

Building Java Programs

Chapter 5
Lecture 5-3: Boolean Logic

reading: 5.3, 5.4

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Type boolean

- **boolean**: A logical type whose values are `true` and `false`.
 - A logical **<test>** is actually a `boolean` expression.
 - Like other types, it is legal to:
 - create a `boolean` variable
 - pass a `boolean` value as a parameter
 - return a `boolean` value from methods
 - call a method that returns a `boolean` and use it as a test

```
boolean minor    = (age < 21);  
boolean isProf  = name.contains("Prof");  
boolean lovesCSE = true;  
  
// allow only CSE-loving students over 21  
if (minor || isProf || !lovesCSE) {  
    System.out.println("Can't enter the club!");  
}
```

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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)

```
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...");
}
```

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Returning boolean

```
public static boolean isPrime(int n) {
    int factors = 0;
    for (int i = 1; i <= n; i++) {
        if (n % i == 0) {
            factors++;
        }
    }
    if (factors == 2) {
        return true;
    } else {
        return false;
    }
}
```

- Calls to methods returning `boolean` can be used as tests:

```
if (isPrime(57)) {
    ...
}
```

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Boolean question

- Improve our "rhyme" / "alliterate" program to use boolean methods to test for rhyming and alliteration.

Type two words: **Bare blare**

They rhyme!

They alliterate!

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Boolean answer

```
if (rhyme(word1, word2)) {
    System.out.println("They rhyme!");
}
if (alliterate(word1, word2)) {
    System.out.println("They alliterate!");
}
...

// Returns true if s1 and s2 end with the same two letters.
public static boolean rhyme(String s1, String s2) {
    if (s2.length() >= 2 && s1.endsWith(s2.substring(s2.length() - 2))) {
        return true;
    } else {
        return false;
    }
}

// Returns true if s1 and s2 start with the same letter.
public static boolean alliterate(String s1, String s2) {
    if (s1.startsWith(s2.substring(0, 1))) {
        return true;
    } else {
        return false;
    }
}
```

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"Boolean Zen", part 1

- Students new to `boolean` often test if a result is `true`:

```
if (isPrime(57) == true) {    // bad
    ...
}
```

- But this is unnecessary and redundant. Preferred:

```
if (isPrime(57)) {          // good
    ...
}
```

- A similar pattern can be used for a `false` test:

```
if (isPrime(57) == false) { // bad
if (!isPrime(57)) {         // good
```

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"Boolean Zen", part 2

- Methods that return `boolean` often have an `if/else` that returns `true` or `false`:

```
public static boolean bothOdd(int n1, int n2) {
    if (n1 % 2 != 0 && n2 % 2 != 0) {
        return true;
    } else {
        return false;
    }
}
```

- But the code above is unnecessarily verbose.

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Solution w/ boolean variable

- We could store the result of the logical test.

```
public static boolean bothOdd(int n1, int n2) {
    boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
    if (test) { // test == true
        return true;
    } else { // test == false
        return false;
    }
}
```

- Notice: Whatever `test` is, we want to return that.
 - If `test` is `true`, we want to return `true`.
 - If `test` is `false`, we want to return `false`.

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Solution w/ "Boolean Zen"

- Observation: The `if/else` is unnecessary.
 - The variable `test` stores a boolean value; its value is exactly what you want to return. So return that!

```
public static boolean bothOdd(int n1, int n2) {
    boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
    return test;
}
```

- An even shorter version:
 - We don't even need the variable `test`. We can just perform the test and return its result in one step.

```
public static boolean bothOdd(int n1, int n2) {
    return (n1 % 2 != 0 && n2 % 2 != 0);
}
```

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"Boolean Zen" template

- Replace

```
public static boolean <name>(<parameters>) {  
    if (<test>) {  
        return true;  
    } else {  
        return false;  
    }  
}
```

- with

```
public static boolean <name>(<parameters>) {  
    return <test>;  
}
```

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Improved isPrime method

- The following version utilizes Boolean Zen:

```
public static boolean isPrime(int n) {  
    int factors = 0;  
    for (int i = 1; i <= n; i++) {  
        if (n % i == 0) {  
            factors++;  
        }  
    }  
    return factors == 2;    // if n has 2 factors -> true  
}
```

- Modify our Rhyme program to use Boolean Zen.

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Boolean Zen answer

```
public static void main(String[] args) {
    Scanner console = new Scanner(System.in);
    System.out.print("Type two words: ");
    String word1 = console.next().toLowerCase();
    String word2 = console.next().toLowerCase();

    if (rhyme(word1, word2)) {
        System.out.println("They rhyme!");
    }
    if (alliterate(word1, word2)) {
        System.out.println("They alliterate!");
    }
}

// Returns true if s1 and s2 end with the same two letters.
public static boolean rhyme(String s1, String s2) {
    return s2.length() >= 2 && s1.endsWith(s2.substring(s2.length() - 2));
}

// Returns true if s1 and s2 start with the same letter.
public static boolean alliterate(String s1, String s2) {
    return s1.startsWith(s2.substring(0, 1));
}
```

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De Morgan's Law

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

Original Expression	Negated Expression	Alternative
<code>a && b</code>	<code>!a !b</code>	<code>!(a && b)</code>
<code>a b</code>	<code>!a && !b</code>	<code>!(a b)</code>

- Example:

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

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Boolean practice questions

- Write a method named `isVowel` that returns whether a `String` is a vowel (a, e, i, o, or u), case-insensitively.
 - `isVowel("q")` returns `false`
 - `isVowel("A")` returns `true`
 - `isVowel("e")` returns `true`
- Change the above method into an `isNonVowel` that returns whether a `String` is any character except a vowel.
 - `isNonVowel("q")` returns `true`
 - `isNonVowel("A")` returns `false`
 - `isNonVowel("e")` returns `false`

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Boolean practice answers

```
// Enlightened version. I have seen the true way (and false way)
public static boolean isVowel(String s) {
    return s.equalsIgnoreCase("a") || s.equalsIgnoreCase("e") ||
           s.equalsIgnoreCase("i") || s.equalsIgnoreCase("o") ||
           s.equalsIgnoreCase("u");
}

// Enlightened "Boolean Zen" version
public static boolean isNonVowel(String s) {
    return !s.equalsIgnoreCase("a") && !s.equalsIgnoreCase("e") &&
           !s.equalsIgnoreCase("i") && !s.equalsIgnoreCase("o") &&
           !s.equalsIgnoreCase("u");

    // or, return !isVowel(s);
}
```

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When to return?

- Methods with loops and return values can be tricky.
 - When and where should the method return its result?
- Write a method `seven` that accepts a `Random` parameter and uses it to draw up to ten lotto numbers from 1-30.
 - If any of the numbers is a lucky 7, the method should stop and return `true`. If none of the ten are 7 it should return `false`.
 - The method should print each number as it is drawn.

```
15 29 18 29 11 3 30 17 19 22      (first call)
29 5 29 4 7                        (second call)
```

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Flawed solution

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");

        if (num == 7) {
            return true;
        } else {
            return false;
        }
    }
}
```

- The method always returns immediately after the first roll.
- This is wrong if that roll isn't a 7; we need to keep rolling.

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Returning at the right time

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");

        if (num == 7) { // found lucky 7; can exit now
            return true;
        }
    }

    return false; // if we get here, there was no 7
}
```

- Returns `true` immediately if 7 is found.
- If 7 isn't found, the loop continues drawing lotto numbers.
- If all ten aren't 7, the loop ends and we return `false`.

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while loop question

- Write a method `digitSum` that accepts an integer parameter and returns the sum of its digits.
 - Assume that the number is non-negative.
 - Example: `digitSum(29107)` returns `2+9+1+0+7` or `19`
 - Hint: Use the `%` operator to extract a digit from a number.

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while loop answer

```
public static int digitSum(int n) {  
    n = Math.abs(n);           // handle negatives  
    int sum = 0;  
    while (n > 0) {  
        sum = sum + (n % 10); // add last digit  
        n = n / 10;          // remove last digit  
    }  
    return sum;  
}
```

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Boolean return questions

- `hasAnOddDigit` : returns true if any digit of an integer is odd.
 - `hasAnOddDigit(4822116)` returns true
 - `hasAnOddDigit(2448)` returns false
- `allDigitsOdd` : returns true if every digit of an integer is odd.
 - `allDigitsOdd(135319)` returns true
 - `allDigitsOdd(9174529)` returns false
- `isAllVowels` : returns true if every char in a String is a vowel.
 - `isAllVowels("eIeIo")` returns true
 - `isAllVowels("oink")` returns false
- These problems are available in our Practice-It! system under **5.x**.

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Boolean return answers

```
public static boolean hasAnOddDigit(int n) {
    while (n != 0) {
        if (n % 2 != 0) { // check whether last digit is odd
            return true;
        }
        n = n / 10;
    }
    return false;
}

public static boolean allDigitsOdd(int n) {
    while (n != 0) {
        if (n % 2 == 0) { // check whether last digit is even
            return false;
        }
        n = n / 10;
    }
    return true;
}

public static boolean isAllVowels(String s) {
    for (int i = 0; i < s.length(); i++) {
        String letter = s.substring(i, i + 1);
        if (!isVowel(letter)) {
            return false;
        }
    }
    return true;
}
```

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