Topic 14
while loops and loop patterns

"Given enough eyeballs, all bugs are shallow (e.g., given a large enough beta-tester and co-developer base, almost every problem will be characterized quickly and the fix obvious to someone)."

-Linus’s Law, by Eric Raymond

A deceptive problem...

- Write a method `printNumbers` that prints each number from 1 to a given maximum, separated by commas.

For example, the call:

```
printNumbers(5)
```

should print:

```
1, 2, 3, 4, 5
```

Flawed solutions

- public static void printNumbers(int max) {
  for (int i = 1; i <= max; i++) {
    System.out.print(i + " ");
  }
  System.out.println(); // to end the line of output
}
- Output from `printNumbers(5)`: 1, 2, 3, 4, 5,

- public static void printNumbers(int max) {
  for (int i = 1; i <= max; i++) {
    System.out.print(", " + i);
  }
  System.out.println(); // to end the line of output
}
- Output from `printNumbers(5)`: , 1, 2, 3, 4, 5

Fence post analogy

- We print `n` numbers but need only `n - 1` commas.
- Similar to building a fence with wires separated by posts:
  - If we use a flawed algorithm that repeatedly places a post + wire, the last post will have an extra dangling wire.

```
for (length of fence) {
  place a post.
  place some wire.
}
```
Fencepost loop

- Add a statement outside the loop to place the initial "post."
  - Also called a fencepost loop or a "loop-and-a-half" solution.

  place a post.
  for (length of fence - 1) {
    place some wire.
    place a post.
  }

Fencepost method solution

```java
public static void printNumbers(int max) {
    System.out.print(1);
    for (int i = 2; i <= max; i++) {
        System.out.print("", " + i);
    }
    System.out.println(); // to end the line
}
```

- Alternate solution: Either first or last "post" can be taken out:

```java
public static void printNumbers(int max) {
    for (int i = 1; i <= max - 1; i++) {
        System.out.print(i + "", ");
    }
    System.out.println(max); // to end the line
}
```

Fencepost question

- Modify your method printNumbers into a new method printPrimes that prints all prime numbers up to a max.
  - Example: printPrimes(50) prints
    2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47
  - If the maximum is less than 2, print no output.

- To help you, write a method countFactors which returns the number of factors of a given integer.
  - countFactors(20) returns 6 due to factors 1, 2, 4, 5, 10, 20.

Fencepost answer

```java
// Prints all prime numbers up to the given max.
public static void printPrimes(int max) {
    if (max >= 2) {
        System.out.print("2");
        for (int i = 3; i <= max; i++) {
            if (countFactors(i) == 2) {
                System.out.print("", " + i");
            }
        }
        System.out.println();
    }
}
```

```java
// Returns how many factors the given number has.
public static int countFactors(int number) {
    int count = 0;
    for (int i = 1; i <= number; i++) {
        if (number % i == 0) {
            count++;
            // i is a factor of number
        }
    }
    return count;
}
```
while loops

reading: 5.1

Categories of loops

- **definite loop**: Executes a known number of times.
  - The for loops we have seen are definite loops.
    - Print "hello" 10 times.
    - Find all the prime numbers up to an integer \( n \).
    - Print each odd number between 5 and 127.

- **indefinite loop**: One where the number of times its body repeats is not known in advance.
  - Prompt the user until they type a non-negative number.
  - Print random numbers until a prime number is printed.
  - Repeat until the user has typed "q" to quit.

The **while** loop

- **while loop**: Repeatedly executes its body as long as a logical test is true.

```java
while (<test>) {
    <statement(s>);
}
```

Example:

```java
int num = 1;        // initialization
while (num <= 200) {    // test
    System.out.print(num + " ");
    num = num * 2;        // update
}
```

// output: 1 2 4 8 16 32 64 128

Example **while loop**

```java
// finds the first factor of 91, other than 1
int n = 91;
int factor = 2;
while (n % factor != 0) {
    factor++;
}
System.out.println("First factor is " + factor);
```

// output: First factor is 7

- **while** is better than for because we don't know how many times we will need to increment to find the factor.
What is output by the following code?
```java
int sum = 0;
int limit = 60;
int val = 1;
while(val < limit) {
    sum++;
}
System.out.print(sum);
```
A. 0    B. 60    C. 61
D. No output due to syntax error
E. No output due to some other reason

Solution?
```java
Scanner console = new Scanner(System.in);int sum = 0;
String response = "dummy"; // "dummy" value, anything but ""
while (!response.equals("")) {
    System.out.print("Type a line (or nothing to exit): ");
    response = console.nextLine();
    sum += response.length();
}
System.out.println("You typed a total of " + sum + " characters.");
```

Sentinel values
- **sentinel**: A value that signals the end of user input.
  - **sentinel loop**: Repeats until a sentinel value is seen.
- Example: Write a program that prompts the user for text until the user types nothing, then output the total number of characters typed.
  - (In this case, the *empty* string is the sentinel value.)
  ```java
  Type a line (or nothing to exit): hello
  Type a line (or nothing to exit): this is a line
  Type a line (or nothing to exit): 
  You typed a total of 19 characters.
  ```

Changing the sentinel value
- Modify your program to use "quit" as the sentinel value.
- Example log of execution:
  ```java
  Type a line (or "quit" to exit): hello
  Type a line (or "quit" to exit): this is a line
  Type a line (or "quit" to exit): quit
  You typed a total of 19 characters.
  ```
Changing the sentinel value

- Changing the sentinel's value to "\texttt{quit}" does not work!

```java
Scanner console = new Scanner(System.in);
int sum = 0;
String response = "dummy"; // "dummy" value, anything but "quit"
while (!response.equals("quit")) {
    System.out.print("Type a line (or \"quit\" to exit): ");
    response = console.nextLine();
    sum += response.length();
}
System.out.println("you typed a total of " + sum + " characters.");
```

- This solution produces the wrong output. Why?
  You typed a total of 23 characters.

The problem with the code

- The code uses a pattern like this:
  ```java
  sum = 0.
  while (input is not the sentinel) {
    prompt for input; read input. // place a "post"
    add input length to the sum.
  }
  ```

A fencepost solution

- On the last pass, the sentinel's length (4) is added to the sum:
  ```java
  prompt for input; read input ("\texttt{quit}").
  add input length (4) to the sum.
  ```

- This is a fencepost problem.
  - Must read $N$ lines, but only sum the lengths of the first $N-1$.

- Sentinel loops often utilize a fencepost "loop-and-a-half" style solution by pulling some code out of the loop.
Correct code

Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Type a line (or \"quit\" to exit): ");
String response = console.nextLine();

while (!response.equals("quit")) {
    sum += response.length();  // moved to top of loop
    System.out.print("Type a line (or \"quit\" to exit): ");
    response = console.nextLine();
}

System.out.println("You typed a total of "+ sum + " characters.");

Sentinel as a constant

public static final String SENTINEL = "quit";
...
Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Type a line (or \"" + SENTINEL + \"\" to exit): ");
String response = console.nextLine();

while (!response.equals(SENTINEL)) {
    sum += response.length();  // moved to top of loop
    System.out.print("Type a line (or \"" + SENTINEL + \"\" to exit): ");
    response = console.nextLine();
}

System.out.println("You typed a total of "+ sum + " characters.");

examples

• write a method to improve checking if a number is prime or not
  – when can we stop?
• Write a program that flips a coin until there is a run of 10 flips of the same side in a row
  – how many flips were there before 10 in a row?
  – repeat the experiment 1000 times, what is the average number of flips