`, and `long`). A character involved in a bit operation is converted to an integer. All bitwise operators can form bitwise assignment operators, such as `^=`, `|=`, `<<=`, `>>=`, and `>>>=`.

Table G.1

Operator	*Name*	*Example (using bytes in the example)*	*Description*
`&`	Bitwise AND	10101110 `&` 10010010 yields 10000010	The AND of two corresponding bits yields a 1 if both bits are 1.
`|`	Bitwise inclusive OR	10101110 `|` 10010010 yields 10111110	The OR of two corresponding bits yields a 1 if either bit is 1.
`^`	Bitwise exclusive OR	10101110 `^` 10010010 yields 00111100	The XOR of two corresponding bits yields a 1 only if two bits are different.
`~`	One's complement	~10101110 yields 01010001	The operator toggles each bit from 0 to 1 and from 1 to 0.
`<<`	Left shift	10101110 `<<` 2 yields 10111000	The operator shifts bits in the first operand left by the number of bits specified in the second operand, filling with 0s on the right.
`>>`	Right shift with sign extension	10101110 `>>` 2 yields 11101011 00101110 `>>` 2 yields 00001011	The operator shifts bit in the first operand right by the number of bits specified in the second operand, filling with the highest (sign) bit on the left.
`>>>`	Unsigned right shift with zero extension	10101110 `>>>` 2 yields 00101011 00101110 `>>>` 2 yields 00001011	The operator shifts bit in the first operand right by the number of bits specified in the second operand, filling with 0s on the left.

Note

Programs using the bitwise operators are more efficient than the arithmetic operators. For example, to multiply an `int` value `x` by `2`, you can write `x << 1` rather than `x * 2`.

Appendix H

Regular Expressions

Often, you need to write the code to validate user input such as to check whether the input is a number, a string with all lowercase letters, or a Social Security number. How do you write this type of code? A simple and effective way to accomplish this task is to use the regular expression.

regular expression

A *regular expression* (abbreviated *regex*) is a string that describes a pattern for matching a set of strings. Regular expression is a powerful tool for string manipulations. You can use regular expressions for matching, replacing, and splitting strings.

H.1 Matching Strings

matches

Let us begin with the `matches` method in the `String` class. At first glance, the `matches` method is very similar to the `equals` method. For example, the following two statements both evaluate to `true`:

```
"Java".matches("Java");
"Java".equals("Java");
```

However, the `matches` method is more powerful. It can match not only a fixed string, but also a set of strings that follow a pattern. For example, the following statements all evaluate to `true`:

```
"Java is fun".matches("Java.*")
"Java is cool".matches("Java.*")
"Java is powerful".matches("Java.*")
```

`"Java.*"` in the preceding statements is a regular expression. It describes a string pattern that begins with Java followed by any zero or more characters. Here, the substring `.*` matches any zero or more characters.

H.2 Regular Expression Syntax

A regular expression consists of literal characters and special symbols. Table H.1 lists some frequently used syntax for regular expressions.

Table H.1 Frequently Used Regular Expressions

Regular Expression	*Matches*	*Example*
x	a specified character x	Java matches Java
.	any single character	Java matches J..a
(ab|cd)	ab or cd	ten matches t(en|im)
[abc]	a, b, or c	Java matches Ja[uvwx]a

(*continued*)

Regular Expression	*Matches*	*Example*
[^abc]	any character except a, b, or c	Java matches Ja[^ars]a
[a-z]	a through z	Java matches [A-M]av[a-d]
[^a-z]	any character except a through z	Java matches Jav[^b-d]
[a-e[m-p]]	a through e or m through p	Java matches [A-G[I-M]]av[a-d]
[a-e&&[c-p]]	intersection of a-e with c-p	Java matches [A-P&&[I-M]]av[a-d]
\d	a digit, same as [0-9]	Java2 matches "Java[\\d]"
\D	a non-digit	$Java matches "[\\D][\\D]ava"
\w	a word character	Java1 matches "[\\w]ava[\\d]"
\W	a non-word character	$Java matches "[\\W][\\w]ava"
\s	a whitespace character	"Java 2" matches "Java\\s2"
\S	a non-whitespace char	Java matches "[\\S]ava"
*p**	zero or more occurrences of pattern *p*	aaaa matches "a*" abab matches "(ab)*"
p+	one or more occurrences of pattern *p*	a matches "a+b*" able matches "(ab)+.*"
p?	zero or one occurrence of pattern *p*	Java matches "J?Java" ava matches "J?ava"
p{n}	exactly n occurrences of pattern *p*	Java matches "Ja{1}.*" Java does not match ".{2}"
p{n,}	at least n occurrences of pattern *p*	aaaa matches "a{1,}" a does not match "a{2,}"
p{n,m}	between n and m occurrences (inclusive)	aaaa matches "a{1,9}" abb does not match "a{2,9}bb"
\p{P}	a punctuation character !"#$%&'()*+, -./:;<=>?@ [\]^_'{|}~	J?a matches "J\\p{P}a" J?a. does not match "J\\p{P}a"

Note

Backslash is a special character that starts an escape sequence in a string. So you need to use \\ to represent a literal character \.

Note

Recall that a *whitespace character* is ' ', '\t', '\n', '\r', or '\f'. So \s is the same as [\t\n\r\f], and \S is the same as [^ \t\n\r\f].

Note

A word character is any letter, digit, or the underscore character. So \w is the same as [a-z[A-Z][0-9]_] or simply [a-zA-Z0-9_], and \W is the same as [^a-zA-Z0-9_].

Note

The entries *, +, ?, {n}, {n,}, and {n, m} in Table H.1 are called *quantifiers* that specify how many times the pattern before a quantifier may repeat. For example, A* quantifier matches zero or more **A**'s, **A+** matches one or more **A**'s, **A?** matches zero or one **A**, **A{3}** matches exactly **AAA**, **A{3,}** matches at least three **A**'s, and **A{3,6}** matches between 3 and 6 **A**'s. ***** is the same as **{0,}**, **+** is the same as **{1,}**, and **?** is the same as **{0,1}**.

Caution

Do not use spaces in the repeat quantifiers. For example, **A{3,6}** cannot be written as **A{3, 6}** with a space after the comma.

Note

You may use parentheses to group patterns. For example, **(ab){3}** matches **ababab**, but **ab{3}** matches **abbb**.

Let us use several examples to demonstrate how to construct regular expressions.

Example 1

The pattern for Social Security numbers is **xxx-xx-xxxx**, where **x** is a digit. A regular expression for Social Security numbers can be described as

```
[\\d]{3}-[\\d]{2}-[\\d]{4}
```

For example,

```
"111-22-3333".matches("[\\d]{3}-[\\d]{2}-[\\d]{4}") returns true.
"11-22-3333".matches("[\\d]{3}-[\\d]{2}-[\\d]{4}") returns false.
```

Example 2

An even number ends with digits **0**, **2**, **4**, **6**, or **8**. The pattern for even numbers can be described as

```
[\\d]*[02468]
```

For example,

```
"123".matches("[\\d]*[02468]") returns false.
"122".matches("[\\d]*[02468]") returns true.
```

Example 3

The pattern for telephone numbers is **(xxx) xxx-xxxx**, where **x** is a digit and the first digit cannot be zero. A regular expression for telephone numbers can be described as

```
\\([1-9][\\d]{2}\\) [\\d]{3}-[\\d]{4}
```

Note the parentheses symbols **(** and **)** are special characters in a regular expression for grouping patterns. To represent a literal **(** or **)** in a regular expression, you have to use **\\(** and **\\)**. For example,

```
"(912) 921-2728".matches("\\([1-9][\\d]{2}\\) [\\d]{3}-[\\d]{4}")
returns true.
"921-2728".matches("\\([1-9][\\d]{2}\\) [\\d]{3}-[\\d]{4}") returns
false.
```

Example 4

Suppose the last name consists of at most 25 letters, and the first letter is in uppercase. The pattern for a last name can be described as

```
[A-Z][a-zA-Z]{1,24}
```

Note you cannot have arbitrary whitespace in a regular expression. For example, `[A-Z][a-zA-Z]{1, 24}` would be wrong.
For example,

```
"Smith".matches("[A-Z][a-zA-Z]{1,24}") returns true.
"Jones123".matches("[A-Z][a-zA-Z]{1,24}") returns false.
```

Example 5

Java identifiers are defined in Section 2.3, Identifiers.

- An identifier must start with a letter, an underscore (_), or a dollar sign ($). It cannot start with a digit.
- An identifier is a sequence of characters that consists of letters, digits, underscores (_), and dollar signs ($).

The pattern for identifiers can be described as

```
[a-zA-Z_$][\\w$]*
```

Example 6

What strings are matched by the regular expression `"Welcome to (Java|HTML)"`? The answer is `Welcome to Java` or `Welcome to HTML`.

Example 7

What strings are matched by the regular expression `".*"`? The answer is any string.

H.3 Replacing and Splitting Strings

The `matches` method in the `String` class returns `true` if the string matches the regular expression. The `String` class also contains the `replaceAll`, `replaceFirst`, and `split` methods for replacing and splitting strings, as shown in Figure H.1.

java.lang.String	
+matches(regex: String): boolean	Returns true if this string matches the pattern.
+replaceAll(regex: String, replacement: String): String	Returns a new string that replaces all matching substrings with the replacement.
+replaceFirst(regex: String, replacement: String): String	Returns a new string that replaces the first matching substring with the replacement.
+split(regex: String): String[]	Returns an array of strings consisting of the substrings split by the matches.
+split(regex: String, limit: int): String[]	Same as the preceding split method except that the limit parameter controls the number of times the pattern is applied.

FIGURE H.1 The `String` class contains the methods for matching, replacing, and splitting strings using regular expressions.

The `replaceAll` method replaces all matching substring, and the `replaceFirst` method replaces the first matching substring. For example, the code

```
System.out.println("Java Java Java".replaceAll("v\\w", "wi"));
```

displays

```
Jawi Jawi Jawi
```

and this code

```
System.out.println("Java Java Java".replaceFirst("v\\w", "wi"));
```

displays

```
Jawi Java Java
```

There are two overloaded `split` methods. The `split(regex)` method splits a string into substrings delimited by the matches. For example, the statement

```
String[] tokens = "Java1HTML2Perl".split("\\d");
```

splits string `"Java1HTML2Perl"` into `Java`, `HTML`, and `Perl` and saves in `tokens[0]`, `tokens[1]`, and `tokens[2]`.

In the `split(regex, limit)` method, the `limit` parameter determines how many times the pattern is matched. If `limit <= 0`, `split(regex, limit)` is same as `split(regex)`. If `limit > 0`, the pattern is matched at most `limit – 1` times. Here are some examples:

```
"Java1HTML2Perl".split("\\d", 0); splits into Java, HTML, Perl
"Java1HTML2Perl".split("\\d", 1); splits into Java1HTML2Perl
"Java1HTML2Perl".split("\\d", 2); splits into Java, HTML2Perl
"Java1HTML2Perl".split("\\d", 3); splits into Java, HTML, Perl
"Java1HTML2Perl".split("\\d", 4); splits into Java, HTML, Perl
"Java1HTML2Perl".split("\\d", 5); splits into Java, HTML, Perl
```

Note

By default, all the quantifiers are *greedy*. This means that they will match as many occurrences as possible. For example, the following statement displays `JRvaa`, since the first match is `aaa`:

```
System.out.println("Jaaavaa".replaceFirst("a+", "R"));
```

You can change a qualifier's default behavior by appending a question mark (`?`) after it. The quantifier becomes *reluctant* or *lazy*, which means that it will match as few occurrences as possible. For example, the following statement displays `JRaavaa`, since the first match is `a`:

```
System.out.println("Jaaavaa".replaceFirst("a+?", "R"));
```

H.4 Replacing Partial Content in a Matched Substring

Sometimes, you need to make a replacement for partial content in a matched string. For example, suppose we have a text as follows:

```
String text = "3 * (x – y) is in lines 12-56.";
```

We would like to replace the text to

```
"3 * (x – y) is in lines 12 to 56.";
```

Note the `–` symbol is replaced to the word `"to"` if it is preceded by the word `"lines"` and between two numbers. We would like to replace all the occurrences of the `–` symbol by the word `"to"` for such cases in a text. To accomplish this, we will find a matching substring with the pattern `[lines \\d+-\\d+"]` and then replace the `–` symbol in the pattern by the word `"to"`. This can be done using the `Pattern` and `Matcher` classes.

The `Pattern` class is a compiled representation of a regular expression. You can create an instance of `Pattern` using `Pattern.compile(regex)`. The resulting pattern can then be used to create a `Matcher` object. For example, the following code creates a `Pattern` object `p` and creates a `Matcher` object `m` for the text using the pattern `p`:

```
String regex = "lines \\d+-\\d+";
Pattern p = Pattern.compile(regex);
Matcher m = p.matcher(text);
```

You can now use the `find()` method in the `Matcher` class to find a matched substring for the pattern, use the `group()` method to return the matched substring, and replace the `–` symbol in the matched string, and then use the `addReplacement` and `addTail` methods to add the text and its replacement into a `StringBuilder`.

The complete code is given in Listing H.1

LISTING H.1 PatternMatcherDemo.java

```
1  import java.util.regex.Matcher;
2  import java.util.regex.Pattern;
3
4  public class PatternMatcherDemo {
5    public static void main(String args[]) {
6     String text = "3 * (x – y) is in lines 12–56.";
7      String regex = "lines \\d+-\\d+";
8      Pattern p = Pattern.compile(regex);
9      Matcher m = p.matcher(text);
10
11     StringBuffer sb = new StringBuffer();
12     while (m.find()) {
13        String replacement = m.group();
14        replacement = replacement.replace("-", " to ");
15        m.appendReplacement(sb, replacement);
16    }
17
18    m.appendTail(sb);
19    System.out.println(sb.toString());
20  }
26 }
```

This is an elaborated process. Invoking `m.find()` (line 12) scans the text to find the next match for the pattern in the text from the starting position. Initially, the starting position is at index `0`. Invoking `m.group()` (line 13) returns the matched substring to `String replacement`. The `String`'s `replace` method replaces `"-"` with `"to"` (line 14). Invoking `m.appendReplace(sb, replacement)` appends the current unmatched content in the text to `sb` and then appends `replacement` to `sb`, where `sb` is a `StringBuilder`. Note that the current unmatched content are the substring that has been scanned by `m.find()`, but not part of the matched string. The loop (lines 12-16) continues to find the next matching, obtain the matched substring, replace the partial content in the substring, and append the unmatched content and the replacement to `sb`. The loop ends when no more matches can be found. The program then invokes the `m.addTail(sb)` method to append the remaining unmatched content in the text to `sb` (line 18).

Note that all these methods `find()`, `group()`, `addReplacement`, and `addTail` are used together in a find-replace-append loop. When `m.find()` is invoked for the first time, the starting position is at index `0`. When `m.find()` is invoked again, it first resets the starting position to pass the end of the matched substring.

APPENDIX I

Enumerated Types

I.1 Simple Enumerated Types

An enumerated type defines a list of enumerated values. Each value is an identifier. For example, the following statement declares a type, named **MyFavoriteColor**, with values **RED**, **BLUE**, **GREEN**, and **YELLOW** in this order:

```
enum MyFavoriteColor {RED, BLUE, GREEN, YELLOW};
```

A value of an enumerated type is like a constant and so, by convention, is spelled with all uppercase letters. So, the preceding declaration uses **RED**, not **red**. By convention, an enumerated type is named like a class with first letter of each word capitalized.

Once a type is defined, you can declare a variable of that type:

```
MyFavoriteColor color;
```

The variable **color** can hold one of the values defined in the enumerated type **MyFavoriteColor** or **null**, but nothing else. Java enumerated type is *type-safe*, meaning that an attempt to assign a value other than one of the enumerated values or **null** will result in a compile error.

The enumerated values can be accessed using the syntax

```
EnumeratedTypeName.valueName
```

For example, the following statement assigns enumerated value **BLUE** to variable **color**:

```
color = MyFavoriteColor.BLUE;
```

Note you have to use the enumerated type name as a qualifier to reference a value such as **BLUE**.

As with any other type, you can declare and initialize a variable in one statement:

```
MyFavoriteColor color = MyFavoriteColor.BLUE;
```

An enumerated type is treated as a special class. An enumerated type variable is therefore a reference variable. An enumerated type is a subtype of the **Object** class and the **Comparable** interface. Therefore, an enumerated type inherits all the methods in the **Object** class and the **compareTo** method in the **Comparable** interface. Additionally, you can use the following methods on an enumerated object:

- **public String name();**
  Returns a name of the value for the object.
- **public int ordinal();**
  Returns the ordinal value associated with the enumerated value. The first value in an enumerated type has an ordinal value of 0, the second has an ordinal value of 1, the third one 3, and so on.

Listing I.1 gives a program that demonstrates the use of enumerated types.

LISTING I.1 EnumeratedTypeDemo.java

```
 1 public class EnumeratedTypeDemo {
 2   static enum Day {SUNDAY, MONDAY, TUESDAY, WEDNESDAY, THURSDAY,
 3     FRIDAY, SATURDAY};
 4
 5   public static void main(String[] args) {
 6     Day day1 = Day.FRIDAY;
 7     Day day2 = Day.THURSDAY;
 8
 9     System.out.println("day1's name is " + day1.name());
10     System.out.println("day2's name is " + day2.name());
11     System.out.println("day1's ordinal is " + day1.ordinal());
12     System.out.println("day2's ordinal is " + day2.ordinal());
13
14     System.out.println("day1.equals(day2) returns " +
15       day1.equals(day2));
16     System.out.println("day1.toString() returns " +
17       day1.toString());
18     System.out.println("day1.compareTo(day2) returns " +
19       day1.compareTo(day2));
20   }
21 }
```

define an enum type

declare an enum variable

get enum name

get enum ordinal

compare enum values

```
day1's name is FRIDAY
day2's name is THURSDAY
day1's ordinal is 5
day2's ordinal is 4
day1.equals(day2) returns false
day1.toString() returns FRIDAY
day1.compareTo(day2) returns 1
```

An enumerated type **Day** is defined in lines 2 and 3. Variables **day1** and **day2** are declared as the **Day** type and assigned enumerated values in lines 6 and 7. Since **day1**'s value is **FRIDAY**, its ordinal value is 5 (line 11). Since **day2**'s value is **THURSDAY**, its ordinal value is 4 (line 12).

Since an enumerated type is a subclass of the **Object** class and the **Comparable** interface, you can invoke the methods **equals**, **toString**, and **compareTo** from an enumerated object reference variable (lines 14–19). **day1.equals(day2)** returns true if **day1** and **day2** have the same ordinal value. **day1.compareTo(day2)** returns the difference between **day1**'s ordinal value and **day2**'s.

Alternatively, you can rewrite the code in Listing I.1 into Listing I.2.

LISTING I.2 StandaloneEnumTypeDemo.java

```
public class StandaloneEnumTypeDemo {
  public static void main(String[] args) {
    Day day1 = Day.FRIDAY;
    Day day2 = Day.THURSDAY;

    System.out.println("day1's name is " + day1.name());
    System.out.println("day2's name is " + day2.name());
    System.out.println("day1's ordinal is " + day1.ordinal());
```

```
9        System.out.println("day2's ordinal is " + day2.ordinal());
10
11       System.out.println("day1.equals(day2) returns " +
12         day1.equals(day2));
13       System.out.println("day1.toString() returns " +
14         day1.toString());
15       System.out.println("day1.compareTo(day2) returns " +
16         day1.compareTo(day2));
17     }
18   }
19
20   enum Day {SUNDAY, MONDAY, TUESDAY, WEDNESDAY, THURSDAY,
21     FRIDAY, SATURDAY}
```

An enumerated type can be defined inside a class, as shown in lines 2 and 3 in Listing I.1, or standalone as shown in lines 20 and 21 in Listing I.2. In the former case, the type is treated as an inner class. After the program is compiled, a class named EnumeratedTypeDemo$Day.class is created. In the latter case, the type is treated as a stand-alone class. After the program is compiled, a class named Day.class is created.

Note

When an enumerated type is declared inside a class, the type must be declared as a member of the class and cannot be declared inside a method. Furthermore, the type is always **static**. For this reason, the **static** keyword in line 2 in Listing I.1 may be omitted. The visibility modifiers on inner class can be also be applied to enumerated types defined inside a class.

Tip

Using enumerated values (e.g., **Day.MONDAY**, **Day.TUESDAY**, and so on) rather than literal integer values (e.g., 0, 1, and so on) can make the program easier to read and maintain.

I.2 Using if or switch Statements with an Enumerated Variable

An enumerated variable holds a value. Often, your program needs to perform a specific action depending on the value. For example, if the value is **Day.MONDAY**, play soccer; if the value is **Day.TUESDAY**, take piano lesson, and so on. You can use an **if** statement or a **switch** statement to test the value in the variable, as shown in (a) and (b).

```
if (day.equals(Day.MONDAY)) {
  // process Monday
}
else if (day.equals(Day.TUESDAY)) {
  // process Tuesday
}
else
  ...
```

(a)

Equivalent

```
switch (day) {
  case MONDAY:
    // process Monday
    break;
  case TUESDAY:
    // process Tuesday
    break;
  ...
}
```

(b)

In the **switch** statement in (b), the case label is an unqualified enumerated value (e.g., **MONDAY**, but not **Day.MONDAY**).

I.3 Processing Enumerated Values Using a Foreach Loop

Each enumerated type has a static method `values()` that returns all enumerated values for the type in an array. For example,

```
Day[] days = Day.values();
```

You can use a regular for loop in (a) or foreach loop in (b) to process all the values in the array.

```
for (int i = 0; i < days.length; i++)
  System.out.println(days[i]);
```

(a)

Equivalent

```
for (Day day: days)
  System.out.println(day);
```

(b)

I.4 Enumerated Types with Data Fields, Constructors, and Methods

The simple enumerated types introduced in the preceding section define a type with a list of enumerated values. You can also define an enumerate type with data fields, constructors, and methods, as shown in Listing I.3.

Listing I.3 TrafficLight.java

```
1  public enum TrafficLight {
2    RED ("Please stop"), GREEN ("Please go"),
3    YELLOW ("Please caution");
4
5    private String description;
6
7    private TrafficLight(String description) {
8      this.description = description;
9    }
10
11   public String getDescription() {
12     return description;
13   }
14 }
```

The enumerated values are defined in lines 2 and 3. The value declaration must be the first statement in the type declaration. A data field named `description` is declared in line 5 to describe an enumerated value. The constructor `TrafficLight` is declared in lines 7–9. The constructor is invoked whenever an enumerated value is accessed. The enumerated value's argument is passed to the constructor, which is then assigned to `description`.

Listing I.4 gives a test program to use `TrafficLight`.

Listing I.4 TestTrafficLight.java

```
public class TestTrafficLight {
  public static void main(String[] args) {
    TrafficLight light = TrafficLight.RED;
    System.out.println(light.getDescription());
  }
}
```

An enumerated value `TrafficLight.red` is assigned to variable `light` (line 3). Accessing `TrafficLight.RED` causes the JVM to invoke the constructor with argument “please stop”. The methods in enumerated type are invoked in the same way as the methods in a class. `light.getDescription()` returns the description for the enumerated value (line 4).

Note

The Java syntax requires that the constructor for enumerated types be private to prevent it from being invoked directly. The private modifier may be omitted. In this case, it is considered private by default.

APPENDIX J

The Big-O, Big-Omega, and Big-Theta Notations

Chapter 22 presented the Big-O notation in laymen's term. In this appendix, we give a precise mathematic definition for the Big-O notation. We will also present the Big-Omega and Big-Theta notations.

J.1 The Big-O Notation

The Big-O notation is an asymptotic notation that describes the behavior of a function when its argument approaches a particular value or infinity. Let $f(n)$ and $g(n)$ be two functions, we say that $f(n)$ is $O(g(n))$, pronounced "big-O of $g(n)$", if there is a constant c $(c > 0)$ and value m such that $f(n) \leq c \times g(n)$, for $n \geq m$.

For example, $f(n) = 5n^3 + 8n^2$ is $O(n^3)$, because you can find $c = 13$ and $m = 1$ such that $f(n) \leq cn^3$ for $n \geq m$. $f(n) = 6n\log n + n^2$ is $O(n^2)$, because you can find $c = 7$ and $m = 2$ such that $f(n) \leq cn^2$ for $n \geq m$. $f(n) = 6n\log n + 400n$ is $O(n\log n)$, because you can find $c = 406$ and $m = 2$ such that $f(n) \leq cn\log n$ for $n \geq m$. $f(n) = n^2$ is $O(n^3)$, because you can find $c = 1$ and $m = 1$ such that $f(n) \leq cn^3$ for $n \geq m$. Note that there are infinite number of choices of c and m such that $f(n) \leq c \times g(n)$ for $n \geq m$.

The Big-O notation denotes that a function $f(n)$ is asymptotically less than or equal to another function $g(n)$. This allows you to simplify the function by ignoring multiplicative constants and discarding the non-dominating terms in the function.

J.2 The Big-Omega Notation

The Big-Omega notation is the opposite of the Big-O notation. It is an asymptotic notation that denotes that a function $f(n)$ is greater than or equal to another function $g(n)$. Let $f(n)$ and $g(n)$ be two functions, we say that $f(n)$ is $\Omega(g(n))$, pronounced "big-Omega of $g(n)$", if there is a constant $c(c > 0)$ and value m such that $f(n) \geq c \times g(n)$, for $n \geq m$.

For example, $f(n) = 5\mathrm{n}^3 + 8\mathrm{n}^2$ is $\Omega(\mathrm{n}^3)$, because you can find $c = 5$ and $m = 1$ such that $f(n) \geq cn^3$ for $n \geq m$. $f(n) = 6n\log n + n^2$ is $\Omega(n^2)$, because you can find $c = 1$ and $m = 1$ such that $f(n) \geq cn^2$ for $n \geq m$. $f(n) = 6n\log n + 400n$ is $\Omega(n\log n)$, because you can find $c = 6$ and $m = 1$ such that $f(n) \geq cn\log n$ for $n \geq m$. $f(n) = n^2$ is $\Omega(n)$, because you can find $c = 1$ and $m = 1$ such that $f(n) \geq cn$ for $n \geq m$. Note that there are infinite number of choices of c and m such that $f(n) \geq c \times g(n)$ for $n \geq m$.

J.3 The Big-Theta Notation

The Big-Theta notation denotes that two functions are the same asymptotically. Let $f(n)$ and $g(n)$ be two functions, we say that $f(n)$ is $\Theta(g(n))$, pronounced "big-Theta of $g(n)$", if $f(n)$ is $O(g(n))$ and $f(n)$ is $\Omega(g(n))$.

For example, $f(n) = 5n^3 + 8n^2$ is $\Theta(n^3)$, because you $f(n)$ is $O(n^3)$ and $f(n)$ is $\Omega(n^3)$. $f(n) = 6n\log n + 400n$ is $\Theta(n\log n)$, because $f(n)$ is $O(n\log n)$ and $f(n)$ is $\Theta(n\log n)$.

Note

The Big-O notation gives an upper bound of a function. The Big-Omega notation gives a lower bound of a function. The Big-Theta notation gives a tight bound of a function. For simplicity, the Big-O notation is often used, even though the Big-Theta notation may be more factually appropriate.

Java Quick Reference

Console Input

```
Scanner input = new Scanner(System.in);
int intValue = input.nextInt();
long longValue = input.nextLong();
double doubleValue = input.nextDouble();
float floatValue = input.nextFloat();
String string = input.next();
String line = input.nextLine();
```

Console Output

```
System.out.println(anyValue);
```

Conditional Expression

```
boolean-expression ? expression1 :
  expression2

y = (x > 0) ? 1 : -1

System.out.println(number % 2 == 0 ?
  "number is even" : "number is odd");
```

Primitive Data Types

byte	8 bits
short	16 bits
int	32 bits
long	64 bits
float	32 bits
double	64 bits
char	16 bits
boolean	true/false

Arithmetic Operators

+	addition
-	subtraction
*****	multiplication
/	division
%	remainder
++var	preincrement
--var	predecrement
var++	postincrement
var--	postdecrement

Assignment Operators

=	assignment
+=	addition assignment
-=	subtraction assignment
***=**	multiplication assignment
/=	division assignment
%=	remainder assignment

Relational Operators

<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	equal to
!=	not equal

Logical Operators

&&	short circuit AND
||	short circuit OR
!	NOT
^	exclusive OR

if Statements

```
if (condition) {
  statements;
}

if (condition) {
  statements;
}
else {
  statements;
}

if (condition1) {
  statements;
}
else if (condition2) {
  statements;
}
else {
  statements;
}
```

switch Statements

```
switch (intExpression) {
  case value1:
    statements;
    break;
  ...
  case valuen:
    statements;
    break;
  default:
    statements;
}
```

loop Statements

```
while (condition) {
  statements;
}

do {
  statements;
} while (condition);

for (init; condition;
  adjustment) {
  statements;
}
```

Companion Website: www.pearsonhighered.com/liang

Java Quick Reference

Frequently Used Static Constants/Methods

```
Math.PI
Math.random()
Math.pow(a, b)
Math.abs(a)
Math.max(a, b)
Math.min(a, b)
Math.sqrt(a)
Math.sin(radians)
Math.asin(a)
Math.toRadians(degrees)
Math.toDegress(radians)
System.currentTimeMillis()
Integer.parseInt(string)
Integer.parseInt(string, radix)
Double.parseDouble(string)
Arrays.sort(type[] list)
Arrays.binarySearch(type[] list, type key)
```

Array/Length/Initializer

```
int[] list = new int[10];
list.length;
int[] list = {1, 2, 3, 4};
```

Multidimensional Array/Length/Initializer

```
int[][] list = new int[10][10];
list.length;
list[0].length;
int[][] list = {{1, 2}, {3, 4}};
```

Ragged Array

```
int[][] m = {{1, 2, 3, 4},
             {1, 2, 3},
             {1, 2},
             {1}};
```

Text File Output

```
PrintWriter output =
  new PrintWriter(filename);
output.print(...);
output.println(...);
output.printf(...);
```

Text File Input

```
Scanner input = new Scanner(
  new File(filename));
```

File Class

```
File file =
  new File(filename);
file.exists()
file.renameTo(File)
file.delete()
```

Object Class

```
Object o = new Object();
o.toString();
o.equals(o1);
```

Comparable Interface

```
c.compareTo(Comparable)
c is a Comparable object
```

String Class

```
String s = "Welcome";
String s = new String(char[]);
int length = s.length();
char ch = s.charAt(index);
int d = s.compareTo(s1);
boolean b = s.equals(s1);
boolean b = s.startsWith(s1);
boolean b = s.endsWith(s1);
boolean b = s.contains(s1);
String s1 = s.trim();
String s1 = s.toUpperCase();
String s1 = s.toLowerCase();
int index = s.indexOf(ch);
int index = s.lastIndexOf(ch);
String s1 = s.substring(ch);
String s1 = s.substring(i,j);
char[] chs = s.toCharArray();
boolean b = s.matches(regex);
String s1 = s.replaceAll(regex,repl);
String[] tokens = s.split(regex);
```

ArrayList Class

```
ArrayList<E> list = new ArrayList<>();
list.add(object);
list.add(index, object);
list.clear();
Object o = list.get(index);
boolean b = list.isEmpty();
boolean b = list.contains(object);
int i = list.size();
list.remove(index);
list.set(index, object);
int i = list.indexOf(object);
int i = list.lastIndexOf(object);
```

printf Method

```
System.out.printf("%b %c %d %f %e %s",
  true, 'A', 45, 45.5, 45.5, "Welcome");
System.out.printf("%-5d %10.2f %10.2e %8s",
  45, 45.5, 45.5, "Welcome");
```

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