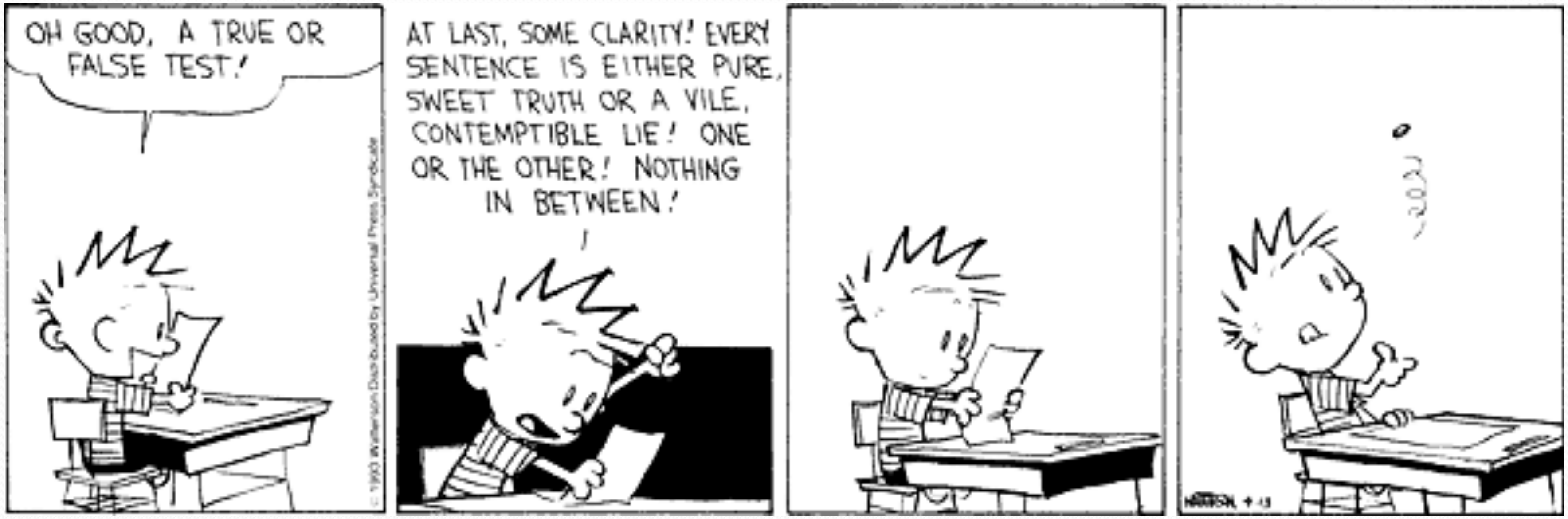
Building Java Programs

Chapter 5
Lecture 12: Boolean Logic and Assertions

reading: 5.3 – 5.5


OH GOOD, A TRUE OR FALSE TEST!
AT LAST, SOME CLARITY! EVERY SENTENCE IS EITHER PURE, SWEET TRUTH OR A VILE, CONTEMPTIBLE LIE! ONE OR THE OTHER! NOTHING IN BETWEEN!
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WATTERSON 4-13

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!");
}
```

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...");
}
```

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)) {
    ...
}
```

"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
```

"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.

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`.

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);
}
```

"Boolean Zen" template

- Replace

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

- with

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

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
}
```

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

  - Example:

Original Code	Negated Code

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

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`

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);
}
```

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)
```

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 draw.
- This is wrong if that draw isn't a 7; we need to keep drawing.

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`.

`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.

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;
}
```

Boolean return questions

- `hasAnOddDigit` : returns `true` if <u>any</u> digit of an integer is odd.
  - `hasAnOddDigit(4822116)` returns `true`
  - `hasAnOddDigit(2448)` returns `false`

- `allDigitsOdd` : returns `true` if <u>every</u> digit of an integer is odd.
  - `allDigitsOdd(135319)` returns `true`
  - `allDigitsOdd(9174529)` returns `false`

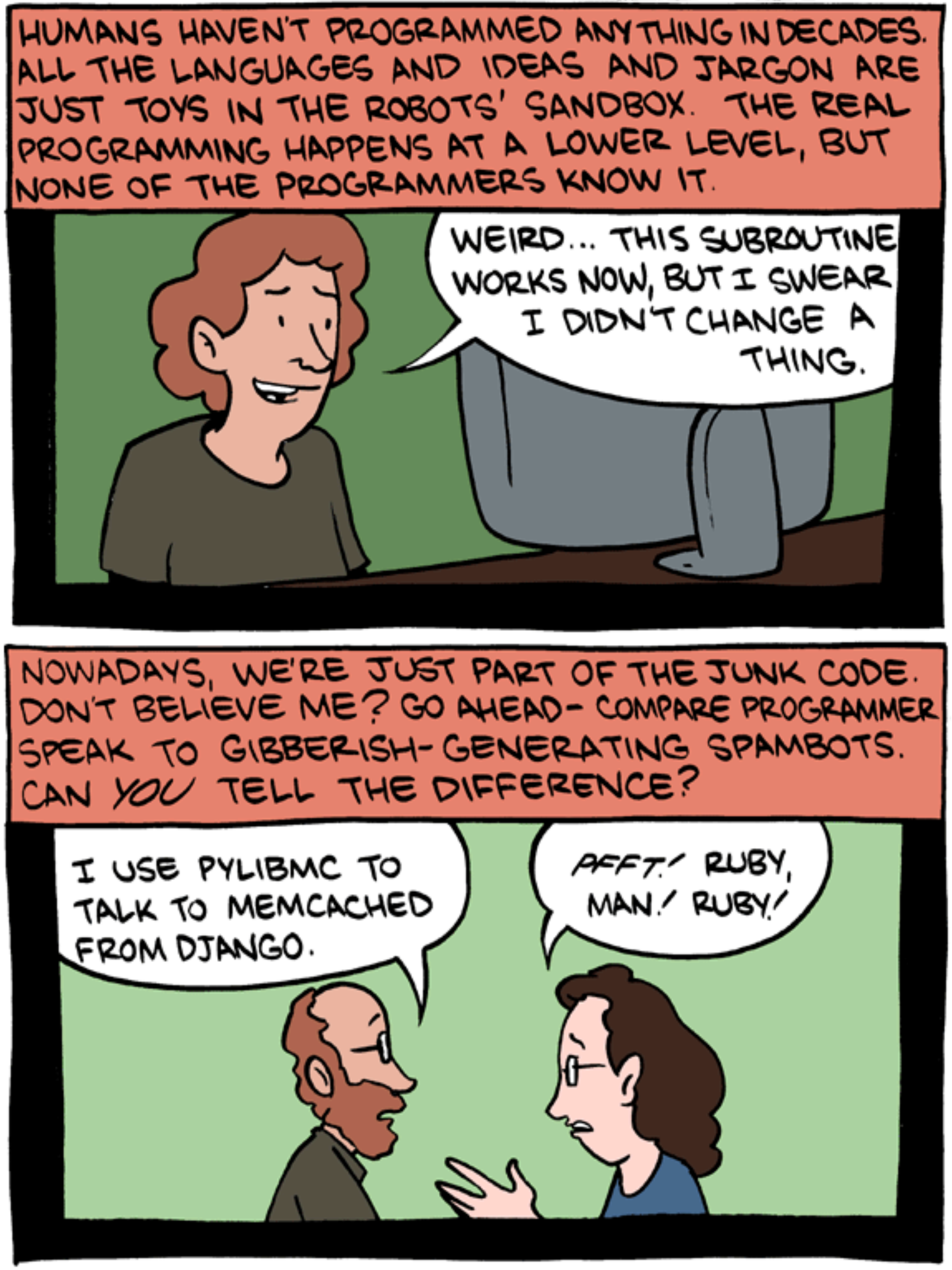
- `isAllVowels` : returns `true` if <u>every</u> char in a `String` is a vowel.
  - `isAllVowels("eIeIo")` returns `true`
  - `isAllVowels("oink")` returns `false`
    - These problems are available in our Practice-It! system under **5.x**.

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;
}
```


HUMANS HAVEN'T PROGRAMMED ANYTHING IN DECADES. ALL THE LANGUAGES AND IDEAS AND JARGON ARE JUST TOYS IN THE ROBOTS' SANDBOX. THE REAL PROGRAMMING HAPPENS AT A LOWER LEVEL, BUT NONE OF THE PROGRAMMERS KNOW IT.
WEIRD... THIS SUBROUTINE WORKS NOW, BUT I SWEAR I DIDN'T CHANGE A THING.
NOWADAYS, WE'RE JUST PART OF THE JUNK CODE. DON'T BELIEVE ME? GO AHEAD- COMPARE PROGRAMMER SPEAK TO GIBBERISH-GENERATING SPAMBOTS. CAN *YOU* TELL THE DIFFERENCE?
I USE PYLIBMC TO TALK TO MEMCACHED FROM DJANGO.
PFFT! RUBY, MAN! RUBY!

Punchline to a longer comic: http://www.smbc-comics.com/index.php?db=comics&id=2362#comic

Logical assertions

- **assertion**: A statement that is either true or false.

  Examples:
  - Java was created in 1995.
  - The sky is purple.
  - 23 is a prime number.
  - 10 is greater than 20.
  - x divided by 2 equals 7. *(depends on the value of x)*

- An assertion might be false ("The sky is purple" above), but it is still an assertion because it is a true/false statement.

Reasoning about assertions

- Suppose you have the following code:

```
if (x > 3) {
    // Point A
    x--;
} else {
    // Point B
    x++;
    // Point C
}
// Point D
```

- What do you know about `x`'s value at the three points?
  - Is `x > 3`? Always? Sometimes? Never?

Assertions in code

- We can make assertions about our code and ask whether they are true at various points in the code.
  - Valid answers are ALWAYS, NEVER, or SOMETIMES.

```
System.out.print("Type a nonnegative number: ");
double number = console.nextDouble();
// Point A: is number < 0.0 here?            (SOMETIMES)

while (number < 0.0) {
    // Point B: is number < 0.0 here?        (ALWAYS)
    System.out.print("Negative; try again: ");

    number = console.nextDouble();
    // Point C: is number < 0.0 here?        (SOMETIMES)
}

// Point D: is number < 0.0 here?            (NEVER)
```

Reasoning about assertions

- Right after a variable is initialized, its value is known:

```
int x = 3;
// is x > 0?  ALWAYS
```

- In general you know nothing about parameters' values:

```
public static void mystery(int a, int b) {
// is a == 10?  SOMETIMES
```

- But inside an `if`, `while`, etc., you may know something:

```
public static void mystery(int a, int b) {
    if (a < 0) {
        // is a == 10?  NEVER
        ...
    }
}
```

Assertions and loops

- At the start of a loop's body, the loop's test must be `true`:

```
while (y < 10) {
    // is y < 10?  ALWAYS
    ...
}
```

- After a loop, the loop's test must be `false`:

```
while (y < 10) {
    ...
}
// is y < 10?  NEVER
```

- Inside a loop's body, the loop's test may become `false`:

```
while (y < 10) {
    y++;
    // is y < 10?  SOMETIMES
}
```

"Sometimes"

- Things that cause a variable's value to be unknown (often leads to "sometimes" answers):
  - reading from a `Scanner`
  - reading a number from a `Random` object
  - a parameter's initial value to a method

- If you can reach a part of the program both with the answer being "yes" and the answer being "no", then the correct answer is "sometimes".
  - If you're unsure, "Sometimes" is a good guess.

Assertion example 1

```
public static void mystery(int x, int y) {
    int z = 0;

    // Point A

    while (x >= y) {
        // Point B
        x = x - y;
        z++;

        if (x != y) {
            // Point C
            z = z * 2;
        }

        // Point D

    }

    // Point E
    System.out.println(z);
}
```

Which of the following assertions are true at which point(s) in the code? Choose ALWAYS, NEVER, or SOMETIMES.

	x < y	x == y	z == 0
Point A	SOMETIMES	SOMETIMES	ALWAYS
Point B	NEVER	SOMETIMES	SOMETIMES
Point C	SOMETIMES	NEVER	NEVER
Point D	SOMETIMES	SOMETIMES	NEVER
Point E	ALWAYS	NEVER	SOMETIMES

Assertion example 2

```
public static int mystery(Scanner console) {
    int prev = 0;
    int count = 0;
    int next = console.nextInt();

    // Point A

    while (next != 0) {
        // Point B

        if (next == prev) {
            // Point C

            count++;
        }

        prev = next;
        next = console.nextInt();

        // Point D

    }

    // Point E

    return count;
}
```

Which of the following assertions are true at which point(s) in the code? Choose ALWAYS, NEVER, or SOMETIMES.

	`next == 0`	`prev == 0`	`next == prev`
Point A	SOMETIMES	ALWAYS	SOMETIMES
Point B	NEVER	SOMETIMES	SOMETIMES
Point C	NEVER	NEVER	ALWAYS
Point D	SOMETIMES	NEVER	SOMETIMES
Point E	ALWAYS	SOMETIMES	SOMETIMES

Assertion example 3

```
// Assumes y >= 0, and returns x^y
public static int pow(int x, int y) {
    int prod = 1;

    // Point A
    while (y > 0) {
        // Point B
        if (y % 2 == 0) {
            // Point C
            x = x * x;
            y = y / 2;
            // Point D
        } else {
            // Point E
            prod = prod * x;
            y--;
            // Point F
        }
    }
    // Point G
    return prod;
}
```

Which of the following assertions are true at which point(s) in the code? Choose ALWAYS, NEVER, or SOMETIMES.

	`y > 0`	`y % 2 == 0`
Point A	SOMETIMES	SOMETIMES
Point B	ALWAYS	SOMETIMES
Point C	ALWAYS	ALWAYS
Point D	ALWAYS	SOMETIMES
Point E	ALWAYS	NEVER
Point F	SOMETIMES	ALWAYS
Point G	NEVER	ALWAYS