

# **Unit 3: Boolean Expressions, if Statements**

## **Compound Boolean Expressions and Comparing Objects**

Adapted from:

- 1) Building Java Programs: A Back to Basics Approach  
by Stuart Reges and Marty Stepp
- 2) Runestone CSAwesome Curriculum

# Evaluating logic expressions

Sometimes it is useful to use **nested if conditions**: if statements within if statements.

```
// if x is odd
if (x % 2 != 0) {
    // if x is positive
    if (x > 0) {
        ...
    }
}
```

We can combine the above nested if conditions using **logical operators**.

# Logical operators

- Tests can be combined using *logical operators*:

Operator	Description	Example	Result
&&	and	(2 == 3) && (-1 < 5)	false
	or	(2 == 3)    (-1 < 5)	true
!	not	!(2 == 3)	true

- "Truth tables" for each, used with logical values  $p$  and  $q$ :

<b>p</b>	<b>q</b>	<b>p &amp;&amp; q</b>	<b>p    q</b>
true	true	true	true
true	false	false	true
false	true	false	true
false	false	false	false

<b>p</b>	<b>!p</b>
true	false
false	true

# Combining Tests

The following code

```
// if x is odd
if (x % 2 != 0) {
    // if x is positive
    if (x > 0) {
        ...
    }
}
```

is equivalent to:

```
// if x is odd and positive
if (x % 2 != 0 && x > 0) {
    ...
}
```

# Using boolean

```
boolean goodAge      = age >= 12 && age < 29;  
boolean goodHeight   = height >= 78 && height < 84;  
boolean rich         = salary >= 100000.0;  
if ((goodAge && goodHeight) || rich) {  
    System.out.println("Okay, let's go out!");  
}  
else{  
    System.out.println("It's not you, it's me...");  
}
```

# Evaluating logic expressions

- Relational operators have lower precedence than math.

```
5 * 7 >= 3 + 5 * (7 - 1)
```

```
5 * 7 >= 3 + 5 * 6
```

```
35 >= 3 + 30
```

```
35 >= 33
```

```
true
```

- Relational operators cannot be "chained" as in algebra.

```
2 <= x <= 10
```

```
true <= 10
```

```
error!
```

(assume that x is 15)

- Instead, combine multiple tests with && or ||

```
2 <= x && x <= 10
```

```
true && false
```

```
false
```

# Order of Operations

<b>Precedence</b>	<b>Operator</b>	<b>Operation</b>
highest	**	exponentiation
	-	negation
	*, /, %	multiplication, division, modulo
	+, -	adding, subtraction
	==, !=, <, >, <=, >=	comparisons(relationals)
	not	logical not
	and	logical and
	or	logical or
lowest	=	assignment

# Evaluating logic expressions

AND is evaluated before OR.

```
int x = 2;
```

```
int y = 4;
```

```
int z = 5;
```

```
z > 2 || x > 3 && y < 3 ;
```

```
// true if evaluate && before ||
```

```
// false if evaluate || before &&
```

```
// the correct answer is true: &&
```

```
// MUST be evaluated before ||
```



# Logical questions

- What is the result of each of the following expressions?

```
int x = 42;  
int y = 17;  
int z = 25;
```

- `y < x && y <= z`
- `x % 2 == y % 2 || x % 2 == z % 2`
- `x <= y + z && x >= y + z`
- `!(x < y && x < z)`
- `(x + y) % 2 == 0 || !((z - y) % 2 == 0)`

## Answers:

- true
- false
- true
- true
- false

# if/else with return

*// Returns the larger of the two given integers.*

```
public static int max(int a, int b) {  
    if (a > b) {  
        return a;  
    }  
    else {  
        return b;  
    }  
}
```

- Methods can return different values using `if/else`
  - Whichever path the code enters, it will return that value.
  - Returning a value causes a method to immediately exit.
  - All paths through the code must reach a `return` statement.

# All paths must return

```
public static int max(int a, int b) {  
    if (a > b) {  
        return a;  
    }  
    // Error: not all paths return a value  
}
```

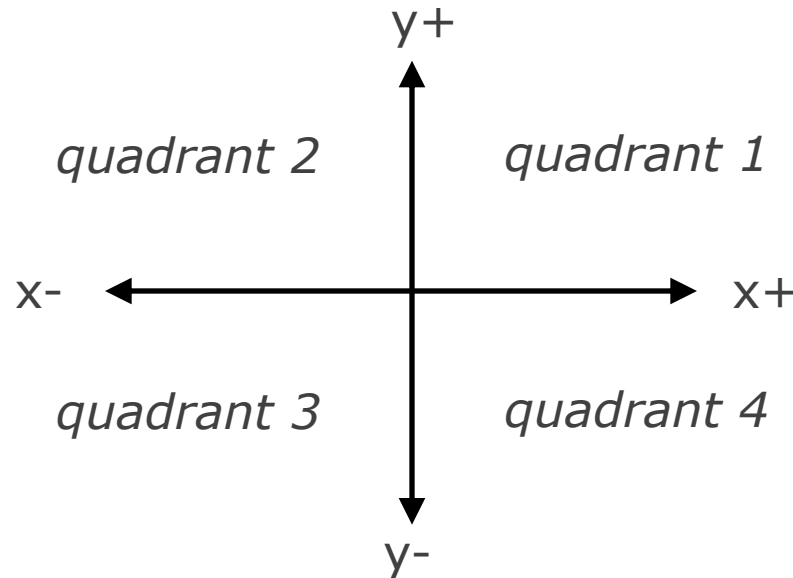
- The following also does not compile:

```
public static int max(int a, int b) {  
    if (a > b) {  
        return a;  
    }  
    else if (b >= a) {  
        return b;  
    }  
}
```

- The compiler thinks `if/else/if` code might skip all paths, even though mathematically it must choose one or the other.

# if/else, return question

- Write a method `quadrant` that accepts a pair of real numbers  $x$  and  $y$  and returns the quadrant for that point:



- Example: `quadrant(-4.2, 17.3)` returns 2
  - If the point falls directly on either axis, return 0.

# if/else, return answer

```
public static int quadrant(double x, double y) {  
    if (x > 0 && y > 0) {  
        return 1;  
    }  
    else if (x < 0 && y > 0) {  
        return 2;  
    }  
    else if (x < 0 && y < 0) {  
        return 3;  
    }  
    else if (x > 0 && y < 0) {  
        return 4;  
    }  
    else {          // at least one coordinate equals 0  
        return 0;  
    }  
}
```

# De Morgan's Law

- **De Morgan's Law:** Rules used to negate boolean tests.
  - Useful when you want the opposite of an existing test.

`!(a && b) = !a || !b`

`!(a || b) = !a && !b`

- Example:

Original Code	Negated Code
<pre>if (x == 7 &amp;&amp; y &gt; 3) {     ... }</pre>	<pre>if (x <b>!=</b> 7 <b>  </b> y <b>&lt;=</b> 3) {     ... }</pre>

# De Morgan's Law

In Java:

```
!((age < 12) || (age >= 65))
```

In English: *It is not the case that age less than 12 or age greater than or equal to 65. !!!?*

Simplify using de Morgan's Law:

```
!(age < 12) && !(age >= 65)
```

The reverse the meaning of the relational expressions:

```
(age >= 12) && (age < 65)
```

That is, *when age is at least 12 and less than 65.*

# Truth Tables

Truth tables can be used to prove Boolean identities.

For example, use a truth table to prove:

$$\neg (a \ \&\& \ b) = \neg a \ || \ \neg b$$

<b>a</b>	<b>b</b>	<b><math>\neg(a \ \&amp;\&amp; \ b)</math></b>	<b><math>\neg a \    \ \neg b</math></b>
true	true	false	false
true	false	true	true
false	true	true	true
false	false	true	true

Since both expressions have the same values in all cases, they are equivalent.



# "Short-circuit" evaluation

Java stops evaluating a test if it knows the answer.

- `&&` stops early if any part of the test is `false`
- `||` stops early if any part of the test is `true`

```
int count = <input from user>;
int sum = <input from user>;
if(count > 0 && (double)sum / count > 10) {
    System.out.println("average > 10");
}
else{
    System.out.println("count <= 0 or average <= 10");
}
```

If `count = 0` above, there is a potential to divide by 0. However, short-circuit prevents this since `count > 0` is `false`, it stops early and no division by zero was performed.

# Boolean practice questions

Write a method named `isVowel` that returns whether a `String` is a vowel (a, e, i, o, or u). Assume all letters are lowercase.

- `isVowel("q")` returns `false`
- `isVowel("a")` returns `true`
- `isVowel("e")` returns `true`

```
public static boolean isVowel(String s) {  
    return s.equals("a") || s.equals("e") ||  
           s.equals("i") || s.equals("o") ||  
           s.equals("u");  
}
```

# Boolean practice questions

Change the above method into an `isNonVowel` method that returns whether a `String` is any character except a vowel.

- `isNonVowel("q")` returns `true`
- `isNonVowel("a")` returns `false`
- `isNonVowel("e")` returns `false`

What's the wrong strategy?

**// Enlightened "Boolean Zen" version**

```
public static boolean isNonVowel(String s) {  
    return !s.equals("a") && !s.equals("e") &&  
           !s.equals("i") && !s.equals("o") &&  
           !s.equals("u");  
  
}
```

# Boolean practice questions

Use `isVowel` to write `isNonVowel`.

```
// Enlightened "Boolean Zen" version
public static boolean isNonVowel(String s) {
    return !isVowel(s);
}
```

# Comparing Objects

Two objects are considered **aliases** when they both reference the same object. Comparing using `==` check whether two variables are aliases. Consider the `Sprite` class we discussed in Unit 2 used to represent a game character.

```
public class Aliases
{
    public static void main(String[] args) {
        Sprite player = new Sprite(30, 50);
        Sprite another = player;
        System.out.println(player == another); // true
    }
}
```

Both object references `player` and `another` points to the same address hence the same object in memory.

# Comparing Objects

Two **different** objects can have the same attributes/data.

```
public class Aliases2
{
    public static void main(String[] args) {
        Sprite player = new Sprite(30, 50);
        Sprite another = new Sprite(30, 50);
        System.out.println(player == another); // false!
        System.out.println(player != another); // true!
    }
}
```

The references `player` and `another` above are two different `Sprite` objects(created individually using `new`) but both are located at the same coordinate.

# equals

We saw that for String objects, `==` is used to check if the two String references point to the same object whereas the `equals` method check if they have the same characters.

```
String a = "hi";  
String b = new String("hi");  
System.out.println(a == b); // false, different objects  
System.out.println(a.equals(b)); // true
```

# equals

Later in Unit 5 when we write our own objects, it will be useful to implement the `equals` method for our class so check whether two different objects are equivalent.

For example, consider `Point` objects with attributes `x` and `y` representing points on the plane. Although the following two points are distinct programmatically. They are equivalent mathematically. The `equals` method will allow us to detect this. More on this later.

```
Point a = new Point(3,4);  
Point b = new Point(3,4);  
System.out.println(a == b); // false, different objects  
System.out.println(a.equals(b)); // true
```



# References

1) Building Java Programs: A Back to Basics Approach by Stuart Reges and Marty Stepp

2) Runestone CSAwesome Curriculum:

<https://runestone.academy/runestone/books/published/csawesome/index.html>

For more tutorials/lecture notes in Java, Python, game programming, artificial intelligence with neural networks:

<https://longbaonguyen.github.io>