

Program Logic and Indefinite Loops

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,

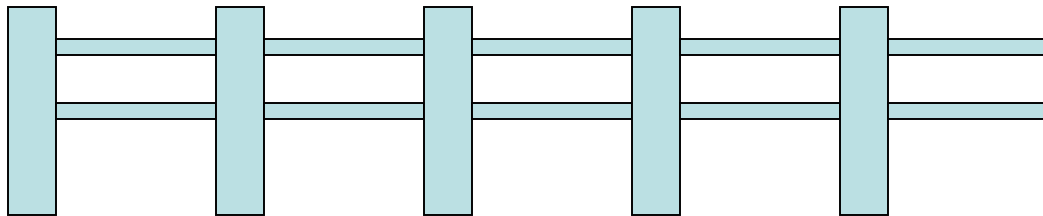
- ```
public static void printNumbers(int max) {  
    for (int i = 1; i <= max; i++) {  
        System.out.print(", " + i);  
    }  
    System.out.println(); // to end the line of output  
}
```

– 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.

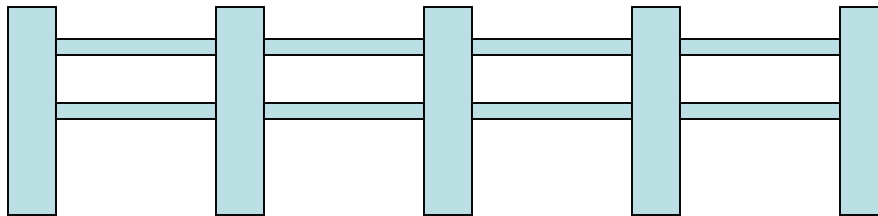
place a post.

for (length of fence - 1) {

place some wire.

place a post.

}



Fencepost method solution

```
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:

```
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

// 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();  
    }  
}
```

// 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

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 types "q" to quit.

The while loop

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

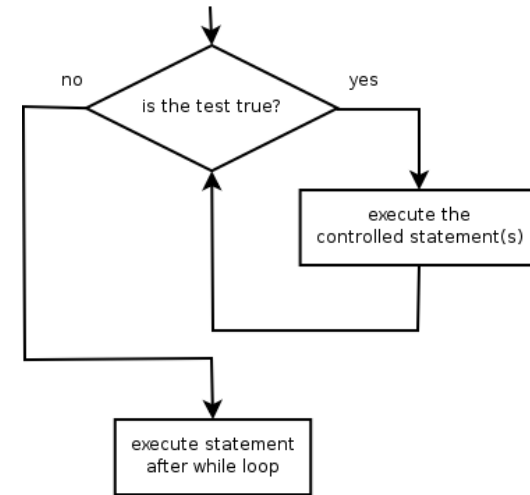
```
while (test) {  
    statement(s);  
}
```

- Example:

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

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

```
// initialization  
// test  
  
// update
```



Example while loop

```
// 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.

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 numbers until the user types 0, then outputs their sum.
 - (In this case, 0 is the sentinel value.)

```
Enter a number (0 to quit): 10
Enter a number (0 to quit): 20
Enter a number (0 to quit): 30
Enter a number (0 to quit): 0
The sum is 60
```

Flawed sentinel solution

- What's wrong with this solution?

```
Scanner console = new Scanner(System.in);  
int sum = 0;  
int number = 1;    // "dummy value", anything but 0  
  
while (number != 0) {  
    System.out.print("Enter a number (0 to quit): ");  
    number = console.nextInt();  
    sum = sum + number;  
}  
  
System.out.println("The total is " + sum);
```

Changing the sentinel value

- Modify your program to use a sentinel value of -1.
 - Example log of execution:

```
Enter a number (-1 to quit): 15  
Enter a number (-1 to quit): 25  
Enter a number (-1 to quit): 10  
Enter a number (-1 to quit): 30  
Enter a number (-1 to quit): -1  
The total is 80
```

Changing the sentinel value

- To see the problem, change the sentinel's value to -1:

```
Scanner console = new Scanner(System.in);
int sum = 0;
int number = 1;  // "dummy value", anything but -1

while (number != -1) {
    System.out.print("Enter a number (-1 to quit): ");
    number = console.nextInt();
    sum = sum + number;
}

System.out.println("The total is " + sum);
```

- Now the solution produces the wrong output. Why?

The total was 79

The problem with our code

- Our code uses a pattern like this:

sum = 0.

while (input is not the sentinel) {

prompt for input; read input.

add input to the sum.

}

- On the last pass, the sentinel -1 is added to the sum:

prompt for input; read input (-1).

add input (-1) to the sum.

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

A fencepost solution

sum = 0.

prompt for input; read input.

// place a "post"

while (input is not the sentinel) {

add input to the sum.

// place a "wire"

prompt for input; read input.

// place a "post"

}

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

Correct sentinel code

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

// pull one prompt/read ("post") out of the loop
System.out.print("Enter a number (-1 to quit): ");
int number = console.nextInt();

while (number != -1) {
    sum = sum + number;          // moved to top of loop
    System.out.print("Enter a number (-1 to quit): ");
    number = console.nextInt();
}

System.out.println("The total is " + sum);
```

Sentinel as a constant

```
public static final int SENTINEL = -1;
...
Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Enter a number (" + SENTINEL +
                 " to quit): ");
int number = console.nextInt();

while (number != SENTINEL) {
    sum = sum + number;           // moved to top of loop
    System.out.print("Enter a number (" + SENTINEL +
                    " to quit): ");
    number = console.nextInt();
}

System.out.println("The total is " + sum);
```

The Random class

- A Random object generates pseudo-random numbers.
 - Class Random is found in the `java.util` package.

```
import java.util.*;
```

Method name	Description
<code>nextInt()</code>	returns a random integer
<code>nextInt(max)</code>	returns a random integer in the range $[0, \textit{max})$ in other words, 0 to <i>max</i> -1 inclusive
<code>nextDouble()</code>	returns a random real number in the range $[0.0, 1.0)$

- Example:

```
Random rand = new Random();  
int randomNumber = rand.nextInt(10);    // 0-9
```

Generating random numbers

- Common usage: to get a random number from 1 to N

```
int n = rand.nextInt(20) + 1;    // 1-20 inclusive
```

- To get a number in arbitrary range $[min, max]$ inclusive:

```
name.nextInt(size of range) + min
```

- where (**size of range**) is (**max** - **min** + 1)

- Example: A random integer between 4 and 10 inclusive:

```
int n = rand.nextInt(7) + 4;
```

Random and other types

- `nextDouble` method returns a double between 0.0 - 1.0

- Example: Get a random GPA value between 1.5 and 4.0:

```
double randomGpa = rand.nextDouble() * 2.5 + 1.5;
```

- Any set of possible values can be mapped to integers

- code to randomly play Rock-Paper-Scissors:

```
int r = rand.nextInt(3);  
if (r == 0) {  
    System.out.println("Rock");  
} else if (r == 1) {  
    System.out.println("Paper");  
} else { // r == 2  
    System.out.println("Scissors");  
}
```

Random question

- Write a program that simulates rolling of two 6-sided dice until their combined result comes up as 7.

$$2 + 4 = 6$$

$$3 + 5 = 8$$

$$5 + 6 = 11$$

$$1 + 1 = 2$$

$$4 + 3 = 7$$

You won after 5 tries!

Random answer

```
// Rolls two dice until a sum of 7 is reached.
```

```
import java.util.*;
```

```
public class Dice {
```

```
    public static void main(String[] args) {
```

```
        Random rand = new Random();
```

```
        int tries = 0;
```

```
        int sum = 0;
```

```
        while (sum != 7) {
```

```
            // roll the dice once
```

```
            int roll1 = rand.nextInt(6) + 1;
```

```
            int roll2 = rand.nextInt(6) + 1;
```

```
            sum = roll1 + roll2;
```

```
            System.out.println(roll1 + " + " + roll2 + " = " + sum);
```

```
            tries++;
```

```
        }
```

```
        System.out.println("You won after " + tries + " tries!");
```

```
    }
```

```
}
```

Random question

- Write a program that plays an adding game.
 - Ask user to solve random adding problems with 2-5 numbers.
 - The user gets 1 point for a correct answer, 0 for incorrect.
 - The program stops after 3 incorrect answers.

$$4 + 10 + 3 + 10 = \underline{27}$$

$$9 + 2 = \underline{11}$$

$$8 + 6 + 7 + 9 = \underline{25}$$

Wrong! The answer was 30

$$5 + 9 = \underline{13}$$

Wrong! The answer was 14

$$4 + 9 + 9 = \underline{22}$$

$$3 + 1 + 7 + 2 = \underline{13}$$

$$4 + 2 + 10 + 9 + 7 = \underline{42}$$

Wrong! The answer was 32

You earned 4 total points.

Random answer

// Asks the user to do adding problems and scores them.

```
import java.util.*;
```

```
public class AddingGame {
```

```
    public static void main(String[] args) {
```

```
        Scanner console = new Scanner(System.in);
```

```
        Random rand = new Random();
```

// play until user gets 3 wrong

```
int points = 0;
```

```
int wrong = 0;
```

```
while (wrong < 3) {
```

```
    int result = play(console, rand);    // play one game
```

```
    if (result > 0) {
```

```
        points++;
```

```
    } else {
```

```
        wrong++;
```

```
    }
```

```
}
```

```
System.out.println("You earned " + points + " total points.");
```

```
}
```

Random answer 2

...

```
// Builds one addition problem and presents it to the user.
// Returns 1 point if you get it right, 0 if wrong.
public static int play(Scanner console, Random rand) {
    // print the operands being added, and sum them
    int operands = rand.nextInt(4) + 2;
    int sum = rand.nextInt(10) + 1;
    System.out.print(sum);

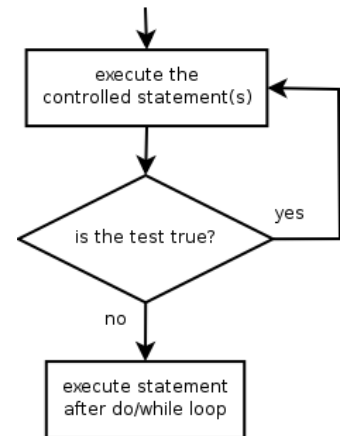
    for (int i = 2; i <= operands; i++) {
        int n = rand.nextInt(10) + 1;
        sum += n;
        System.out.print(" + " + n);
    }
    System.out.print(" = ");

    // read user's guess and report whether it was correct
    int guess = console.nextInt();
    if (guess == sum) {
        return 1;
    } else {
        System.out.println("Wrong! The answer was " + sum);
        return 0;
    }
}
```

The do/while loop

- **do/while loop:** Performs its test at the *end* of each repetition.
 - Guarantees that the loop's `{ }` body will run at least once.

```
do {  
    statement(s);  
} while (test);
```



// Example: prompt until correct password is typed

```
String phrase;  
do {  
    System.out.print("Type your password: ");  
    phrase = console.next();  
} while (!phrase.equals("abracadabra"));
```

do/while example

```
// Rolls two dice until a sum of 7 is reached.
```

```
import java.util.*;
```

```
public class Dice {
```

```
    public static void main(String[] args) {
```

```
        Random rand = new Random();
```

```
        int tries = 0;
```

```
        int sum;
```

```
        do {
```

```
            int roll1 = rand.nextInt(6) + 1;    // one roll
```

```
            int roll2 = rand.nextInt(6) + 1;
```

```
            sum = roll1 + roll2;
```

```
            System.out.println(roll1 + " + " + roll2 + " = " + sum);
```

```
            tries++;
```

```
        } while (sum != 7);
```

```
        System.out.println("You won after " + tries + " tries!");
```

```
    }
```

```
}
```

Type boolean

String test methods

Method	Description
<code>equals(str)</code>	whether two strings contain the same characters
<code>equalsIgnoreCase(str)</code>	whether two strings contain the same characters, ignoring upper vs. lower case
<code>startsWith(str)</code>	whether one contains other's characters at start
<code>endsWith(str)</code>	whether one contains other's characters at end
<code>contains(str)</code>	whether the given string is found within this one

- Some methods return logical values.
 - A call to such a method is used as a **test** in a loop or `if`.

```
String name = console.next();  
if (name.contains("Prof")) {  
    System.out.println("When are your office hours?");  
} else if (name.equalsIgnoreCase("STUART")) {  
    System.out.println("Let's talk about meta!");  
}
```


Type boolean

- **boolean**: A logical type whose values are `true` and `false`.
 - A logical **test** is actually a `boolean` expression.
 - 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 >= 16 && 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 var

- 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;  
}
```


"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`
- The following test will crash if `s2`'s length is less than 2:

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

- The following test will not crash; it stops if `length < 2`:

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

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

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 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`

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;
}
```