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

https://longbaonguyen.github.io

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*:

p	q	p && q	p || q
`true`	`true`	`true`	`true`
`true`	`false`	`false`	`true`
`false`	`true`	`false`	`true`
`false`	`false`	`false`	`false`

p	!p
`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`

- Why is type `boolean` useful?
  - Can capture a complex logical test result and use it later
  - Can write a method that does a complex test and returns it
  - Makes code more readable
  - Can pass around the result of a logical test (as param/return)

```
int age = 21, height = 88;
double salary = 100000;

boolean goodAge    = age >= 12 && age < 29; //true
boolean goodHeight = height >= 78 && height < 84; //false
boolean rich       = salary >= 100000.0; //true
```

Using `boolean`

```
boolean goodAge    = age >= 21 && 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

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

Evaluating logic expressions

AND is evaluated before OR.

```
int x = 2;
int y = 4;
int z = 5;

boolean a = 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.

Correction

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

OR

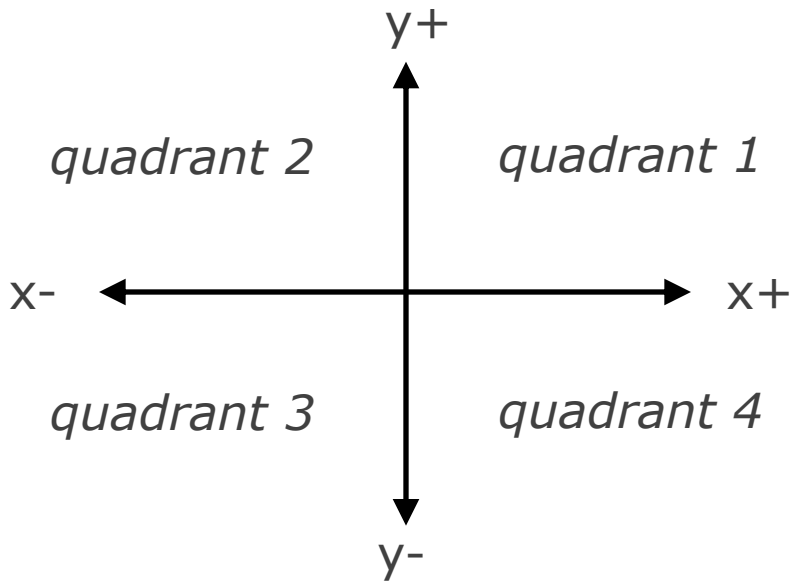
```
public static int max(int a, int b) {
    if (a > b) {
        return a;
    }

    return b;

}
```

`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

`if (x == 7 && y > 3) {`
`  ...`
`}`
	`if (x != 7 || y <= 3) {`
	`  ...`
	`}`

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:

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

a	b	!(a && b)	!a || !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");
}
```

OR alternatively, use indexOf:

```
public static boolean isVowel(String s) {
    return s.length() == 1 && "aeiou".indexOf(s) != -1;
}
```

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 Main{
  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 Main{
  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
```

Note: DO NOT USE == for Strings! Always use .equals

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(same data).

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
```

Lab 1: BMI

Create a new repl for this lab.

Formula for body mass index (BMI):

$$BMI = \frac{weight}{height^2} \times 703$$

BMI	Weight class
below 18.5	underweight
[18.5 – 25)	normal
[25.0 – 30)	overweight
30.0 and up	obese

Write a program that produces output like the following. Use Scanner for input.

```
Height (in inches): 70.0
Weight (in pounds) 194.25
BMI = 27.868928571428572
Overweight
```

Lab 1: BMI

Your program must include two methods:1) the method `bmi` which takes two double parameters height and weight and returns the bmi and 2) the method `weightClass` which takes two double parameters height and weight and returns a string classifying the weight class. **The weightClass method must call the bmi method!**

```
public static double bmi(double height, double
  weight)
{…}

public static String weightClass(double height,
  double weight)
{…}
```

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