The Java Language Specification

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The Java Language Specification

This document is a preliminary specification of the JavaTM language. Both the specification and the language are subject to change. When a feature that exists in both Java and ANSI C isn't explained fully in this specification, the feature should be assu med to work as it does in ANSI C. Send comments on the Java Language and specification to java@java.Sun.COM. See also http://java.sun.com/mail.html for a list of Java-related mailing lists.

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The Java Spec: Appendix: Floating Point

A Appendix: Floating Point

This appendix discusses properties of Java floating point arithmetic: general precision notes and special values, binary format conversion, ordering. At the end is a section summarizing the differences between Java arithmetic and the IEEE 754 standard. Fo r more information on the IEEE 754 standard, see "IEEE Standard for Binary Floating-Point Arithmetic, ANSI/IEEE Std. 754-1985."

Operations involving only single-precision float and integer values are performed using at least single-precision arithmetic and produce a single-precision result. Other operations are performed in double precision and produce a double precision result. Java floating-point arithmetic produces no exceptions.

Underflow is gradual.

A.1 Special Values

There is both a positive zero and a negative zero. The latter can be produced in a number of special circumstances: the total underflow of a * or / of terms of different sign; the addition of -0 to itself or subtraction of positive zero from it; the squar e root of -0. Converting -0 to a string results in a leading `-'. Apart from this, the two zeros are indistinguishable.

Calculations which would produce a value beyond the range of the arithmetic being used deliver a signed infinite result. An infinity (Inf) has a larger magnitude than any value with the same sign. Infinities of the same sign cannot be distinguished. Thus, for instance (1./0.) + (1./0.) == (1./0.). Division of a finite value by infinity yields a 0 result.

Calculations which cannot produce any meaningful numeric result deliver a distinguished result called Not A Number (NaN). Any operation having a NaN as an operand produces a NaN as the result. NaN is not signed and not ordered (see "Ordering") . Division of infinity by infinity yields NaN, as does subtraction of one infinity from another of the same sign.

A.2 Binary Format Conversion

Converting a floating-point value to an integer format results in a value with the same sign as the argument value and having the largest magnitude less than or equal to that of the argument. In other

words, conversion rounds towards zero. Converting infi nity or any value beyond the range of the target integer type gives a result having the same sign as the argument and the maximum magnitude of that sign. Converting NaN results in 0.

Converting an integer to a floating format results in the closest possible value in the target format. Ties are broken in favor of the most even value (having 0 as the least-significant bit).

A.3 Ordering

The usual relational operators can be applied to floating-point values. With the exception of NaN, all floating values are ordered, with -Inf <; all finite values <; Inf.

-Inf == -Inf, +Inf == +Inf, -0. == 0. The ordering relations are transitive. Equality and inequality are reflexive.

NaN is unordered. Thus the result of any order relation between NaN and any other value is false and produces 0. The one exception is that "NaN != anything" is true.

Note that, because NaN is unordered, Java's logical inversion operator, !, does not distribute over floating point relationals as it can over integers.

A.4 Summary of IEEE-754 Differences

Java arithmetic is a subset of the IEEE-754 standard. Here is a summary of the key differences.

- Nonstop Arithmetic--The Java system will not throw exceptions, traps, or otherwise signal the IEEE exceptional conditions: invalid operation, division by zero, overflow, underflow, or inexact. Java has no signaling NaN.

- Rounding--Java rounds inexact results to the nearest representable value, with ties going to the value with a 0 least-significant bit. This is the IEEE default mode. But, Java rounds towards zero when converting a floating value to an integer. Java does n ot provide the user-selectable rounding modes for floating-point computations: up, down, or towards zero.

- Relational set--Java has no relational predicates which include the unordered condition, except for ! =. However, all cases but one can be constructed by the programmer, using the existing relations and logical inversion. The exception case is ordered but unequal. There is no specific IEEE requirement here.

- Extended formats--Java does not support any extended formats, except that double will serve as single-extended. Other extended formats are not a requirement of the standard.

The Java Spec: Appendix: Java Language Grammar

B Appendix: Java Language Grammar

This is a short grammar for a Java compilation unit. A Java program consists of one or more compilation units.

The grammar has undefined terminal symbols DocComment, Identifier, Number, String, and Character. Quoted text signifies literal terminals.

Each rule is of the form nonterminal = meta-expression ; Other meta-notation is: | for alternation, (...) for grouping, postfix ? for 0 or 1 occurrences, postfix + for 1 or more occurrence, and postfix * for 0 or more occurrences.

```
CompilationUnit =
        PackageStatement? ImportStatement* TypeDeclaration*
;
PackageStatement =
        `package' PackageName `;'
;
ImportStatement =
        `import' PackageName `.' `*' `;'
|       `import' ( ClassName | InterfaceName )`;'
;
TypeDeclaration =
        ClassDeclaration
|       InterfaceDeclaration
|       `;'
;
ClassDeclaration =
        Modifier* `class' Identifier
        (`extends' ClassName)?
        (`implements' InterfaceName (`,' InterfaceName)*)?
        `{' FieldDeclaration* `}'
;
InterfaceDeclaration =
        Modifier* `interface' Identifier
        (`extends' InterfaceName (`,' InterfaceName)*)?
        `{' FieldDeclaration* `}'
;
FieldDeclaration =
        DocComment? MethodDeclaration
|       DocComment? ConstructorDeclaration
|       DocComment? VariableDeclaration
|       StaticInitializer
```

```
|       `;'
;
MethodDeclaration =
        Modifier* Type Identifier `(' ParameterList? `)' ( `[' `]' )*
        ( `{' Statement* `}' | `;' )
;
ConstructorDeclaration =
        Modifier* Identifier `(' ParameterList? `)'
        `{' Statement* `}'
;
VariableDeclaration =
        Modifier* Type VariableDeclarator (`,' VariableDeclarator)* `;'
;
VariableDeclarator =
        Identifier (`[' `]')* (`=' VariableInitializer)?
;

VariableInitializer  =
        Expression
|       `{'  ( VariableInitializer  ( `,' VariableInitializer  )* `,'? )? `}'
;
StaticInitializer =
        `static' `{' Statement* `}'
;
ParameterList =
        Parameter (`,' Parameter)*
;
Parameter =
        TypeSpecifier Identifier (`[' `]')*
;
Statement =
        VariableDeclaration
|       Expression `;'
|       `{' Statement* `}'
|       `if' `(' Expression `)' Statement (`else' Statement)?
|       `while' `(' Expression `)' Statement
|       `do' Statement `while' `(' Expression `)' `;'
|       `try' Statement (`catch' `(' Parameter `)' Statement)*
                (`finally' Statement)?
|       `switch' `(' Expression `)' `{' Statement* `}'
|       `synchronized' `(' Expression `)' Statement
|       `return' Expression? `;'
|       `throw' Expression `;'
|       `case' Expression `:'
|       `default' `:'
|       Identifier `:' Statement
|       `break' Identifier? `;'
|       `continue' Identifier? `;'
|       `;'
;
Expression =
        Expression `+' Expression
|       Expression `-' Expression
|       Expression `*' Expression
|       Expression `/' Expression
|       Expression `%' Expression
|       Expression `^' Expression
```

```
|       Expression `&;' Expression
|       Expression `|' Expression
|       Expression `&;&;' Expression
|       Expression `||' Expression
|       Expression `<;<;` Expression
|       Expression `>;>;' Expression
|       Expression `>;>;>;' Expression
|       Expression `=' Expression
|       Expression `+=' Expression
|       Expression `-=' Expression
|       Expression `*=' Expression
|       Expression `/=' Expression
|       Expression `%=' Expression
|       Expression `^=' Expression
|       Expression `&;=' Expression
|       Expression `|=' Expression
|       Expression `<;<;=' Expression
|       Expression `>;>;=' Expression
|       Expression `>;>;>;=' Expression
|       Expression `<;` Expression
|       Expression `>;' Expression
|       Expression `<;=' Expression
|       Expression `>;=' Expression
|       Expression `==' Expression
|       Expression `!=' Expression
|       Expression `.' Expression
|       Expression `,' Expression
|       Expression `instanceof' ( ClassName | InterfaceName )
|       Expression `?' Expression `:' Expression
|       Expression `[' Expression `]'
|       `++' Expression
|       `--' Expression
|       Expression `++'
|       Expression `--'
|       `-' Expression
|       `!' Expression
|       `~' Expression
|       `(' Expression  `)'
|       `(' Type `)' Expression
|       Expression  `(' ArgList? `)'
|       `new' ClassName  `(' ArgList?`)'
|       `new' TypeSpecifier  ( `[' Expression `]' )+ (`['  `]')*
|       `new' `(' Expression  `)'
|       `true'
|       `false'
|       `null'
|       `super'
|       `this'
|       Identifier
|       Number
|       String
|       Character
;
ArgList =
        Expression (`,' Expression )*
;
Type =
```

```
        TypeSpecifier (`[' `]')*
;
TypeSpecifier =
        `boolean'
|       `byte'
|       `char'
|       `short'
|       `int'
|       `float'
|       `long'
|       `double'
|       ClassName
|       InterfaceName
;


Modifier =
        `public'
|       `private'
|       `protected'
|       `static'
|       `final'
|       `native'
|       `synchronized'
|       `abstract'
|       `threadsafe'
|       `transient'
;
PackageName =
        Identifier
|       PackageName `.' Identifier
;

ClassName =
        Identifier
|       PackageName `.' Identifier
;

InterfaceName =
        Identifier
|       PackageName `.' Identifier
;
```

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The Java Spec: Program Structure

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1 Program Structure

The source code for an Java program consists of one or more compilation units. Each compilation unit can contain only the following (in addition to white space and comments):

- a package statement (see Packages)
- import statements (see Packages)
- class declarations (see Classes)
- interface declarations (see Interfaces)

Although each Java compilation unit can contain multiple classes or interfaces, at most one class or interface per compilation unit can be public (see Classes).

When Java source code is compiled, the result is Java bytecode. Java bytecode consists of machine-independent instructions that can be interpreted efficiently by the Java runtime system. The Java runtime system operates like a virtual machine, for information see The Java Virtual Machine Specification.

In the current Java implementation, each compilation unit is a file with a ".java" suffix.

The Java Language Specification

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The Java Spec: Lexical Issues

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2 Lexical Issues

During compilation, the characters in Java source code are reduced to a series of tokens. The Java compiler recognizes five kinds of tokens: identifiers, keywords, literals, operators, and miscellaneous separators. Comments and white space such as blanks, tabs, line feeds, and are not tokens, but they often are used to separate tokens.

Java programs are written using the Unicode character set or some character set that is converted to Unicode before being compiled.

2.1 Comments

The Java language has three styles of comments:

// text
All characters from // to the end of the line are ignored.
/ text */*
All characters from /* to */ are ignored.
*/** text */*
These comments are treated specially when they occur immediately before any declaration. They should not be used any other place in the code. These comments indicate that the enclosed text should be included in automatically generated documentation as a description of the declared item.

2.2 Identifiers

Identifiers must start with a letter, underscore ("_"), or dollar sign ("$"); subsequent characters can also contain digits (0-9). Java uses the Unicode character set. For the purposes of determining what is a legal identifier the following are considered "letters:"

- The characters "A" through "Z"
- The characters "a" through "z"
- All Unicode characters with a character number above hex 00C0

Other characters valid after the first letter of an identifier include every character except those in the segment of Unicode reserved for special characters.

Thus, "garç;on" and "Mjø;lner" are legal identifiers, but strings containing characters such as "xa6 " are not.

For more information on the Unicode standard, see The Unicode Standard, Worldwide Character Encoding, Version 1.0, Volumes 1&;2. The FTP address for Unicode, Inc. (formerly the Unicode Consortium) is unicode.org.

2.3 Keywords

The following identifiers are reserved for use as keywords. They cannot be used in any other way.

abstract	default	goto[a]	null	synchronized
boolean	do	if	package	this
break	double	implements	private	threadsafe
byte	else	import	protected	throw
byvalue[a]	extends	instanceof	public	transient
case	false	int	return	true
catch	final	interface	short	try
char	finally	long	static	void
class	float	native	super	while
const[a]	for	new	switch	
continue				

a. Reserved but currently unused.

2.4 Literals

Literals are the basic representation of any integer, floating point, boolean, character, or string value.

2.4.1 Integer Literals

Integers can be expressed in decimal (base 10), hexadecimal (base 16), or octal (base 8) format. A decimal integer literal consists of a sequence of digits (optionally suffixed as described below) without a leading 0 (zero). An integer can be expressed in octal or hexadecimal rather than decimal. A leading 0 (zero) on an integer literal means it is in octal; a leading 0x (or 0X) means hexadecimal. Hexadecimal integers can include digits (0-9) and the letters a-f and A-F. Octal integers can include only the digits 0-7.

Integer literals are of type int unless they are larger than 32-bits, in which case they are of type long (see Integer Types). A literal can be forced to be long by appending an L or l to its value.

The following are all legal integer literals:

```
2, 2L  0777  0xDeadBeef
```

2.4.2 Floating Point Literals

A floating point literal can have the following parts: a decimal integer, a decimal point ("."), a fraction (another decimal number), an exponent, and a type suffix. The exponent part is an e or E followed by an integer, which can be signed. A floating po int literal must have at least one digit, plus either a decimal point or e (or E). Some examples of floating point literals are:

```
3.1415 3.1E12  .1e12  2E12
```

As described in Floating Point Types , the Java language has two floating point types: float (IEEE 754 single precision) and double (IEEE 754 double precision). You specify the type of a floating point literal as follows:

```
2.0d or 2.0D         double
2.0f or 2.0F or 2.0  float
```

2.4.3 Boolean Literals

The boolean type has two literal values: true and false. See Boolean Types for more information on boolean values.

2.4.4 Character Literals

A character literal is a character (or group of characters representing a single character) enclosed in single quotes. Characters have type char and are drawn from the Unicode character set (see Character Types). The following escape sequences allow for the representation of some non-graphic characters as well as the single quote, "`" and the backslash "\", in Java code:

continuation	<newline>	\
new-line	NL (LF)	\n
horizontal tab	HT	\t
back space	BS	\b
carriage return	CR	\r
form feed	FF	\f
backslash	\	\\
single quote	'	\'
double quote	"	\"
octal bit pattern	0ddd	\ddd
hex bit pattern	0xdd	\xdd
unicode char	0xdddd	\udddd

2.4.5 String Literals

A string literal is zero or more characters enclosed in double quotes. Each string literal is implemented as a String object (not as an array of characters). For example, "abc" creates an new instance of class String. The following are all legal string literals:

```
"" \\ the empty string
"\""
"This is a string"
"This is a \
   two-line string"
```

2.5 Operators and Miscellaneous Separators

The following characters are used in source code as operators or separators:

```
+  -  !  %  ^  &;  *  |  ~  /  >;  <;

(  )  {  }  [  ]  ;  ?  :  ,  .  =
```

In addition, the following character combinations are used as operators:

```
++ -- == <;= >;= != <;<; >;>;

>;>;>; += -= *= /= &;=|=
```

```
^=   %= <;<;= >;>;= >;>;>;= || &;&;
```

For more information see Operators.

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The Java Spec: Types

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3 Types

Every variable and every expression has a type. Type determines the allowable range of values a variable can hold, allowable operations on those values, and the meanings of the operations. Built-in types are provided by the Java language. Programmers can compose new types using the class and interface mechanisms (see Classes and Interfaces).

The Java language has two kinds of types: simple and composite. Simple types are those that cannot be broken down; they are atomic. The integer, floating point, boolean, and character types are all simple types. Composite types are built on simple types. The language has three kinds of composite types: arrays, classes, and interfaces. Simple types and arrays are discussed in this section.

3.1 Numeric Types

3.1.1 Integer Types

Integers are similar to those in C and C++, with two exceptions: all integer types are machine independent, and some of the traditional definitions have been changed to reflect changes in the world since C was introduced. The four integer types have widths of 8, 16, 32, and 64 bits and are signed.

Width	Name
8	byte
16	short
32	int
64	long

A variable's type does not directly affect its storage allocation. Type only determines a variable's arithmetic properties and legal range of values. If a value is assigned to a variable that is outside the legal range of the variable, the value is reduced modulo the range.

3.1.2 Floating Point Types

The float keyword denotes single precision (32 bit); double denotes double precision (64 bit). The result of a binary operator on two float operands is a float. If either operand is a double, the result is a double.

Floating point arithmetic and data formats are defined by IEEE 754. See Appendix: Floating Point for details on the floating point implementation.

3.1.3 Character Types

The language uses the Unicode character set throughout. Consequently the char data type is defined as a 16-bit unsigned integer.

3.2 Boolean Types

The boolean type is used for variables that can be either true or false, and for methods that return true and false values. It's also the type that is returned by the relational operators (e.g., ">;=").

Boolean values are not numbers and cannot be converted into numbers by casting.

3.3 Arrays

Arrays in the language are first class objects. They replace pointer arithmetic. All objects (including arrays) are referred to by pointers that cannot be damaged by being manipulated as numbers. Arrays are created using the new operator:

```
char s[] = new char[30];
```

The first element of an array is at index 0 (zero). Specifying dimensions in the declarations is not allowed. Every allocation of an array must be explicit--use new every time:

```
int i[] = new int[3];
```

The language does not support multi-dimensional arrays. Instead, programmers can create arrays of arrays:

```
int i[][] = new int[3][4];
```

At least one dimension must be specified but other dimensions can be explicitly allocated by a program at a later time. For example:

```
int i[][] = new int[3][];
```

is a legal declaration.

In addition to the C-style array declaration, where brackets follow the name of the variable or method, Java allows brackets following the array element type. The following two lines are equivalent:

```
int iarray[];
int[] iarray;
```

as are the following method declarations:

```
byte    f( int n )[];
byte[]  f( int n );
```

Subscripts are checked to make sure they're valid:

```
int a[] = new int[10];
a[5] = 1;
a[1] = a[0] + a[2];
a[-1]         = 4;         // Throws an ArrayIndexOutOfBoundsException
                           // at runtime
a[10] = 2;                 // Throws an ArrayIndexOutOfBoundsException
                           // at runtime
```

Array dimensions must be integer expressions:

```
int n;
...
float arr[] = new float[n + 1];
```

The length of any array can be found by using .length:

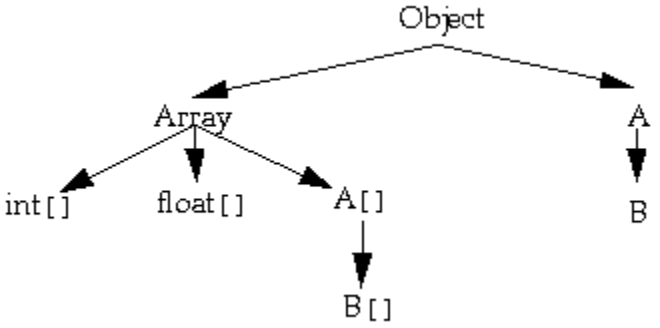
```
int a[][] = new int[10][3];
println(a.length);           // prints 10
println(a[0].length);        // prints 3
```

3.3.1 Array Detail

Arrays are instances of subclasses of class Object. In the class hierarchy there is a class named Array, which has one instance variable, "length". For each primitive type there is a corresponding subclass of Array. Similarly, for all classes a corresponding subclass of Array implicitly exists. For example:

```
new Thread[n]
```

creates an instance of Thread[]. If class A is a superclass of class B (i.e., B extends A) then A[] is a superclass of B[] (see the diagram below).



Hence, you can assign an array to an Object:

```
Object o;
int a[] = new int[10];
o = a;
```

and you can cast an Object to an array:

```
a = (int[])o;
```

Array classes cannot be explicitly subclassed.

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The Java Spec: Classes

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4 Classes

Classes represent the classical object oriented programming model. They support data abstraction and implementations tied to data. In Java, each new class creates a new type.

To make a new class, the programmer must base it on an existing class. The new class is said to be derived from the existing class. The derived class is also called a subclass of the other, which is known as a superclass. Class derivation is transitive: if B is a subclass of A, and C is a subclass of B, then C is a subclass of A.

The immediate superclass of a class and the interfaces (see Interfaces) that the class implements (if any) are indicated in the class declaration by the keywords extends and implements, respectively:

```
[Doc comment] [Modifiers] class Classname

   extends Superclassname]
```

```
    implements Interface{, Interface}] {

        ClassBody

}
```

For example:

```
/** 2 dimensional point */
public class Point {
    float x, y;
    ...
}

/** Printable point */
class PrintablePoint extends Points implements Printable {
    ...
    public void print() {
        ...
    }
}
```

All classes are derived from a single root class: Object. Every class except Object has exactly one immediate superclass. If a class is declared without specifying an immediate superclass, Object is assumed. For example, the following:

```
class Point {
    float x, y;
}
```

is the same as:

```
class Point extends Object {
    float x, y;
}
```

The language supports only single inheritance. Through a feature known as interfaces, it supports some features that in other languages are supported through multiple inheritance (see Interfaces).

4.1 Casting Between Class Types

The language supports casting between types and because each class is a new type, Java supports casting between class types. If B is a subclass of A, then an instance of B can be used as an instance of

A. No explicit cast is required, but an explicit cast is legal--this is called widening. If an instance of A needs to be used as if it were an instance of B, the programmer can write a type conversion or cast--this is called narrowing. Casts from a class to a subclass are always checked at runtime to make sure that the object is actually an instance of the subclass (or one of its subclasses). Casting between sibling classes is a compile-time error. The syntax of a class cast is:

```
(classname)ref
```

where (classname) is the object being cast to and ref is the object being cast.

Casting affects only the reference to the object, not the object itself. However, access to instance variables is affected by the type of the object reference. Casting an object from one type to another may result in a different instance variable being accessed even though the same variable name is used.

```
class ClassA {
    String name = "ClassA";
}

class ClassB extends ClassA {  // ClassB is a subclass of ClassA
    String name= "ClassB";
}

class AccessTest {
    void test() {
        ClassB b = new ClassB();
        println(b.name);         // print: ClassB

        ClassA a;
        a = (ClassA)b;
        println(a.name);         // print: ClassA
    }
}
```

4.2 Methods

Methods are the operations that can be performed on an object or class. They can be declared in either classes or interfaces, but they can be implemented only in classes. (All user-defined operations in the language are implemented with methods.)

A method declaration in a class has the following form (native and abstract methods have no method body):

```
[Doc comment] [Modifiers] returnType methodName ( parameterList ) {

        [methodBody]
```

```
}
```

Methods:

- Have a return type unless they're constructors, in which case they have no return type. If a non-constructor method does not return any value, it must have a void return type.
- Have a parameter list consisting of comma-separated pairs of types and parameter names. The parameter list should be empty if the method has no parameters.

Variables declared in methods (local variables) can't hide other local variables or parameters in the same method. For example, if a method is implemented with a parameter named i, it's a compile-time error for the method to declare a local variable named i. In the following example:

```
class Rectangle {
    void vertex(int i, int j) {
        for (int i = 0; i <;= 100; i++) {   // ERROR
        ...
        }
    }
}
```

the declaration of "i" in the for loop of the method body of "vertex" is a compile-time error.

The language allows polymorphic method naming--declaring a method with a name that has already been used in the class or its superclass--for overriding and overloading methods. Overriding means providing a different implementation of an inherited method. Overloading means declaring a method that has the same name as another method, but a different parameter list.

Note: Return types are not used to distinguish methods. Within a class scope, methods that have the same name and parameter list, i.e., the same number, position, and types of parameters, must return the same type. It is a compile-time error to declare such a method with a different return type.

4.2.1 Instance Variables

All variables in a class declared outside the scope of a method and not marked static (see Static Methods, Variables, and Initializers) are instance variables. (Variables declared inside the scope of a method are considered local variables.) Instance variables can have modifiers (see Modifiers).

Instance variables can be of any type and can have initializers. If an instance variable does not have an initializer, it is initialized to zero; boolean variables are initialized to false; and objects are initialized to null. An example of an initializer for an instance variable named j is:

```
class A {
    int j = 23;
```

```
    ...
}
```

4.2.2 The this and super Variables

Inside the scope of a non-static method, the name this represents the current object. For example, an object may need to pass itself as an argument to another object's method:

```
class MyClass {
    void aMethod(OtherClass obj) {
        ...
        obj.Method(this);
            ...
    }
}
```

Any time a method refers to its own instance variables or methods, an implicit "this." is in front of each reference:

```
class Foo {
    int a, b, c;
        ...
    void myPrint(){
        print(a + "\n");     // a == "this.a"
    }
        ...
}
```

The super variable is similar to the this variable. The this variable contains a reference to the current object; its type is the class containing the currently executing method. The super variable contains a reference which has the type of the superclass.

4.2.3 Setting Local Variables

Methods are rigorously checked to be sure that all local variables (variables declared inside a method) are set before they are referenced. Using a local variable before it is initialized is a compile-time error.

4.3 Overriding Methods

To override a method, a subclass of the class that originally declared the method must declare a method with the same name, return type (or a subclass), and parameter list. When the method is invoked on an instance of the subclass, the new method is calle d rather than the original method. The overridden method can be invoked using the super variable such that:

```
setThermostat(...)          // refers to the overriding method
super.setThermostat(...)    // refers to the overridden method
```

4.4 Overload Resolution

Overloaded methods have the same name as an existing method, but differ in the number and/or the types of arguments. Overload resolution involves determining which overloaded method to invoke. The return type is not considered when resolving overloaded me thods. Methods may be overloaded within the same class. The order of method declaration within a class is not significant.

Methods may be overloaded by varying both the number and the type of arguments. The compiler determines which matching method has the lowest type conversion cost. Only methods with the same name and number of arguments are considered for matching. The cos t of matching a method is the maximum cost of converting any one of its arguments. There are two types of arguments to consider:, object types and base types.

The cost of converting among object types is the number of links in the class tree between the actual parameter's class and the prototype parameter's class. Only widening conversions are considered. (See Casting Between Class Types for more information on object conversion.) No conversion is necessary for argument types that match exactly, making their cost 0.

The cost of converting base types is calculated from the table below. Exact matches cost 0.

		To						
		byte	short	char	int	long	float	double
From	byte	0	1	2	3	4	6	7
	short	10	0	10	1	2	4	5
	char	11	10	0	1	2	4	5
	int	12	11	11	0	1	5	4
	long	12	11	11	10	0	6	5
	float	15	14	13	12	11	0	1
	double	16	15	14	13	12	10	0

Note: Cost >= 10 causes data loss.

Cost >;= 10 causes data loss.

Once a conversion cost is assigned to each matching method, the compiler chooses the method which has the lowest conversion cost. If there is more than one potential method with the same lowest cost the match is ambiguous and a compile-time error occurs.

For example:

```
class A {
    int method(Object o, Thread t);
    int method(Thread t, Object o);
```

```
    void g(Object o, Thread t) {
        method(o, t);     // calls the first method.
        method(t, o);     // calls the second method.
        method(t,   t);     // ambiguous - compile-time error
    }
}
```

Note: The names of parameters are not significant. Only the number, type, and order are.

4.5 Constructors

Constructors are special methods provided for initialization. They are distinguished by having the same name as their class and by not having any return type. Constructors are automatically called upon the creation of an object. They cannot be called expl icitly through an object. If you want to be able to call the constructor outside the package, make the constructor public (see Access Specifiers for more information).

Constructors can be overloaded by varying the number and types of parameters, just as any other method can be overloaded.

```
class Foo {
    int x;
    float y;
    Foo() {
        x = 0;
        y = 0.0;
    }
    Foo(int a) {
        x = a;
        y = 0.0;
    }
    Foo(float a) {
        x = 0;
        y = a;
    }
    Foo(int a, float b) {
        x = a;
        y = b;
    }
    static void myFoo() {
        Foo obj1 = new Foo();       //calls Foo();
        Foo obj2 = new Foo(4);      //calls Foo(int a);
        Foo obj3 = new Foo(4.0);    //calls Foo(float a);
        Foo obj4 = new Foo(4, 4.0); //calls Foo(int a, float b);
    }
}
```

The instance variables of superclasses are initialized by calling either a constructor for the immediate superclass or a constructor for the current class. If neither is specified in the code, the superclass constructor that has no parameters is invoked. If a constructor calls another constructor in this class or a constructor in the immediate super class, that call must be the first thing in the constructor body. Instance

variables can't be referenced before calling the constructor.

Invoking a constructor of the immediate superclass is done as follows:

```
class MyClass extends OtherClass {
    MyClass(someParameters) {
        /* Call immediate superclass constructor */
        super(otherParameters);
        ...
    }
    ...
}
```

Invoking a constructor in the current class is done as follows:

```
class MyClass extends OtherClass {
    MyClass(someParameters) {
        ...
    }
    MyClass(otherParameters) {
        /* Call the constructor in this class that has the
           specified parameter list. */
        this(someParameters);
        ...
    }
    ...
}
```

The Foo and FooSub methods below are examples of constructors.

```
class Foo extends Bar {
    int a;
    Foo(int a) {
        // implicit call to Bar()
        this.a = a;
    }
    Foo() {
        this(42);        // calls Foo(42) instead of Bar()
    }
}

class FooSub extends Foo {
    int b;
    FooSub(int b) {
        super(13);      // calls Foo(13); without this line,
                        // would have called Foo()
        this.b = b;
    }
}
```

If a class declares no constructors, the compiler automatically generates one of the following form:

```
class MyClass extends OtherClass {
    MyClass() {    // automatically generated
        super();
    }
}
```

4.6 Object Creation--the new Operator

A class is a template used to define the state and behavior of an object. An object is an instance of a class. All instances of classes are allocated in a garbage collected heap. Declaring a reference to an object does not allocate any storage for that object. The programmer must explicitly allocate the storage for objects, but no explicit deallocation is required; the garbage collector automatically reclaims the memory when it is no longer needed.

To allocate storage for an object, use the new operator. In addition to allocating storage, new initializes the instance variables and then calls the instance's constructor. The constructor is a method that initializes an object (see Constructors). The following syntax allocates and initializes a new instance of a class named ClassA:

```
a = new ClassA();
```

This constructor syntax provides arguments to the constructor:

```
b = new ClassA(3,2);
```

A third form of allocator allows the class name to be provided as a String expression. The String is evaluated at runtime, and new returns an object of type Object, which must be cast to the desired type.

```
b = new ( "Class"+"A" );
```

In this case, the constructor without arguments is called.

4.6.1 Garbage Collection

The garbage collector makes most aspects of storage management simple and robust. Programs never need to explicitly free storage: it is done for them automatically. The garbage collector never frees pieces of memory that are still referenced, and it alway s frees pieces that are not. This makes both dangling pointer bugs and storage leaks impossible. It also frees designers from having to figure out which parts of a system have to be responsible for managing storage.

4.6.2 Finalization

The Java language includes the concept of object finalization. Java finalization is generalization of garbage collection that allows a program to free arbitrary resources (e.g., file descriptors or graphics contexts) owned by objects that cannot be access ed by any Java program. Reclaiming an object's memory by garbage collection does not guarantee that these resources will be reclaimed*1.

4.6.3 The null Reference

The keyword null is a predefined constant that represents "no instance." null can be used anywhere an instance is expected and can be cast to any class type.

4.7 Static Methods, Variables, and Initializers

Variables and methods declared in a class can be declared static, which makes them apply to the class itself, rather than to an instance of the class. In addition, a block of code within a class definition can be declared static. Such a block of code is called a static initializer.

Static variables can have initializers, just as instance variables can. See Order of Initialization for more information. A static variable exists only once per class, no matter how many instances of the class exist. Both static variables and static methods are accessed using the class name. For convenience, they can also be accessed using an instance of the class.

```
    class Ahem {
        int i;                                  // Instance variable
        static int j;                           // Static variable
        static int arr[] = new int[12];
        static {                                // static initializer:
                                              // initialize the array
            for (int i = 0; i <; arr.length; i++) {
                arr[i] = i;
            }
        }

        void seti(int i) {                      // Instance method
            this.i = i;
        }
        static void setj(int j) {               // Static method
            Ahem.j = j;
}
        static void clearThroat() {
            Ahem a = new Ahem();
            Ahem.j = 2;       // valid; static var via class
            a.j = 3;          // valid; static var via instance
            Ahem.setj(2);     // valid; static method via class
            a.setj(3);        // valid; static method via instance
            a.i = 4;          // valid; instance var via instance
            Ahem.i = 5;       // ERROR; instance var via class
            a.seti(4);        // valid; instance method via instance
            Ahem.seti(5);     // ERROR; instance method via class
```

```
    }
}
```

4.7.1 Order of Declarations

The order of declaration of classes and the methods and instance variables within them is irrelevant. However, it is possible for cycles to exist during initialization. For information on cycles during initialization see Order of Initialization . Methods are free to make forward references to other methods and instance variables. The following is legal:

```
class A {
    void a() {
        f.set(42);
    }
    B f;
}
class B {
    void set(long n) {
        this.n = n; }
    long n;
}
```

4.7.2 Order of Initialization

When a class is loaded, all of its static initialization code is executed. Static initializers are executed at the same time that static variables are initialized. The initializations occur in lexical order. For example, a class C is declared as follows:

```
class C {
    static int a = 1;
    static {
        a++;
        b = 7;
    }
    static int b = 2;
}
```

When class C is loaded, the following occurs in order:

- a is set to 1
- the static initializer is executed, setting a to 2 and b to 7
- b is set to 2

If any static initialization code has a reference to some other, unloaded class, that class is loaded and its

static initialization code is executed first. Each unloaded class referenced during static initialization is loaded and initialized before the cl ass that referenced it. If at any time during this initialization sequence a reference is made to an uninitialized class that is earlier in the sequence, a cycle is created. A cycle causes a NoClassDefFoundException to be thrown.

For example, if ClassA is loaded, its static initialization code is executed. However, ClassA's static initialization code can have a reference to another unloaded class, for example, ClassB. In that case, ClassB is loaded and its static initialization oc curs before ClassA's. Then, ClassA's static initializations are executed. A cycle is created if ClassB has a reference to ClassA in its static initialization code.

It is an compile-time error for instance or static variable initializations to have a forward dependency. For example, the following code:

```
int i = j + 2;
int j = 4;
```

results in a compile-time error.

An instance variable's initialization can have an apparent forward dependency on a static variable. For example in the following code fragment:

```
int i = j + 2;          // Instance variable
static int j = 4;       // Static variable
```

it appears that i has a forward dependency on j. However, i is initialized to 6 and j is initialized to 4. This initialization occurs because j is a static variable and is initalized before the instance variable. Thus, j is initialized to 4 before i is initialized.

Static methods cannot refer to instance variables; they can only use static variables and static methods.

4.8 Access Specifiers

Access specifiers are modifiers that allow programmers to control access to methods and variables. The keywords used to control access are public, private, and protected. Methods marked as public can be accessed from anywhere by anyone. Methods marked as private can be accessed only from within the class in which they are declared. Since private methods are not visible outside the class, they are effectively final and cannot be overridden (see Final Classes, Methods, and Variables for more information). Moreover, you cannot override a non-private method and give it private access. The protected access specifier makes a variable or method accessible to subclasses, but not to any other classes.

Public access can be applied to classes, methods, and variables. Classes, methods, and variables marked as public can be accessed from anywhere by any other class or method. The access of a public method cannot be changed by overriding it.

Classes, methods, and variables that do not have either private or public access specified can be accessed only from within the package where they are declared (see Packages).

4.9 Variable Scoping Rules

Within a package, when a class is defined as a subclass of another, declarations made in the superclass are visible in the subclass. When a variable is referenced inside a method definition, the following scoping rules are used:

1. The current block is searched first, and then all enclosing blocks, up to and including the current method. This is considered the local scope.

After the local scope, the search continues in the class scope:

1. The variables of the current class are searched.

2. If the variable is not found, variables of all superclasses are searched, starting with the immediate superclass, and continuing up through class Object until the variable is found. If the variable is not found, imported classes and package names are searched. If it is not found, it is a compile-time error.

Multiple variables with the same name within the same class are not allowed and result in a compile-time error.

4.10 Modifiers

4.10.1 Threadsafe Variables

An instance or static variable can be marked threadsafe to indicate that the variable will never be changed by some other thread while one thread is using it, i.e., the variable never changes asynchronously. The purpose of marking a variable as threadsafe is to allow the compiler to perform some optimizations that may mask the occurrence of asynchronous changes. The primary optimization enabled by the use of threadsafe is the caching of instance variables in registers.

4.10.2 Transient Variables

The transient flag is available to the interpreter and is intended to be used for persistent objects. Variables marked transient are treated specially when instances of the class are written out as persistent objects.

4.10.3 Final Classes, Methods, and Variables

The final keyword is a modifier that marks a class as never having subclasses, a method as never being overridden, or a variable as having a constant value. It is a compile-time error to override a final method, subclass a final class, or change the value of a final variable. Variables marked as final behave like constants.

Using final lets the compiler perform a variety of optimizations. One such optimization is inline expansion

of method bodies, which may be done for small, final methods (where the meaning of small is implementation dependent).

Examples of the various final declarations are:

```
class Foo {
    final int value = 3;             // final variable
    final int foo(int a, int b) {    // final method
        ...
    }
}
```

4.10.4 Native Methods

Methods marked as native are implemented in a platform-dependent language, e.g., C, not Java Native methods do not have a method body, instead the declaration is terminated with a semicolon. Constructors cannot be marked as native. Though implemented in a platform-dependent language, native methods behave exactly as non-native methods do, for example, it is possible to override them. An example of a native method declaration is:

```
native long timeOfDay();
```

4.10.5 Abstract Methods

Abstract methods provide the means for a superclass or interface to define a protocol that subclasses must implement. Methods marked as abstract must be defined in a subclass of the class in which they are declared. An abstract method does not have a method body; instead the declaration is terminated with a semi-colon.

The following rules apply to the use of the abstract keyword:

- Constructors cannot be marked as abstract.
- Static methods cannot be abstract.
- Private methods cannot be abstract.
- Abstract methods must be defined in some subclass of the class in which they are declared.
- A method that overrides a superclass method cannot be abstract.
- Classes that contains abstract methods and classes that inherit abstract methods without overriding them are considered abstract classes.
- It is a compile-time error to instantiate an abstract class or attempt to call an abstract method directly.

4.10.6 Synchronized Methods and Blocks

The synchronized keyword is a modifier that marks a method or block of code as being required to acquire a lock. The lock is necessary so that the synchronized code does not run at the same time as other code that needs access to the same resource. Each objec t has exactly one lock associated with it; each class also has exactly one lock. Synchronized methods are reentrant.

When a synchronized method is invoked, it waits until it can acquire the lock for the current instance (or class, if it's a static method). After acquiring the lock, it executes its code and then releases the lock.

Synchronized blocks of code behave similarly to synchronized methods. The difference is that instead of using the lock for the current instance or class, they use the lock associated with the object or class specified in the block's synchronized statement.

Synchronized blocks are declared as follows:

```
/* ...preceding code in the method... */
synchronized(<;object or class name>;) {      //sync. block
    /* code that requires synchronized access */
}
/* ...remaining code in the method... */
```

An example of the declaration of a synchronized method is:

```
class Point {
    float x, y;
    synchronized void scale(float f) {
        x *= f;
        y *= f;
    }
}
```

An example of a synchronized block is:

```
class Rectangle {
    Point topLeft;
    ...
    void print() {
        synchronized (topLeft) {
            println("topLeft.x = " + topLeft.x);
            println("topLeft.y = " + topLeft.y);
        }
        ...
    }
}
```

The Java Language Specification

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The Java Spec: Interfaces

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5 Interfaces

An interface specifies a collection of methods without implementing their bodies. Interfaces provide encapsulation of method protocols without restricting the implementation to one inheritance tree. When a class implements an interface, it generally must implement the bodies of all the methods described in the interface. (If the implementing class is abstract--never implemented--it can leave the implementation of some or all of the interface methods to its subclasses.)

Interfaces solve some of the same problems that multiple inheritance does without as much overhead at runtime. However, because interfaces involve dynamic method binding, there is a small performance penalty to using them.

Using interfaces allows several classes to share a programming interface without having to be fully aware of each other's implementation. The following example shows an interface declaration (with the interface keyword) and a class that implements the interface:

```
public interface Storing {
    void freezeDry(Stream s);
    void reconstitute(Stream s);
}
public class Image implements Storing, Painting {
    ...
    void freezeDry(Stream s) {
        // JPEG compress image before storing
        ...
    }
    void reconstitute (Stream s) {
        // JPEG decompress image before reading
        ...
    }
}
```

Like classes, interfaces are either private (the default) or public. The scope of public and private interfaces is the same as that of public and private classes, respectively. Methods in an interface are always public. Variables are public, static, and final.

5.1 Interfaces as Types

The declaration syntax interfaceName variableName declares a variable or parameter to be an instance of some class that implements interfaceName. Interfaces behave exactly as classes when used as a type. This lets the programmer specify that an object mus t implement a given interface, without having to know the exact type or inheritance of that object. Using interfaces makes it unnecessary to force related classes to share a common abstract superclass or to add methods to Object.

The following pseudocode illustrates the interfaceName variableName syntax:

```
class StorageManager {
    Stream stream;
    ...
    // Storing is the interface name
    void pickle(Storing obj) {
        obj.freezeDry(stream);
    }
}
```

5.2 Methods in Interfaces

Methods in interfaces are declared as follows:

```
returnType methodName ( parameterList );
```

The declaration contains no modifiers. All methods specified in an interface are public and abstract and no other modifiers may be applied.

See Abstract Methods for more information on abstract methods.

5.3 Variables in Interfaces

Variables declared in interfaces are final, public, and static. No modifiers can be applied. Variables in interfaces must be initialized.

5.4 Combining Interfaces

Interfaces can incorporate one or more other interfaces, using the extends keyword as follows:

```
interface DoesItAll extends Storing, Painting {
    void doesSomethingElse();
```

```
    }
```

The Java Spec: Packages

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6 Packages

Packages are groups of classes and interfaces. They are a tool for managing a large namespace and avoiding conflicts. Every class and interface name is contained in some package. By convention, package names consist of period-separated words, with the first name representing the organization that developed the package.

6.1 Specifying a Compilation Unit's Package

The package that a compilation unit is in is specified by a package statement. When this statement is present, it must be the first non-comment, non-white space line in the compilation unit. It has the following format:

```
package packageName;
```

When a compilation unit has no package statement, the unit is placed in a default package, which has no name.

6.2 Using Classes and Interfaces from Other Packages

The language provides a mechanism for making the definitions and implementations of classes and interfaces available across packages. The import keyword is used to mark classes as being imported into the current package. A compilation unit automatically imports every class and interface in its own package.

Code in one package can specify classes or interfaces from another package in one of two ways:

- By prefacing each reference to the class or interface name with the name of its package:

```
// prefacing with a package
```

```
acme.project.FooBar obj = new acme.project.FooBar();
```

- By importing the class or interface or the package that contains it, using an import statement. Importing a class or interface makes the name of the class or interface available in the current namespace. Importing a package makes the names of all of its public classes and interfaces available. The construct:

```
// import all classes from acme.project

import acme.project.*;
```

means that every public class from acme.project is imported.

The following construct imports a single class, Employee_List, from the acme.project package:

```
// import Employee_List from acme.project

import acme.project.Employee_List;

Employee_List obj = new Employee_List();
```

It is illegal to specify an ambiguous class name and doing so always generates a compile-time error. Class names may be disambiguated through the use of a fully qualified class name, i.e., one that includes the name of the class's package.

The Java Spec: Expressions

---

7 Expressions

Expressions in the language are much like expressions in C.

7.1 Operators

The operators, from highest to lowest precedence, are:

```
. [] ()
++ -- ! ~ instanceof
* / %
+ -
<;<; >;>; >;>;>;
<; >; <;= >;=
== !=
&;
^
|
&;&;
||
?:
= op=
,
```

7.1.1 Operators on Integers

For operators with integer results, if any operand is long, the result type is long. Otherwise the result type is int--never byte, short, or char. Thus, if a variable i is declared a short or a byte, i+1 would be an int. When a result outside an operator's range would be produced, the result is reduced modulo the range of the result type.

The unary integer operators are:

Operator	Operation
-	unary negation
~	bitwise complement
++	Increment
--	Decrement

The ++ operator is used to express incrementing directly. Incrementing can also be expressed indirectly using addition and assignment. ++lvalue means lvalue+=1. ++lvalue also means lvalue=lvalue+1 (as long as lvalue has no side effects). The -- operator i s used to express decrementing. The ++ and -- operators can be used as both prefix and postfix operators.

The binary integer operators are:

Operator	Operation[a]
+	addition
-	subtraction
*	multiplication
/	division
%	modulus
&	bitwise AND
|	bitwise OR
^	bitwise XOR
<<	left shift
>>	sign-propagating right shift
>>>	zero-fill right shift

a. **integer** *op* **integer** => **integer**

Integer division rounds toward zero. Division and modulus obey the identity (a/b)*b + (a%b) == a.

The only exceptions for integer arithmetic are caused by a divide or modulus by zero, which throw the ArithmeticException. An underflow generates zero. An overflow leads to wrap-around, i.e., adding 1 to the maximum integer wraps around to the minimum integer.

An op= assignment operator corresponds to each of the binary operators in the above table.

The integer relational operators <;, >;, <;=, >;=, ==, and != produce boolean results.

7.1.2 Operators on Boolean Values

Variables or expressions that are boolean can be combined to yield other boolean values. The unary

operator ! is boolean negation. The binary operators &;, |, and ^ are the logical AND,OR, and XOR operators; they force evaluation of both operands. To avoid evaluation of right-hand operands, you can use the short-cut evaluation operators &;&; and ||. You can also use == and !=. The assignment operators also work: &;=, |=, ^=. The ternary conditional operator ?: works as it does in C.

7.1.3 Operators on Floating Point Values

Floating point values can be combined using the usual operators: unary -; binary +, -, *, and /; and the assignment operators +=, -=, *=, and /=. The ++ and -- operators also work on floating point values (they add or subtract 1.0). In addition, % and %= work on floating point values, i.e.,

```
a % b
```

is the same as:

```
a - ((int)(a / b) * b)
```

This means that a%b is the floating point equivalent of the remainder after division.

Floating point expressions involving only single-precision operands are evaluated using single-precision operations and produce single-precision results. Floating point expressions that involve at least one double-precision operand are evaluated using double-precision operations and produce double-precision results.

The language has no arithmetic exceptions for floating point arithmetic. Following the IEEE 754 floating point specification, the distinguished values Inf and NaN are used instead. Overflow generates Inf. Underflow generates 0. Divide by zero generate s Inf.

The usual relational operators are also available and produce boolean results: >;, <;, >;=, <;=, ==, !=. Because of the properties of NaN, floating point values are not fully ordered, so care must be taken in comparison. For instance, if a<;b is not true, it does not follow that a>;=b. Likewise, a!=b does not imply that a>;b || a<;b. In fact, there may no ordering at all.

Floating point arithmetic and data formats are defined by IEEE 754, "Standard for Floating Point Arithmetic." See Appendix: Floating Point for details on the language's floating point implementation.

7.1.4 Operators on Arrays

The following:

```
<;expression>;[<;expression>;]
```

gets the value of an element of an array. Legal ranges for the expression are from 0 to the length of the array minus 1. The range is checked only at runtime.

7.1.5 Operators on Strings

Strings are implemented as String objects (see String Literals for more information). The operator + concatenates Strings, automatically converting operands into Strings if necessary. If the operand is an object it can define a method call toString() that returns a String in the class of the object.

```
// Examples of the + operator used with strings
float a = 1.0;
print("The value of a is " + a + "\n");
String s = "a = " + a;
```

The += operator works on Strings. Note, that the left hand side (s1 in the following example) is evaluated only once.

```
s1 += a; //s1 = s1 + a; // a is converted to String if necessary
```

7.1.6 Operators on Objects

The binary operator instanceof tests whether the specified object is an instance of the specified class or one of its subclasses. For example:

```
if (thermostat instanceof MeasuringDevice) {
    MeasuringDevice dev = (MeasuringDevice)thermostat;
      ...
}
```

determines whether thermostat is a MeasuringDevice object (an instance of MeasuringDevice or one of its subclasses).

7.2 Casts and Conversions

The Java language and runtime system restrict casts and conversions to help prevent the possibility of corrupting the system. Integers and floating point numbers can be cast back and forth, but integers cannot be cast to arrays or objects. Objects cannot be cast to base types. An instance can be cast to a superclass with no penalty, but casting to a subclass generates a runtime check. If the object being cast to a subclass is not an instance of the subclass (or one of its subclasses), the runtime system throws a ClassCastException.

The Java Spec: Statements

---

8 Statements

8.1 Declarations

Declarations can appear anywhere that a statement is allowed. The scope of the declaration ends at the end of the enclosing block.

In addition, declarations are allowed at the head of for statements, as shown below:

```
for (int i = 0; i <; 10; i++) {
    ...
}
```

Items declared in this way are valid only within the scope of the for statement. For example, the preceding code sample is equivalent to the following:

```
{
    int i = 0;
    for (; i <; 10; i++) {
    ...
    }
}
```

8.2 Expressions

Expressions are statements:

```
a = 3;
```

```
    print(23);
    foo.bar();
```

8.3 Control Flow

The following is a summary of control flow:

```
if(boolean) statement
else statement
switch(e1) {
        case e2: statements
        default: statements
}
break [label];
continue [label];
return e1;
for([e1]; [e2]; [e3]) statement
while(boolean) statement
do statement while(boolean);
label:statement
```

The language supports labeled loops and labeled breaks, for example:

```
    outer:   // the label
        for (int i = 0; i <; 10; i++) {
            for (int j= 0; j<; 10; j++) {
                if (...) {
                    break outer;
                }
                if (...) {
                }
            }
    }
```

The use of labels in loops and breaks has the following rules:

- Any statement can have a label.
- If a break statement has a label it must be the label of an enclosing statement.
- If a continue statement has a label it must be the label of an enclosing loop.

8.4 Exceptions

When an error occurs in an Java program--for example, when an argument has an invalid value--the code that detects the error can throw an exception*1 . By default, exceptions result in the thread

terminating after printing an error message. However, programs can have exception handlers that catch the exception and recover from the error.

Some exceptions are thrown by the Java runtime system. However, any class can define its own exceptions and cause them to occur using throw statements. A throw statement consists of the throw keyword followed by an object. By convention, the object should be an instance of Exception or one of its subclasses. The throw statement causes execution to switch to the appropriate exception han dler. When a throw statement is executed, any code following it is not executed, and no value is returned by its enclosing method. The following example shows how to create a subclass of Exception and throw an exception.

```
class MyException extends Exception {
}

class MyClass {
    void oops() {
        if (/* no error occurred */) {
            ...
        } else { /* error occurred */
        throw new MyException();
        }
    }
}
```

To define an exception handler, the program must first surround the code that can cause the exception with a try statement. After the try statement come one or more catch statements--one per exception class that the program can handle at that point. In each catch statement is exception handling code. For example:

```
try {
    p.a = 10;
} catch (NullPointerException e) {
    println("p was null");
} catch (Exception e) {
    println("other error occurred");
} catch (Object obj) {
    println("Who threw that object?");
}
```

A catch statement is like a method definition with exactly one parameter and no return type. The parameter can be either a class or an interface. When an exception occurs, the nested try/catch statements are searched for a parameter that matches the exception class. The parameter is said to match the exception if it:

- is the same class as the exception; or
- is a superclass of the exception; or
- if the parameter is an interface, the exception class implements the interface.

The first try/catch statement that has a parameter that matches the exception has its catch statement executed. After the catch statement executes, execution resumes after the try/catch statement. It is not possible for an exception handler to resume execution at the point that the exception occurred. For example, this code fragment:

```
print("now ");
try {
    print("is ");
    throw new MyException();
    print("a ");
} catch(MyException e) {
    print("the ");
}
print("time\n");
```

prints "now is the time". As this example shows, exceptions don't have to be used only for error handling, but any other use is likely to result in code that's hard to understand.

Exception handlers can be nested, allowing exception handling to happen in more than one place. Nested exception handling is often used when the first handler can't recover completely from the error, yet needs to execute some cleanup code (as shown in the following code example). To pass exception handling up to the next higher handler, use the throw keyword using the same object that was caught. Note that the method that rethrows the exception stops executing after the throw statement; it never returns.

```
try {
    f.open();
} catch(Exception e) {
    f.close();
    throw e;
}
```

8.4.1 The finally Statement

The following example shows the use of a finally statement that is useful for guaranteeing that some code gets executed whether or not an exception occurs. For example, the following code example:

```
try {
    // do something
} finally {
    // clean up after it
}
```

is similar to:

```
try {
```

```
    // do something
} catch(Object e){
    // clean up after it
    throw e;
}
// clean up after it
```

The finally statement is executed even if the try block contains a return, break, continue, or throw statement. For example, the following code example always results in "finally" being printed, but "after try" is printed only if a != 10.

```
try {
    if (a == 10) {
        return;
    }
} finally {
    print("finally\n");
}
print("after try\n");
```

8.4.2 Runtime Exceptions

This section contains a list of the exceptions that the Java runtime throws when it encounters various errors.

ArithmeticException

Attempting to divide an integer by zero or take a modulus by zero throw the ArithmeticException--no other arithmetic operation in Java throws an exception. For information on how Java handles other arithmetic errors see Operators on Integers and Operators on Floating Point Values.

For example, the following code causes an ArithmeticException to be thrown:

```
class Arith {
    public static void main(String args[]) {
        int j = 0;
        j = j / j;
    }
}
```

NullPointerException

An attempt to access a variable or method in a null object or a element in a null array throws a NullPointerException. For example, the accesses o.length and a[0] in the following class declaration throws a NullPointerException at runtime.

```
class Null {
    public static void main(String args[]) {
```

```
        String o = null;
        int a[] = null;
        o.length();
        a[0] = 0;
    }
}
```

It is interesting to note that if you throw a null object you actually throw a NullPointerException.

IncompatibleClassChangeException

In general the IncompatibleClassChangeException is thrown whenever one class's definition changes but other classes that reference the first class aren't recompiled. Four specific changes that throw a IncompatibleClassChangeException at rutime are:

- A variable's declaration is changed from static to non-static in one class but other classes that access the changed variable aren't recompiled.
- A variable's declaration is changed from non-static to static in one class but other classes that access the changed variable aren't recompiled.
- A field that is declared in one class is deleted but other classes that access the field aren't recompiled.
- A method that is declared in one class is deleted but other classes that access the method aren't recompiled.

ClassCastException

A ClassCastException is thrown if an attempt is made to cast an object O into a class C and O is neither C nor a subclass of C. For more information on casting see Casting Between Class Types.

The following class declaration results in a ClassCastException at runtime:

```
class ClassCast {
    public static void main(String args[]) {
        Object o = new Object();
        String s = (String)o;           // the cast attempt
        s.length();
    }
}
```

NegativeArraySizeException

A NegativeArraySizeException is thrown if an array is created with a negative size. For example, the following class definition throws a NegativeArraySizeException at runtime:

```
class NegArray {
    public static void main(String args[]) {
        int a[] = new int[-1];
```

```
        a[0] = 0;
    }
}
```

OutOfMemoryException

An OutOfMemoryException is thrown when the system can no longer suppy the application with memory. The OutOfMemoryException can only occur during the creation of an object, i.e., when new is called. For example, the following code results in an OutOfMemoryException at runtime:

```
class Link {
    int a[] = new int[1000000];
    Link l;
}
class OutOfMem {
    public static void main(String args[]) {
        Link root = new Link();
        Link cur = root;
        while(true) {
            cur.l = new Link();
            cur = cur.l;
        }
    }
}
```

NoClassDefFoundException

A NoClassDefFoundException is thrown if a class is referenced but the runtime system cannot find the referenced class.

For example, class NoClass is declared:

```
class NoClass {
    public static void main(String args[]) {
        C c = new C();
    }
}
```

When NoClass is run, if the runtime system can't find C.class it throws the NoClassDefFoundException.

C.class must have existed at the time NoClass is compiled.

IncompatibleTypeException

An IncompatibleTypeException is thrown if an attempt is made to instantiate an interface. For example, the following code causes an IncompatibleTypeException to be thrown.

```
interface I {
}
```

```
class IncompType {
    public static void main(String args[]) {
        I r = (I)new("I");
    }
}
```

ArrayIndexOutOfBoundsException

An attempt to access an invalid element in an array throws an ArrayIndexOutOfBoundsException. For example:

```
class ArrayOut {
    public static void main(String args[]) {
        int a[] = new int[0];
        a[0] = 0;
    }
}
```

UnsatisfiedLinkException

An UnsatisfiedLinkException is thrown if a method is declared native and the method cannot be linked to a routine in the runtime.

```
class NoLink {
    static native void foo();

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

InternalException

An InternalException should never be thrown. It's only thrown if some consistency check in the runtime fails. Please send mail to java@java.Sun.COM if you have a reproducible case that throws this exception.

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