



4

Operators

CERTIFICATION OBJECTIVES

- Using Operators

✓ Two-Minute Drill

Q&A Self Test

If you've got variables, you're going to modify them. You'll increment them, add them together, and compare one to another (in about a dozen different ways). In this chapter, you'll learn how to do all that in Java. For an added bonus, you'll learn how to do things that you'll probably never use in the real world, but that will almost certainly be on the exam.

CERTIFICATION OBJECTIVE

Java Operators (Exam Objective 7.6)

7.6 Write code that correctly applies the appropriate operators including assignment operators (limited to: =, +=, -=), arithmetic operators (limited to: +, -, *, /, %, ++, --), relational operators (limited to: <, <=, >, >=, ==, !=), the instanceof operator, logical operators (limited to: &, |, ^, !, &&, ||), and the conditional operator (? :), to produce a desired result. Write code that determines the equality of two objects or two primitives.

Java operators produce new values from one or more operands (just so we're all clear, remember the operands are the things on the right or left side of the operator). The result of most operations is either a `boolean` or numeric value. Because you know by now that Java is not C++, you won't be surprised that Java operators aren't typically overloaded. There are, however, a few exceptional operators that come overloaded:

- The `+` operator can be used to add two numeric primitives together, or to perform a concatenation operation if either operand is a `String`.
- The `&`, `|`, and `^` operators can all be used in two different ways, although as of this version of the exam, their bit-twiddling capabilities won't be tested.

Stay awake. Operators are often the section of the exam where candidates see their lowest scores. Additionally, operators and assignments are a part of many questions in other topics...it would be a shame to nail a really tricky threads question, only to blow it on a pre-increment statement.

Assignment Operators

We covered most of the functionality of the assignment operator, `=`, in Chapter 3. To summarize:

- When assigning a value to a primitive, *size* matters. Be sure you know when implicit casting will occur, when explicit casting is necessary, and when truncation might occur.
- Remember that a reference variable isn't an object; it's a way to *get* to an object. (We know all you C++ programmers are just dying for us to say "it's a pointer", but we're not going to.)
- When assigning a value to a reference variable, *type* matters. Remember the rules for supertypes, subtypes, and arrays.

Next we'll cover a few more details about the assignment operators that are on the exam, and when we get to Chapter 7, we'll take a look at how the assignment operator "=" works with Strings (which are immutable).

exam

Watch

Don't spend time preparing for topics that are no longer on the exam! In a nutshell, the Java 5 exam differs from the 1.4 exam by moving away from bits, and towards the API. Many 1.4 topics related to operators have been removed from the exam, so in this chapter you WON'T see:

- bit shifting operators
- bitwise operators
- two's complement
- divide by zero stuff

It's not that these aren't important topics, it's just that they're not on the exam anymore, and we're really focused on the exam.

Compound Assignment Operators

There are actually 11 or so compound assignment operators, but only the four most commonly used (`+=`, `-=`, `*=`, and `/=`), are on the exam (despite what the objectives say). The compound assignment operators let lazy typists shave a few keystrokes off their workload. Here are several example assignments, first without using a compound operator,

```
y = y - 6;
x = x + 2 * 5;
```

Now, with compound operators:

```
y -= 6;
x += 2 * 5;
```

The last two assignments give the same result as the first two.

exam

Watch

Earlier versions of the exam put big emphasis on operator precedence (like: What's the result of: $x = y++ + ++x/z$;) . Other than a very basic knowledge of precedence (such as: $*$ and $/$ are higher precedence than $+$ and $-$), you won't need to study operator precedence, except that when using a compound operator, the expression on the right side of the $=$ will always be evaluated first. For example, you might expect

```
x *= 2 + 5;
```

to be evaluated like this:

```
x = (x * 2) + 5; // incorrect precedence
```

since multiplication has higher precedence than addition. But instead, the expression on the right is always placed inside parentheses. it is evaluated like this:

```
x = x * (2 + 5);
```

Relational Operators

The exam covers six relational operators ($<$, $<=$, $>$, $>=$, $==$, and $!=$). Relational operators always result in a boolean (true or false) value. This boolean value is most often used in an `if` test, as follows,

```
int x = 8;
if (x < 9) {
    // do something
}
```

but the resulting value can also be assigned directly to a `boolean` primitive:

```
class CompareTest {
    public static void main(String [] args) {
        boolean b = 100 > 99;
        System.out.println("The value of b is " + b);
    }
}
```

Java has four relational operators that can be used to compare any combination of integers, floating-point numbers, or characters:

- `>` greater than
- `>=` greater than or equal to
- `<` less than
- `<=` less than or equal to

Let's look at some legal comparisons:

```
class GuessAnimal {
    public static void main(String[] args) {
        String animal = "unknown";
        int weight = 700;
        char sex = 'm';
        double colorWaveLength = 1.630;
        if (weight >= 500) { animal = "elephant"; }
        if (colorWaveLength > 1.621) { animal = "gray " + animal; }
        if (sex <= 'f') { animal = "female " + animal; }
        System.out.println("The animal is a " + animal);
    }
}
```

In the preceding code, we are using a comparison between characters. It's also legal to compare a character primitive with any number (though it isn't great programming style). Running the preceding class will output the following:

```
The animal is a gray elephant
```

We mentioned that characters can be used in comparison operators. When comparing a character with a character, or a character with a number, Java will use the Unicode value of the character as the numerical value, for comparison.

"Equality" Operators

Java also has two relational operators (sometimes called "equality operators") that compare two similar "things" and return a `boolean` that represents what's true about the two "things" being equal. These operators are

- `==` equals (also known as "equal to")
- `!=` not equals (also known as "not equal to")

Each individual comparison can involve two numbers (including `char`), two `boolean` values, or two object reference variables. You can't compare incompatible types, however. What would it mean to ask if a `boolean` is equal to a `char`? Or if a `Button` is equal to a `String` array? (Exactly, nonsense, which is why you can't do it.) There are four different types of things that can be tested:

- numbers
- characters
- boolean primitives
- Object reference variables

So what does `==` look at? The value in the variable—in other words, the bit pattern.

Equality for Primitives

Most programmers are familiar with comparing primitive values. The following code shows some equality tests on primitive variables:

```
class ComparePrimitives {
    public static void main(String[] args) {
        System.out.println("char 'a' == 'a'? " + ('a' == 'a'));
        System.out.println("char 'a' == 'b'? " + ('a' == 'b'));
        System.out.println("5 != 6? " + (5 != 6));
        System.out.println("5.0 == 5L? " + (5.0 == 5L));
        System.out.println("true == false? " + (true == false));
    }
}
```

This program produces the following output:

```
character 'a' == 'a'? true
character 'a' == 'b'? false
5 != 6? true
5.0 == 5L? true
true == false? false
```

As we can see, usually if a floating-point number is compared with an integer and the values are the same, the `==` operator returns `true` as expected.

Equality for Reference Variables

As we saw earlier, two reference variables can refer to the same object, as the following code snippet demonstrates:

```

JButton a = new JButton("Exit");
JButton b = a;

```

After running this code, both variable `a` and variable `b` will refer to the same object (a `JButton` with the label `Exit`). Reference variables can be tested to see if they refer to the same object by using the `==` operator. Remember, the `==` operator is looking at the bits in the variable, so for reference variables this means that if the

exam

Watch

Don't mistake `=` for `==` in a boolean expression. The following is legal:

```

11. boolean b = false;
12. if (b = true) { System.out.println("b is true");
13. } else { System.out.println("b is false"); }

```

Look carefully! You might be tempted to think the output is `b is false` but look at the boolean test in line 12. The boolean variable `b` is not being compared to `true`, it's being set to `true`, so the `println` executes and we get `b is true`. The result of any assignment expression is the value of the variable following the assignment. This substitution of `=` for `==` works only with boolean variables, since the `if` test can be done only on boolean expressions. Thus, this does not compile:

```

7. int x = 1;
8. if (x = 0) { }

```

Because `x` is an integer (and not a boolean), the result of `(x = 0)` is `0` (the result of the assignment). Primitive `ints` cannot be used where a boolean value is expected, so the code in line 8 won't work unless changed from an assignment (`=`) to an equality test (`==`) as follows:

```

8. if (x == 0) { }

```

bits in both reference variables are identical, then both refer to the same object. Look at the following code:

```
import javax.swing.JButton;
class CompareReference {
    public static void main(String[] args) {
        JButton a = new JButton("Exit");
        JButton b = new JButton("Exit");
        JButton c = a;
        System.out.println("Is reference a == b? " + (a == b));
        System.out.println("Is reference a == c? " + (a == c));
    }
}
```

This code creates three reference variables. The first two, `a` and `b`, are separate `JButton` objects that happen to have the same label. The third reference variable, `c`, is initialized to refer to the same object that `a` refers to. When this program runs, the following output is produced:

```
Is reference a == b? false
Is reference a == c? true
```

This shows us that `a` and `c` reference the same instance of a `JButton`. The `==` operator will not test whether two objects are "meaningfully equivalent," a concept we'll cover in much more detail in Chapter 7, when we look at the `equals()` method (as opposed to the `equals` operator we're looking at here).

Equality for Enums

Once you've declared an enum, it's not expandable. At runtime, there's no way to make additional enum constants. Of course, you can have as many variables as you'd like refer to a given enum constant, so it's important to be able to compare two enum reference variables to see if they're "equal," i.e. do they refer to the same enum constant. You can use either the `==` operator or the `equals()` method to determine if two variables are referring to the same enum constant:

```
class EnumEqual {
    enum Color {RED, BLUE} // ; is optional
    public static void main(String[] args) {
        Color c1 = Color.RED; Color c2 = Color.RED;
        if(c1 == c2) { System.out.println("=="); }
        if(c1.equals(c2)) { System.out.println("dot equals"); }
    }
}
```


(We know } } is ugly, we're prepping you). This produces the output:

```
==
dot equals
```

instanceof Comparison

The `instanceof` operator is used for object reference variables only, and you can use it to check whether an object is of a particular type. By type, we mean class or interface type—in other words, if the object referred to by the variable on the left side of the operator passes the IS-A test for the class or interface type on the right side (Chapter 2 covered IS-A relationships in detail). The following simple example

```
public static void main(String[] args) {
    String s = new String("foo");
    if (s instanceof String) {
        System.out.print("s is a String");
    }
}
```

prints this: `s is a String`

Even if the object being tested is not an actual instantiation of the class type on the right side of the operator, `instanceof` will still return `true` if the object being compared is *assignment compatible* with the type on the right.

The following example demonstrates a common use for `instanceof`: testing an object to see if it's an instance of one of its subtypes, before attempting a "downcast":

```
class A { }
class B extends A {
    public static void main (String [] args) {
        A myA = new B();
        m2(myA);
    }
    public static void m2(A a) {
        if (a instanceof B)
            ((B)a).doBstuff();    // downcasting an A reference
                                   // to a B reference
    }
    public static void doBstuff() {
        System.out.println("'a' refers to a B");
    }
}
```

The preceding code compiles and produces the output:

```
'a' refers to a B
```

In examples like this, the use of the `instanceof` operator protects the program from attempting an illegal downcast.

You can test an object reference against its own class type, or any of its superclasses. This means that *any* object reference will evaluate to `true` if you use the `instanceof` operator against type `Object`, as follows,

```
B b = new B();
if (b instanceof Object) {
    System.out.print("b is definitely an Object");
}
```

which prints this: `b is definitely an Object`

exam

Watch

Look for `instanceof` questions that test whether an object is an instance of an interface, when the object's class implements the interface indirectly. An indirect implementation occurs when one of an object's superclasses implements an interface, but the actual class of the instance does not—for example,

```
interface Foo { }
class A implements Foo { }
class B extends A { }
...
A a = new A();
B b = new B();
```

the following are true:

```
a instanceof Foo
b instanceof A
b instanceof Foo // implemented indirectly
```

An object is said to be of a particular interface type (meaning it will pass the `instanceof` test) if any of the object's superclasses implement the interface.

In addition, it is legal to test whether the null reference is an instance of a class. This will always result in `false`, of course. For example:

```
class InstanceTest {
    public static void main(String [] args) {
        String a = null;
        boolean b = null instanceof String;
        boolean c = a instanceof String;
        System.out.println(b + " " + c);
    }
}
```

prints this: `false false`

instanceof Compiler Error

You can't use the `instanceof` operator to test across two different class hierarchies. For instance, the following will NOT compile:

```
class Cat { }
class Dog {
    public static void main(String [] args) {
        Dog d = new Dog();
        System.out.println(d instanceof Cat);
    }
}
```

Compilation fails—there's no way `d` could ever refer to a `Cat` or a subtype of `Cat`.

exam

Watch

Remember that arrays are objects, even if the array is an array of primitives. Watch for questions that look something like this:

```
int [] nums = new int[3];
if (nums instanceof Object) { } // result is true
```

An array is always an instance of Object. Any array.

Table 4-1 summarizes the use of the `instanceof` operator given the following:

```
interface Face { }
class Bar implements Face{ }
class Foo extends Bar { }
```

TABLE 4-1 Operands and Results Using *instanceof* Operator.

First Operand (Reference Being Tested)	<code>instanceof</code> Operand (Type We're Comparing the Reference Against)	Result
null	Any class or interface type	false
Foo instance	Foo, Bar, Face, Object	true
Bar instance	Bar, Face, Object	true
Bar instance	Foo	false
Foo []	Foo, Bar, Face	false
Foo []	Object	true
Foo [1]	Foo, Bar, Face, Object	true

Arithmetic Operators

We're sure you're familiar with the basic arithmetic operators.

- + addition
- - subtraction
- * multiplication
- / division

These can be used in the standard way:

```
int x = 5 * 3;
int y = x - 4;
System.out.println("x - 4 is " + y); // Prints 11
```

The Remainder (%) Operator

One operator you might not be as familiar with is the remainder operator, `%`. The remainder operator divides the left operand by the right operand, and the result is the remainder, as the following code demonstrates:

```
class MathTest {
    public static void main (String [] args) {
        int x = 15;
        int y = x % 4;
        System.out.println("The result of 15 % 4 is the "
            + "remainder of 15 divided by 4. The remainder is " + y);
    }
}
```

Running class `MathTest` prints the following:

```
The result of 15 % 4 is the remainder of 15 divided by 4. The
remainder is 3
```

(Remember: Expressions are evaluated from left to right by default. You can change this sequence, or *precedence*, by adding parentheses. Also remember that the `*`, `/`, and `%` operators have a higher precedence than the `+` and `-` operators.)

String Concatenation Operator

The plus sign can also be used to concatenate two strings together, as we saw earlier (and as we'll definitely see again):

```
String animal = "Grey " + "elephant";
```

String concatenation gets interesting when you combine numbers with Strings. Check out the following:

```
String a = "String";
int b = 3;
int c = 7;
System.out.println(a + b + c);
```

Will the `+` operator act as a plus sign when adding the `int` variables `b + c`? Or will the `+` operator treat 3 and 7 as characters, and concatenate them individually? Will the result be `String10` or `String37`? OK, you've had long enough to think about it. The `int` values were simply treated as characters and glued on to the right side of the String, giving the result:

```
String37
```

So we could read the previous code as

"Start with `String a`, `String`, and add the character `3` (the value of `b`) to it, to produce a new string `String3`, and then add the character `7` (the value of `c`) to that, to produce a new string `String37`, then print it out."

However, if you put parentheses around the two `int` variables, as follows,

```
System.out.println(a + (b + c));
```

you'll get this: `String10`

Using parentheses causes the `(b + c)` to evaluate first, so the rightmost `+` operator functions as the addition operator, given that both operands are `int` values. The key point here is that within the parentheses, the left-hand operand is not a `String`. If it were, then the `+` operator would perform `String` concatenation. The previous code can be read as

"Add the values of `b + c` together, then take the sum and convert it to a `String` and concatenate it with the `String` from variable `a`."

The rule to remember is this:

If either operand is a `String`, the `+` operator becomes a `String` concatenation operator. If both operands are numbers, the `+` operator is the addition operator.

You'll find that sometimes you might have trouble deciding whether, say, the left-hand operator is a `String` or not. On the exam, don't expect it to always be obvious. (Actually, now that we think about it, don't expect it ever to be obvious.) Look at the following code:

```
System.out.println(x.foo() + 7);
```

You can't know how the `+` operator is being used until you find out what the `foo()` method returns! If `foo()` returns a `String`, then `7` is concatenated to the returned `String`. But if `foo()` returns a number, then the `+` operator is used to add `7` to the return value of `foo()`.

Finally, you need to know that it's legal to mush together the compound additive operator (+) and Strings, like so:

```
String s = "123";  
s += "45";  
s += 67;  
System.out.println(s);
```

Since both times the += operator was used and the left operand was a String, both operations were concatenations, resulting in

```
1234567
```

exam

Watch

If you don't understand how String concatenation works, especially within a print statement, you could actually fail the exam even if you know the rest of the answer to the questions! Because so many questions ask, "What is the result?", you need to know not only the result of the code running, but also how that result is printed. Although there will be at least a few questions directly testing your String knowledge, String concatenation shows up in other questions on virtually every objective. Experiment! For example, you might see a line such as

```
int b = 2;  
System.out.println("" + b + 3);
```

which prints 23

but if the print statement changes to

```
System.out.println(b + 3);
```

then the result becomes 5

Increment and Decrement Operators

Java has two operators that will increment or decrement a variable by exactly one. These operators are composed of either two plus signs (++) or two minus signs (--):

- ++ increment (prefix and postfix)
- -- decrement (prefix and postfix)

The operator is placed either before (prefix) or after (postfix) a variable to change its value. Whether the operator comes before or after the operand can change the outcome of an expression. Examine the following:

```

1. class MathTest {
2.     static int players = 0;
3.     public static void main (String [] args) {
4.         System.out.println("players online: " + players++);
5.         System.out.println("The value of players is "
6.                             + players);
7.         System.out.println("The value of players is now "
8.                             + ++players);
9.     }
10. }
```

Notice that in the fourth line of the program the increment operator is *after* the variable `players`. That means we're using the postfix increment operator, which causes `players` to be incremented by one but only *after* the value of `players` is used in the expression. When we run this program, it outputs the following:

```

%java MathTest
players online: 0
The value of players is 1
The value of players is now 2
```

Notice that when the variable is written to the screen, at first it says the value is 0. Because we used the postfix increment operator, the increment doesn't happen until after the `players` variable is used in the `print` statement. Get it? The "post" in postfix means *after*. Line 5 doesn't increment `players`; it just outputs its value to the screen, so the newly incremented value displayed is 1. Line 6 applies the prefix increment operator to `players`, which means the increment happens *before* the value of the variable is used, so the output is 2.

Expect to see questions mixing the increment and decrement operators with other operators, as in the following example:


```
int x = 2; int y = 3;
if ((y == x++) | (x < ++y)) {
    System.out.println("x = " + x + " y = " + y);
}
```

The preceding code prints: `x = 3 y = 4`

You can read the code as follows: "If 3 is equal to 2 OR 3 < 4"

The first expression compares `x` and `y`, and the result is `false`, because the increment on `x` doesn't happen until *after* the `==` test is made. Next, we increment `x`, so now `x` is 3. Then we check to see if `x` is less than `y`, but we increment `y` *before* comparing it with `x`! So the second logical test is `(3 < 4)`. The result is `true`, so the `print` statement runs.

As with String concatenation, the increment and decrement operators are used throughout the exam, even on questions that aren't trying to test your knowledge of how those operators work. You might see them in questions on `for` loops, exceptions, even threads. Be ready.

exam

Watch

Look out for questions that use the increment or decrement operators on a final variable. Because final variables can't be changed, the increment and decrement operators can't be used with them, and any attempt to do so will result in a compiler error. The following code won't compile:

```
final int x = 5;
int y = x++;
```

and produces the error:

```
Test.java:4: cannot assign a value to final variable x
int y = x++;
        ^
```

You can expect a violation like this to be buried deep in a complex piece of code. If you spot it, you know the code won't compile and you can move on without working through the rest of the code.

This question might seem to be testing you on some complex arithmetic operator trivia, when in fact it's testing you on your knowledge of the `final` modifier.

Conditional Operator

The conditional operator is a *ternary* operator (it has *three* operands) and is used to evaluate `boolean` expressions, much like an `if` statement except instead of executing a block of code if the test is `true`, a conditional operator will assign a value to a variable. In other words, the goal of the conditional operator is to decide which of two values to assign to a variable. This operator is constructed using a `?` (question mark) and a `:` (colon). The parentheses are optional. Its structure is:

```
x = (boolean expression) ? value to assign if true : value to assign if false
```

Let's take a look at a conditional operator in code:

```
class Salary {
    public static void main(String [] args) {
        int numOfPets = 3;
        String status = (numOfPets<4) ? "Pet limit not exceeded"
            : "too many pets";
        System.out.println("This pet status is " + status);
    }
}
```

You can read the preceding code as

Set `numOfPets` equal to 3. Next we're going to assign a `String` to the `status` variable. If `numOfPets` is less than 4, assign "Pet limit not exceeded" to the `status` variable; otherwise, assign "too many pets" to the `status` variable.

A conditional operator starts with a `boolean` operation, followed by two possible values for the variable to the left of the assignment (`=`) operator. The first value (the one to the left of the colon) is assigned if the conditional (`boolean`) test is `true`, and the second value is assigned if the conditional test is `false`. You can even nest conditional operators into one statement:

```
class AssignmentOps {
    public static void main(String [] args) {
        int sizeOfYard = 10;
        int numOfPets = 3;
        String status = (numOfPets<4)?"Pet count OK"
            :(sizeOfYard > 8)? "Pet limit on the edge"
            : "too many pets";
        System.out.println("Pet status is " + status);
    }
}
```

```

    }
}

```

Don't expect many questions using conditional operators, but remember that conditional operators are sometimes confused with assertion statements, so be certain you can tell the difference. Chapter 5 covers assertions in detail.

Logical Operators

The exam objectives specify six "logical" operators (&, |, ^, !, &&, and ||). Some Sun documentation uses other terminology for these operators, but for our purposes the "logical operators" are the six listed above, and in the exam objectives.

Bitwise Operators (Not on the Exam!)

Okay, this is going to be confusing. Of the six logical operators listed above, three of them (&, |, and ^) can also be used as "bitwise" operators. Bitwise operators were included in previous versions of the exam, but they're not on the Java 5 exam. Here are several legal statements that use bitwise operators:

```

byte b1 = 6 & 8;
byte b2 = 7 | 9;
byte b3 = 5 ^ 4;
System.out.println(b1 + " " + b2 + " " + b3);

```

Bitwise operators compare two variables bit by bit, and return a variable whose bits have been set based on whether the two variables being compared had respective bits that were either both "on" (&), one or the other "on" (|), or exactly one "on" (^). By the way, when we run the preceding code, we get

```
0 15 1
```

Having said all this about bitwise operators, the key thing to remember is this:

BITWISE OPERATORS ARE NOT ON THE EXAM!

So why did we bring them up? If you get hold of an old exam preparation book, or if you find some mock exams that haven't been properly updated, you're bound to find questions that perform bitwise operations. Unless you're a glutton for punishment, you can skip this kind of mock question.

Short-Circuit Logical Operators

There are five logical operators on the exam that are used to evaluate statements that contain more than one `boolean` expression. The most commonly used of the five are the two *short-circuit* logical operators. They are

- `&&` short-circuit AND
- `||` short-circuit OR

They are used to link little `boolean` expressions together to form bigger `boolean` expressions. The `&&` and `||` operators evaluate only `boolean` values. For an AND (`&&`) expression to be `true`, both operands must be `true`—for example,

```
if ((2 < 3) && (3 < 4)) { }
```

The preceding expression evaluates to `true` because *both* operand one (`2 < 3`) and operand two (`3 < 4`) evaluate to `true`.

The short-circuit feature of the `&&` operator is so named because it doesn't waste its time on pointless evaluations. A short-circuit `&&` evaluates the left side of the operation first (operand one), and if it resolves to `false`, the `&&` operator doesn't bother looking at the right side of the expression (operand two) since the `&&` operator already *knows* that the complete expression can't possibly be `true`.

```
class Logical {
    public static void main(String [] args) {
        boolean b = true && false;
        System.out.println("boolean b = " + b);
    }
}
```

When we run the preceding code, we get

```
%java Logical
boolean b = false
```

The `||` operator is similar to the `&&` operator, except that it evaluates to `true` if EITHER of the operands is `true`. If the first operand in an OR operation is `true`, the result will be `true`, so the short-circuit `||` doesn't waste time looking at the right side of the equation. If the first operand is `false`, however, the short-circuit `||` has to evaluate the second operand to see if the result of the OR operation will be

true or false. Pay close attention to the following example; you'll see quite a few questions like this on the exam:

```

1. class TestOR {
2.     public static void main(String[] args) {
3.         if ((isItSmall(3)) || (isItSmall(7))) {
4.             System.out.println("Result is true");
5.         }
6.         if ((isItSmall(6)) || (isItSmall(9))) {
7.             System.out.println("Result is true");
8.         }
9.     }
10.
11.     public static boolean isItSmall(int i) {
12.         if (i < 5) {
13.             System.out.println("i < 5");
14.             return true;
15.         } else {
16.             System.out.println("i >= 5");
17.             return false;
18.         }
19.     }
20. }

```

What is the result?

```

% java TestOR
i < 5
Result is true
i >= 5
i >= 5

```

Here's what happened when the `main()` method ran:

1. When we hit line 3, the first operand in the `||` expression (in other words, the *left* side of the `||` operation) is evaluated.
2. The `isItSmall(3)` method is invoked, prints `"i < 5"`, and returns `true`.
3. Because the *first* operand in the `||` expression on line 3 is `true`, the `||` operator doesn't bother evaluating the second operand. So we never see the `"i >= 5"` that would have printed had the *second* operand been evaluated (which would have invoked `isItSmall(7)`).

4. Line 6 is evaluated, beginning with the *first* operand in the `||` expression.
5. The `isItSmall(6)` method is called, prints `"i >= 5"`, and returns `false`.
6. Because the *first* operand in the `||` expression on line 6 is `false`, the `||` operator can't skip the *second* operand; there's still a chance the expression can be `true`, if the *second* operand evaluates to `true`.
7. The `isItSmall(9)` method is invoked and prints `"i >= 5"`.
8. The `isItSmall(9)` method returns `false`, so the expression on line 6 is `false`, and thus line 7 never executes.

exam

Watch

The `||` and `&&` operators work only with boolean operands. The exam may try to fool you by using integers with these operators:

```
if (5 && 6) { }
```

It looks as though we're trying to do a bitwise AND on the bits representing the integers 5 and 6, but the code won't even compile.

Logical Operators (Not Short-Circuit)

There are two *non-short-circuit* logical operators.

- `&` non-short-circuit AND
- `|` non-short-circuit OR

These operators are used in logical expressions just like the `&&` and `||` operators are used, but because they aren't the short-circuit operators, they evaluate both sides of the expression, always! They're inefficient. For example, even if the *first* operand (left side) in an `&` expression is `false`, the *second* operand will still be evaluated—even though it's now impossible for the result to be `true`! And the `|` is just as inefficient: if the *first* operand is `true`, the JVM still plows ahead and evaluates the *second* operand even when it knows the expression will be `true` regardless.

You'll find a lot of questions on the exam that use both the short-circuit and non-short-circuit logical operators. You'll have to know exactly which operands are evaluated and which are not, since the result will vary depending on whether the second operand in the expression is evaluated:

```
int z = 5;
if(++z > 5 || ++z > 6) z++;    // z = 7 after this code
```

versus:

```
int z = 5;
if(++z > 5 | ++z > 6) z++;    // z = 8 after this code
```

Logical Operators ^ and !

The last two logical operators on the exam are

- ^ exclusive-OR (XOR)
- ! boolean invert

The ^ (exclusive-OR) operator evaluates only `boolean` values. The ^ operator is related to the non-short-circuit operators we just reviewed, in that it always evaluates *both* the left and right operands in an expression. For an exclusive-OR (^) expression to be `true`, EXACTLY one operand must be `true`—for example,

```
System.out.println("xor " + ((2<3) ^ (4>3)));
```

produces the output: `xor false`

The preceding expression evaluates to `false` because BOTH operand one (`2 < 3`) and operand two (`4 > 3`) evaluate to `true`.

The ! (boolean invert) operator returns the opposite of a boolean's current value:

```
if(!(7 == 5)) { System.out.println("not equal"); }
```

can be read "if it's not true that `7 == 5`," and the statement produces this output:

```
not equal
```

Here's another example using booleans:

```
boolean t = true;
boolean f = false;
System.out.println("! " + (t & !f) + " " + f);
```

produces the output:

```
! true false
```

In the preceding example, notice that the `&` test succeeded (printing `true`), and that the value of the `boolean` variable `f` did not change, so it printed `false`.

CERTIFICATION SUMMARY

If you've studied this chapter diligently, you should have a firm grasp on Java operators, and you should understand what equality means when tested with the `==` operator. Let's review the highlights of what you've learned in this chapter.

The logical operators (`&&`, `||`, `&`, `|`, and `^`) can be used only to evaluate two `boolean` expressions. The difference between `&&` and `&` is that the `&&` operator won't bother testing the right operand if the left evaluates to `false`, because the result of the `&&` expression can never be `true`. The difference between `||` and `|` is that the `||` operator won't bother testing the right operand if the left evaluates to `true`, because the result is already known to be `true` at that point.

The `==` operator can be used to compare values of primitives, but it can also be used to determine whether two reference variables refer to the same object.

The `instanceof` operator is used to determine if the object referred to by a reference variable passes the IS-A test for a specified type.

The `+` operator is overloaded to perform `String` concatenation tasks, and can also concatenate `Strings` and primitives, but be careful—concatenation can be tricky.

The conditional operator (a.k.a. the "ternary operator") has an unusual, three-operand syntax—don't mistake it for a complex assert statement.

The `++` and `--` operators will be used throughout the exam, and you must pay attention to whether they are prefixed or postfixed to the variable being updated.

Be prepared for a lot of exam questions involving the topics from this chapter. Even within questions testing your knowledge of another objective, the code will frequently use operators, assignments, object and primitive passing, and so on.



TWO-MINUTE DRILL

Here are some of the key points from each section in this chapter.

Relational Operators

- ❑ Relational operators always result in a boolean value (`true` or `false`).
- ❑ There are six relational operators: `>`, `>=`, `<`, `<=`, `==`, and `!=`. The last two (`==` and `!=`) are sometimes referred to as *equality operators*.
- ❑ When comparing characters, Java uses the Unicode value of the character as the numerical value.
- ❑ Equality operators
 - ❑ There are two equality operators: `==` and `!=`.
 - ❑ Four types of things can be tested: numbers, characters, booleans, and reference variables.
- ❑ When comparing reference variables, `==` returns `true` only if both references refer to the same object.

instanceof Operator

- ❑ `instanceof` is for reference variables only, and checks for whether the object is of a particular type.
- ❑ The `instanceof` operator can be used only to test objects (or `null`) against class types that are in the same class hierarchy.
- ❑ For interfaces, an object passes the `instanceof` test if any of its superclasses implement the interface on the right side of the `instanceof` operator.

Arithmetic Operators

- ❑ There are four primary math operators: add, subtract, multiply, and divide.
- ❑ The remainder operator (`%`), returns the remainder of a division.
- ❑ Expressions are evaluated from left to right, unless you add parentheses, or unless some operators in the expression have higher precedence than others.
- ❑ The `*`, `/`, and `%` operators have higher precedence than `+` and `-`.

String Concatenation Operator

- If either operand is a `String`, the `+` operator concatenates the operands.
- If both operands are numeric, the `+` operator adds the operands.

Increment/Decrement Operators

- Prefix operators (`++` and `--`) run before the value is used in the expression.
- Postfix operators (`++` and `--`) run after the value is used in the expression.
- In any expression, both operands are fully evaluated *before* the operator is applied.
- Variables marked `final` cannot be incremented or decremented.

Ternary (Conditional Operator)

- Returns one of two values based on whether a `boolean` expression is `true` or `false`.
 - Returns the value after the `?` if the expression is `true`.
 - Returns the value after the `:` if the expression is `false`.

Logical Operators

- The exam covers six "logical" operators: `&`, `|`, `^`, `!`, `&&`, and `||`.
- Logical operators work with two expressions (except for `!`) that must resolve to `boolean` values.
- The `&&` and `&` operators return `true` only if both operands are `true`.
- The `||` and `|` operators return `true` if either or both operands are `true`.
- The `&&` and `||` operators are known as short-circuit operators.
- The `&&` operator does not evaluate the right operand if the left operand is `false`.
- The `||` does not evaluate the right operand if the left operand is `true`.
- The `&` and `|` operators always evaluate both operands.
- The `^` operator (called the "logical XOR"), returns `true` if exactly one operand is `true`.
- The `!` operator (called the "inversion" operator), returns the opposite value of the `boolean` operand it precedes.

SELF TEST

1. Given:

```
class Hexy {  
    public static void main(String[] args) {  
        Integer i = 42;  
        String s = (i<40)?"life":(i>50)?"universe":"everything";  
        System.out.println(s);  
    }  
}
```

What is the result?

- A. null
- B. life
- C. universe
- D. everything
- E. Compilation fails.
- F. An exception is thrown at runtime.

2. Given:

```
1. class Example {  
2.     public static void main(String[] args) {  
3.         Short s = 15;  
4.         Boolean b;  
5.         // insert code here  
6.     }  
7. }
```

Which, inserted independently at line 5, will compile? (Choose all that apply.)

- A. `b = (Number instanceof s);`
- B. `b = (s instanceof Short);`
- C. `b = s instanceof (Short);`
- D. `b = (s instanceof Number);`
- E. `b = s instanceof (Object);`
- F. `b = (s instanceof String);`

3. Given:

```

1. class Comp2 {
2.     public static void main(String[] args) {
3.         float f1 = 2.3f;
4.         float[][] f2 = {{42.0f}, {1.7f, 2.3f}, {2.6f, 2.7f}};
5.         float[] f3 = {2.7f};
6.         Long x = 42L;
7.         // insert code here
8.         System.out.println("true");
9.     }
10. }

```

And the following five code fragments:

```

F1. if(f1 == f2)
F2. if(f1 == f2[2][1])
F3. if(x == f2[0][0])
F4. if(f1 == f2[1,1])
F5. if(f3 == f2[2])

```

What is true?

- A. One of them will compile, only one will be true.
- B. Two of them will compile, only one will be true.
- C. Two of them will compile, two will be true.
- D. Three of them will compile, only one will be true.
- E. Three of them will compile, exactly two will be true.
- F. Three of them will compile, exactly three will be true.

4. Given:

```

class Fork {
    public static void main(String[] args) {
        if(args.length == 1 | args[1].equals("test")) {
            System.out.println("test case");
        } else {
            System.out.println("production " + args[0]);
        }
    }
}

```

And the command-line invocation:

```
java Fork live2
```

What is the result?

- A. test case
- B. production
- C. test case live2
- D. Compilation fails.
- E. An exception is thrown at runtime.

5. Given:

```
class Foozit {  
    public static void main(String[] args) {  
        Integer x = 0;  
        Integer y = 0;  
        for(Short z = 0; z < 5; z++)  
            if((++x > 2) || (++y > 2))  
                x++;  
        System.out.println(x + " " + y);  
    }  
}
```

What is the result?

- A. 5 1
- B. 5 2
- C. 5 3
- D. 8 1
- E. 8 2
- F. 8 3
- G. 10 2
- H. 10 3

6. Given:

```
class Titanic {
    public static void main(String[] args) {
        Boolean b1 = true;
        boolean b2 = false;
        boolean b3 = true;
        if((b1 & b2) | (b2 & b3) & b3)
            System.out.print("alpha ");
        if((b1 = false) | (b1 & b3) | (b1 | b2))
            System.out.print("beta ");
    }
}
```

What is the result?

- A. beta
- B. alpha
- C. alpha beta
- D. Compilation fails.
- E. No output is produced.
- F. An exception is thrown at runtime.

7. Given:

```
class Feline {
    public static void main(String[] args) {
        Long x = 42L;
        Long y = 44L;
        System.out.print(" " + 7 + 2 + " ");
        System.out.print(foo() + x + 5 + " ");
        System.out.println(x + y + foo());
    }
    static String foo() { return "foo"; }
}
```

What is the result?

- A. 9 foo47 86foo
- B. 9 foo47 4244foo
- C. 9 foo425 86foo

- D. 9 foo425 4244foo
- E. 72 foo47 86foo
- F. 72 foo47 4244foo
- G. 72 foo425 86foo
- H. 72 foo425 4244foo
- I. Compilation fails.

8. Place the fragments into the code to produce the output 33. Note, you must use each fragment exactly once.

CODE:

```
class Incr {
    public static void main(String[] args) {
        Integer x = 7;
        int y = 2;

        x    ___ ___;
        ___ ___ ___;
        ___ ___ ___;
        ___ ___ ___;

        System.out.println(x);
    }
}
```

FRAGMENTS:

Y	Y	Y	Y
y	x	x	
--	*=	*=	*=

9. Given:

```

1. class Maybe {
2.     public static void main(String[] args) {
3.         boolean b1 = true;
4.         boolean b2 = false;
5.         System.out.print(!false ^ false);
6.         System.out.print(" " + (!b1 & (b2 = true)));
7.         System.out.println(" " + (b2 ^ b1));
8.     }
9. }

```

Which are true?

- A. Line 5 produces true.
- B. Line 5 produces false.
- C. Line 6 produces true.
- D. Line 6 produces false.
- E. Line 7 produces true.
- F. Line 7 produces false.

10. Given:

```

class Sixties {
    public static void main(String[] args) {
        int x = 5; int y = 7;
        System.out.print(((y * 2) % x));
        System.out.print(" " + (y % x));
    }
}

```

What is the result?

- A. 1 1
- B. 1 2
- C. 2 1
- D. 2 2
- E. 4 1
- F. 4 2
- G. Compilation fails.
- H. An exception is thrown at runtime.

SELF TEST ANSWERS

1. Given:

```
class Hexy {
    public static void main(String[] args) {
        Integer i = 42;
        String s = (i<40)?"life":(i>50)?"universe":"everything";
        System.out.println(s);
    }
}
```

What is the result?

- A. null
- B. life
- C. universe
- D. everything
- E. Compilation fails.
- F. An exception is thrown at runtime.

Answer:

- D** is correct. This is a ternary nested in a ternary with a little unboxing thrown in. Both of the ternary expressions are false.
- A, B, C, E, and F** are incorrect based on the above. (Objective 7.6)

2. Given:

```
1. class Example {
2.     public static void main(String[] args) {
3.         Short s = 15;
4.         Boolean b;
5.         // insert code here
6.     }
7. }
```

Which, inserted independently at line 5, will compile? (Choose all that apply.)

- A. `b = (Number instanceof s);`
- B. `b = (s instanceof Short);`

- C. `b = s instanceof (Short);`
- D. `b = (s instanceof Number);`
- E. `b = s instanceof (Object);`
- F. `b = (s instanceof String);`

Answer:

- B** and **D** correctly use boxing and `instanceof` together.
- A** is incorrect because the operands are reversed. **C** and **E** use incorrect `instanceof` syntax. **F** is wrong because `Short` isn't in the same inheritance tree as `String`. (Objective 7.6)

3. Given:

```

1. class Comp2 {
2.     public static void main(String[] args) {
3.         float f1 = 2.3f;
4.         float[][] f2 = {{42.0f}, {1.7f, 2.3f}, {2.6f, 2.7f}};
5.         float[] f3 = {2.7f};
6.         Long x = 42L;
7.         // insert code here
8.         System.out.println("true");
9.     }
10. }
```

And the following five code fragments:

```

F1. if (f1 == f2)
F2. if (f1 == f2[2][1])
F3. if (x == f2[0][0])
F4. if (f1 == f2[1,1])
F5. if (f3 == f2[2])
```

What is true?

- A. One of them will compile, only one will be true.
- B. Two of them will compile, only one will be true.
- C. Two of them will compile, two will be true.
- D. Three of them will compile, only one will be true.
- E. Three of them will compile, exactly two will be true.
- F. Three of them will compile, exactly three will be true.

Answer:

- D** is correct. Fragments F2, F3, and F5 will compile, and only F3 is true.
- A, B, C, E, and F** are incorrect. F1 is incorrect because you can't compare a primitive to an array. F4 is incorrect syntax to access an element of a two-dimensional array. (Objective 7.6)

4. Given:

```
class Fork {
    public static void main(String[] args) {
        if(args.length == 1 | args[1].equals("test")) {
            System.out.println("test case");
        } else {
            System.out.println("production " +args[0]);
        }
    }
}
```

And the command-line invocation:

```
java Fork live2
```

What is the result?

- A. test case
- B. production
- C. test case live2
- D. Compilation fails.
- E. An exception is thrown at runtime.

Answer:

- E** is correct. Because the short circuit (`&&`) is not used, both operands are evaluated. Since `args[1]` is past the `args` array bounds, an `ArrayIndexOutOfBoundsException` is thrown.
- A, B, C, and D** are incorrect based on the above. (Objective 7.6)

5. Given:

```
class Foozit {
    public static void main(String[] args) {
        Integer x = 0;
        Integer y = 0;
        for(Short z = 0; z < 5; z++)
            if((++x > 2) || (++y > 2))
                x++;
        System.out.println(x + " " + y);
    }
}
```

What is the result?

- A. 5 1
- B. 5 2
- C. 5 3
- D. 8 1
- E. 8 2
- F. 8 3
- G. 10 2
- H. 10 3

Answer:

- E** is correct. The first two times the `if` test runs, both `x` and `y` are incremented once (the `x++` is not reached until the third iteration). Starting with the third iteration of the loop, `y` is never touched again, because of the short-circuit operator.
- A, B, C, D, F, G,** and **H** are incorrect based on the above.
(Objective 7.6)

6. Given:

```
class Titanic {
    public static void main(String[] args) {
        Boolean b1 = true;
        boolean b2 = false;
        boolean b3 = true;
        if((b1 & b2) | (b2 & b3) & b3)
            System.out.print("alpha ");
        if((b1 = false) | (b1 & b3) | (b1 | b2))
            System.out.print("beta ");
    }
}
```

What is the result?

- A. beta
- B. alpha
- C. alpha beta
- D. Compilation fails.
- E. No output is produced.
- F. An exception is thrown at runtime.

Answer:

- E is correct. In the second `if` test, the leftmost expression is an assignment, not a comparison. Once `b1` has been set to `false`, the remaining tests are all `false`.
- A, B, C, D, and F are incorrect based on the above.
(Objective 7.6)

7. Given:

```
class Feline {
    public static void main(String[] args) {
        Long x = 42L;
        Long y = 44L;
        System.out.print(" " + 7 + 2 + " ");
        System.out.print(foo() + x + 5 + " ");
        System.out.println(x + y + foo());
    }
    static String foo() { return "foo"; }
}
```

What is the result?

- A. 9 foo47 86foo
- B. 9 foo47 4244foo
- C. 9 foo425 86foo
- D. 9 foo425 4244foo
- E. 72 foo47 86foo
- F. 72 foo47 4244foo
- G. 72 foo425 86foo
- H. 72 foo425 4244foo
- I. Compilation fails.

Answer:

- G** is correct. Concatenation runs from left to right, and if either operand is a `String`, the operands are concatenated. If both operands are numbers they are added together. Unboxing works in conjunction with concatenation.
- A, B, C, D, E, F, H, and I** are incorrect based on the above. (Objective 7.6)

8. Place the fragments into the code to produce the output 33. Note, you must use each fragment exactly once.

CODE:

```
class Incr {
    public static void main(String[] args) {
        Integer x = 7;
        int y = 2;

        x    ___ ___;
        ___ ___ ___;
        ___ ___ ___;
        ___ ___ ___;

        System.out.println(x);
    }
}
```

FRAGMENTS:

y	y	y	y
y	x	x	
- =	* =	* =	* =

Answer:

```
class Incr {
    public static void main(String[] args) {
        Integer x = 7;
        int y = 2;
```

```

    x *= x;
    y *= y;
    y *= y;
    x -= y;

    System.out.println(x);
}
}

```

Yeah, we know it's kind of puzzle-y, but you might encounter something like it on the real exam. (Objective 7.6)

9. Given:

```

1. class Maybe {
2.     public static void main(String[] args) {
3.         boolean b1 = true;
4.         boolean b2 = false;
5.         System.out.print(!false ^ false);
6.         System.out.print(" " + (!b1 & (b2 = true)));
7.         System.out.println(" " + (b2 ^ b1));
8.     }
9. }

```

Which are true?

- A. Line 5 produces true.
- B. Line 5 produces false.
- C. Line 6 produces true.
- D. Line 6 produces false.
- E. Line 7 produces true.
- F. Line 7 produces false.

Answer:

- A, D, and F** is correct. The `^` (xor) returns true if exactly one operand is true. The `!` inverts the operand's boolean value. On line 6 `b2 = true` is an assignment not a comparison, and it's evaluated because `&` does not short-circuit it.
 - B, C, and E** are incorrect based on the above.
- (Objective 7.6)

10. Given:

```
class Sixties {  
    public static void main(String[] args) {  
        int x = 5;  
        int y = 7;  
        System.out.print(((y * 2) % x));  
        System.out.print(" " + (y % x));  
    }  
}
```

What is the result?

- A. 1 1
- B. 1 2
- C. 2 1
- D. 2 2
- E. 4 1
- F. 4 2
- G. Compilation fails.
- H. An exception is thrown at runtime.

Answer:

- F** is correct. The % (remainder a.k.a. modulus) operator returns the remainder of a division operation.
- A, B, C, D, E, G, and H** are incorrect based on the above.
(Objective 7.6)