Secure Coding Standards and Issues (Selected) in Java

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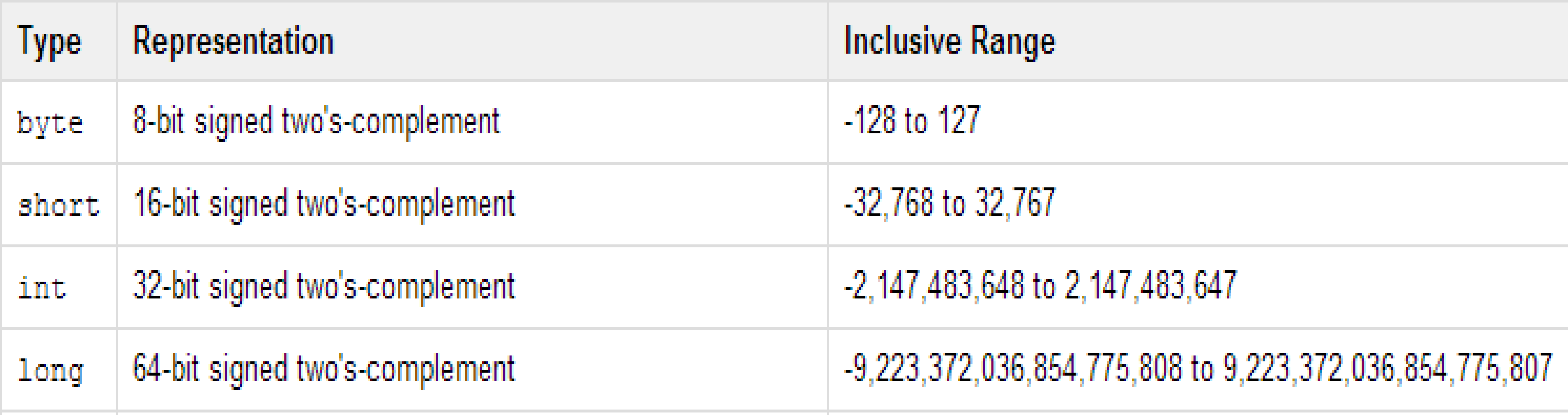
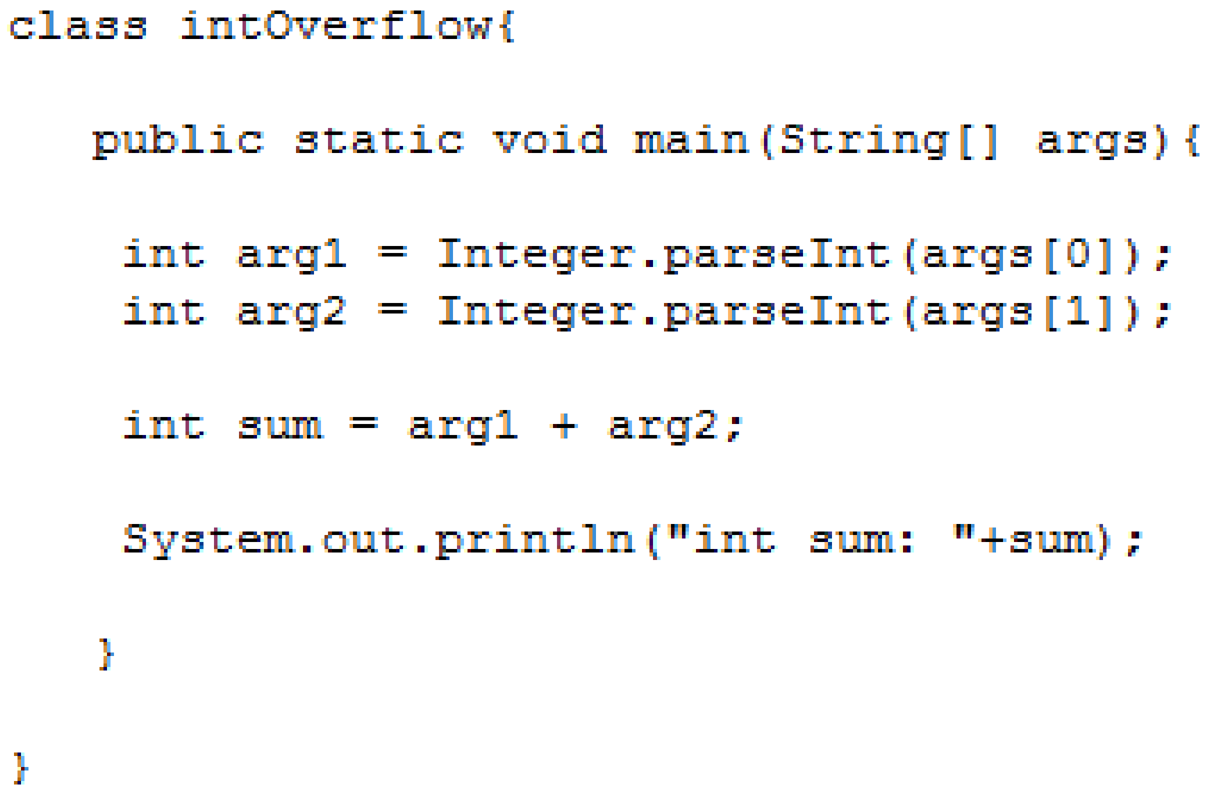
Standard-1: Detect or Prevent Integer Overflow

- Programs should not permit arithmetic operations to exceed the ranges provided by the various primitive integer data types.
  – In the Java language, the only integer operators that can throw an exception are the / and % operators, which throw an *Arithmetic Exception* if the right-hand operand is a 0. In addition, the -- or ++ unary operators throw an *OutofMemoryError* if the decrement or increment operation requires insufficient memory.

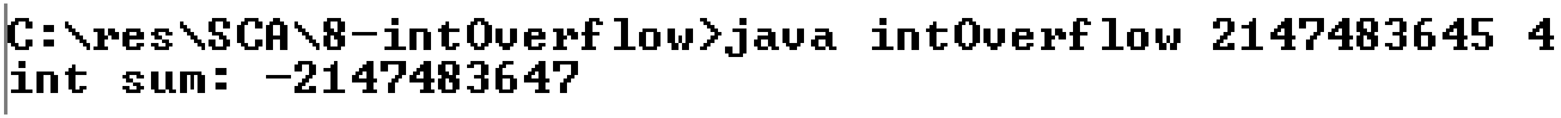


Type	Representation	Inclusive Range
`byte`	8-bit signed two's-complement	-128 to 127
`short`	16-bit signed two's-complement	-32,768 to 32,767
`int`	32-bit signed two's-complement	-2,147,483,648 to 2,147,483,647
`long`	64-bit signed two's-complement	-9,223,372,036,854,775,808 to 9,223,372,036,854,775,807

Vulnerable Program: Integer Overflow



```
class intOverflow{

   public static void main(String[] args){

    int arg1 = Integer.parseInt(args[0]);
    int arg2 = Integer.parseInt(args[1]);

    int sum = arg1 + arg2;

    System.out.println("int sum: "+sum);

   }

}
```



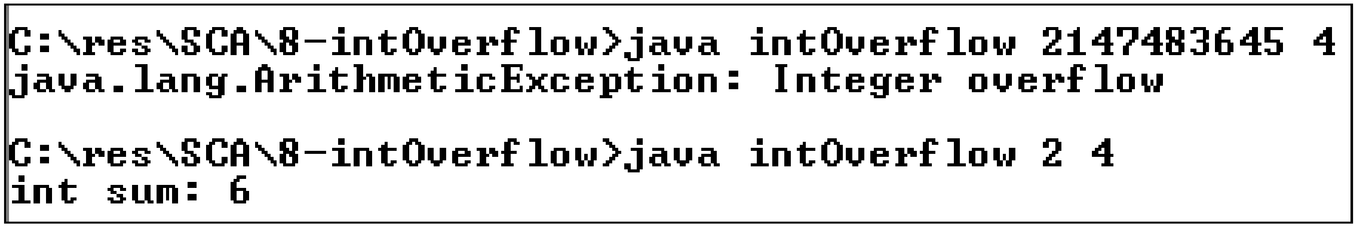
```
C:\res\SCA\8-intOverflow>java intOverflow 2147483645 4
int sum: -2147483647
```

Solution # 1: Pre-condition Testing

- Idea: Check the inputs to *each* arithmetic operator to ensure that overflow cannot occur. Throw an *ArithmeticException* when the operation would overflow if it were performed; otherwise, perform the operation.

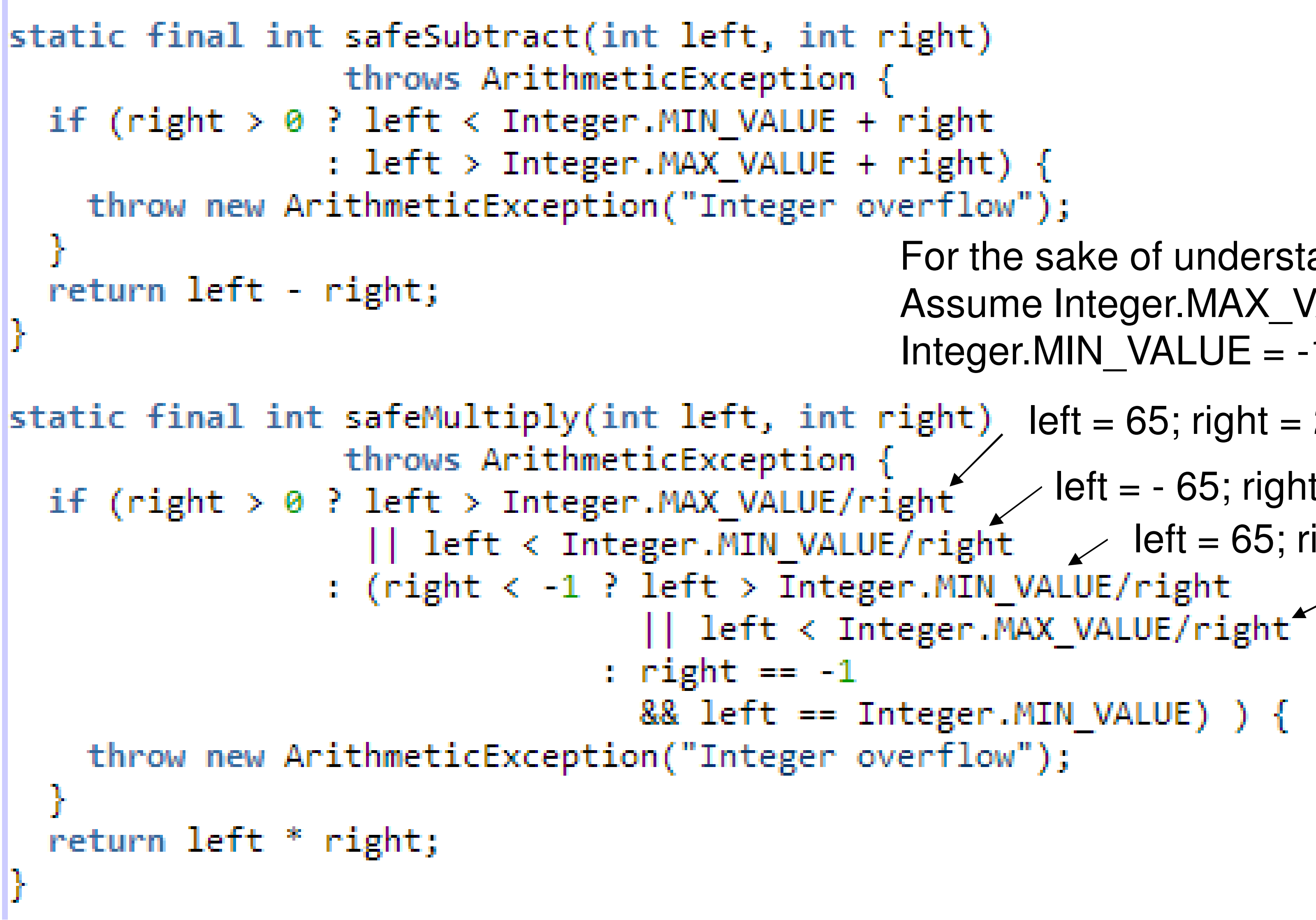
Pre-condition Testing for Addition

```java
class intOverflow{

   public static int safeAdd(int left, int right)
                      throws ArithmeticException{

      if (right > 0 ?
                  left > Integer.MAX_VALUE - right :
                  left < Integer.MIN_VALUE - right){
          throw new ArithmeticException("Integer overflow");
      }

      return left + right;
   }

   public static void main(String[] args){

    int arg1 = Integer.parseInt(args[0]);
    int arg2 = Integer.parseInt(args[1]);

    try{
      int sum = safeAdd(arg1, arg2);
      System.out.println("int sum: "+sum);
      }
     catch(ArithmeticException ae){
         System.out.println(ae);
     }

   }
}
```



```
C:\res\SCA\8-intOverflow>java intOverflow 2147483645 4
java.lang.ArithmeticException: Integer overflow

C:\res\SCA\8-intOverflow>java intOverflow 2 4
int sum: 6
```

Code Segments for Safe Arithmetic



```
static final int safeSubtract(int left, int right)
                 throws ArithmeticException {
  if (right > 0 ? left < Integer.MIN_VALUE + right
                : left > Integer.MAX_VALUE + right) {
    throw new ArithmeticException("Integer overflow");
  }
  return left - right;
}

static final int safeMultiply(int left, int right)
                 throws ArithmeticException {
  if (right > 0 ? left > Integer.MAX_VALUE/right
                  || left < Integer.MIN_VALUE/right
                : (right < -1 ? left > Integer.MIN_VALUE/right
                                || left < Integer.MAX_VALUE/right
                              : right == -1
                                && left == Integer.MIN_VALUE) ) {
    throw new ArithmeticException("Integer overflow");
  }
  return left * right;
}
```

For the sake of understanding,
Assume Integer.MAX_VALUE = 127
Integer.MIN_VALUE = -128

left = 65; right = 2

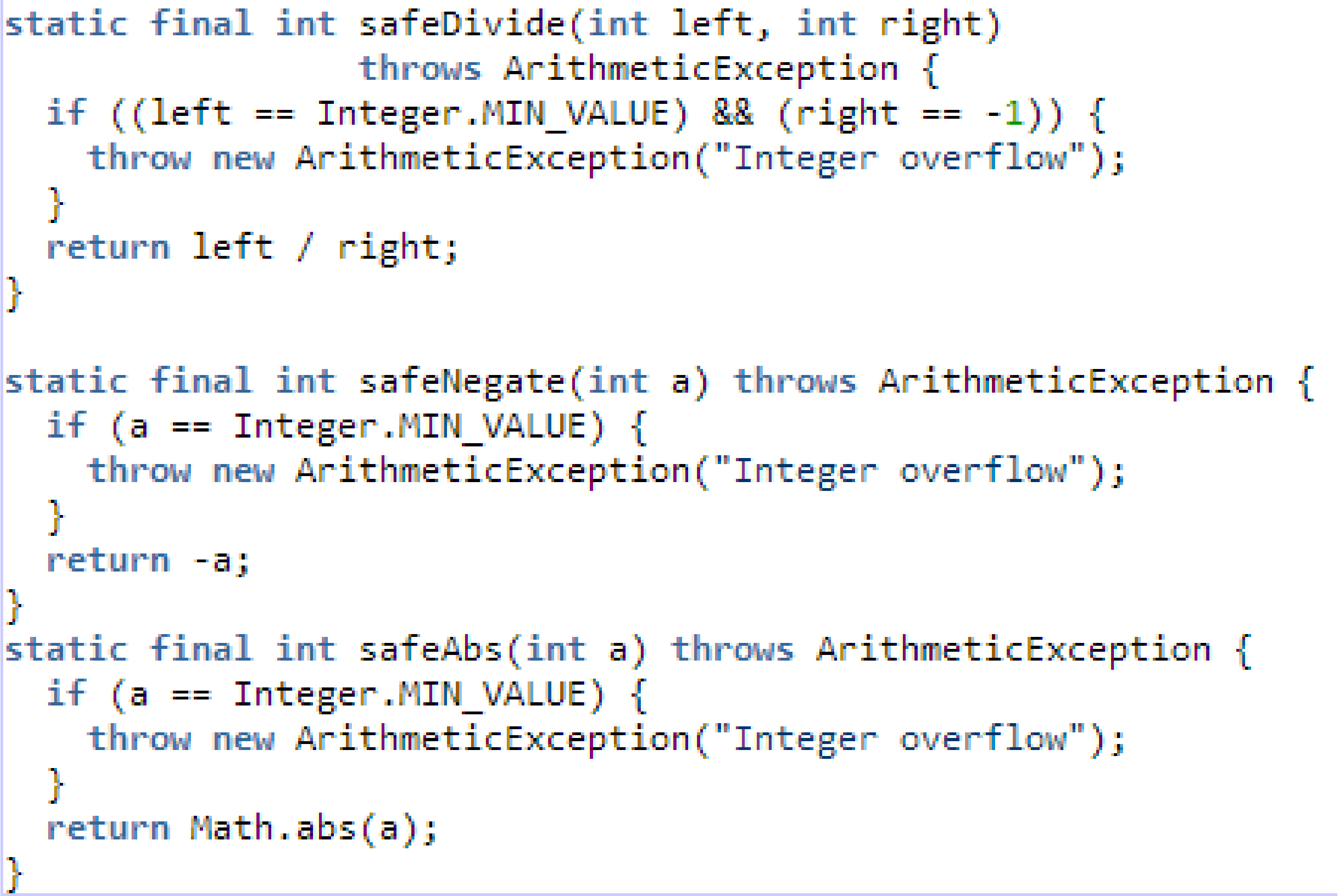
left = - 65; right = 2

left = 65; right = -2

left = - 65;
right = -2

Source: https://www.securecoding.cert.org/confluence/display/java/NUM00-J.+Detect+or+prevent+integer+overflow

Code Segments for Safe Arithmetic



```
static final int safeDivide(int left, int right)
                 throws ArithmeticException {
  if ((left == Integer.MIN_VALUE) && (right == -1)) {
    throw new ArithmeticException("Integer overflow");
  }
  return left / right;
}

static final int safeNegate(int a) throws ArithmeticException {
  if (a == Integer.MIN_VALUE) {
    throw new ArithmeticException("Integer overflow");
  }
  return -a;
}
static final int safeAbs(int a) throws ArithmeticException {
  if (a == Integer.MIN_VALUE) {
    throw new ArithmeticException("Integer overflow");
  }
  return Math.abs(a);
}
```

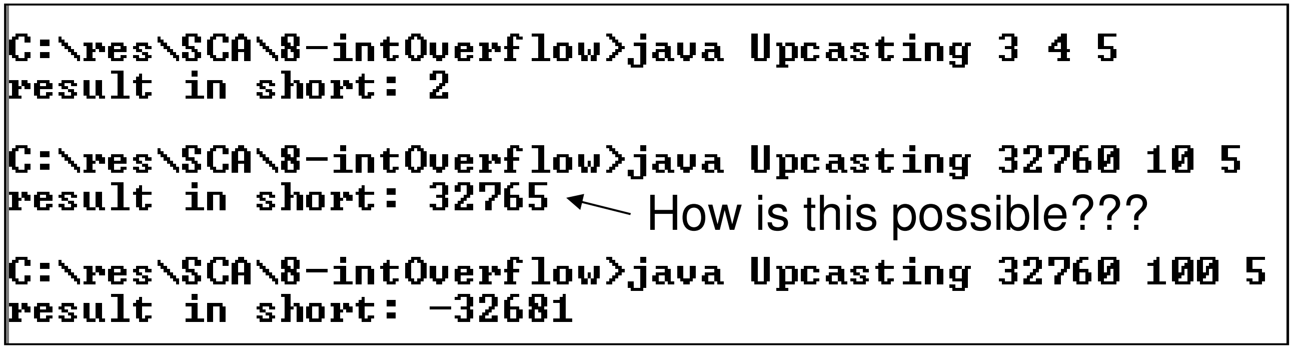
Source: https://www.securecoding.cert.org/confluence/display/java/NUM00-J.+Detect+or+prevent+integer+overflow

Solution # 2: Upcasting

- Idea:
  - Cast the inputs to the next larger integer type
  - Do the arithmetic operation on the larger type
  - Check the value of each intermediate result and final result to see if it would still fit within the range of the original integer type; if not raise an *ArithmeticException*
  - Downcast the final result to the original smaller type before assigning the result to a variable of smaller type and throw an

Vulnerable Program

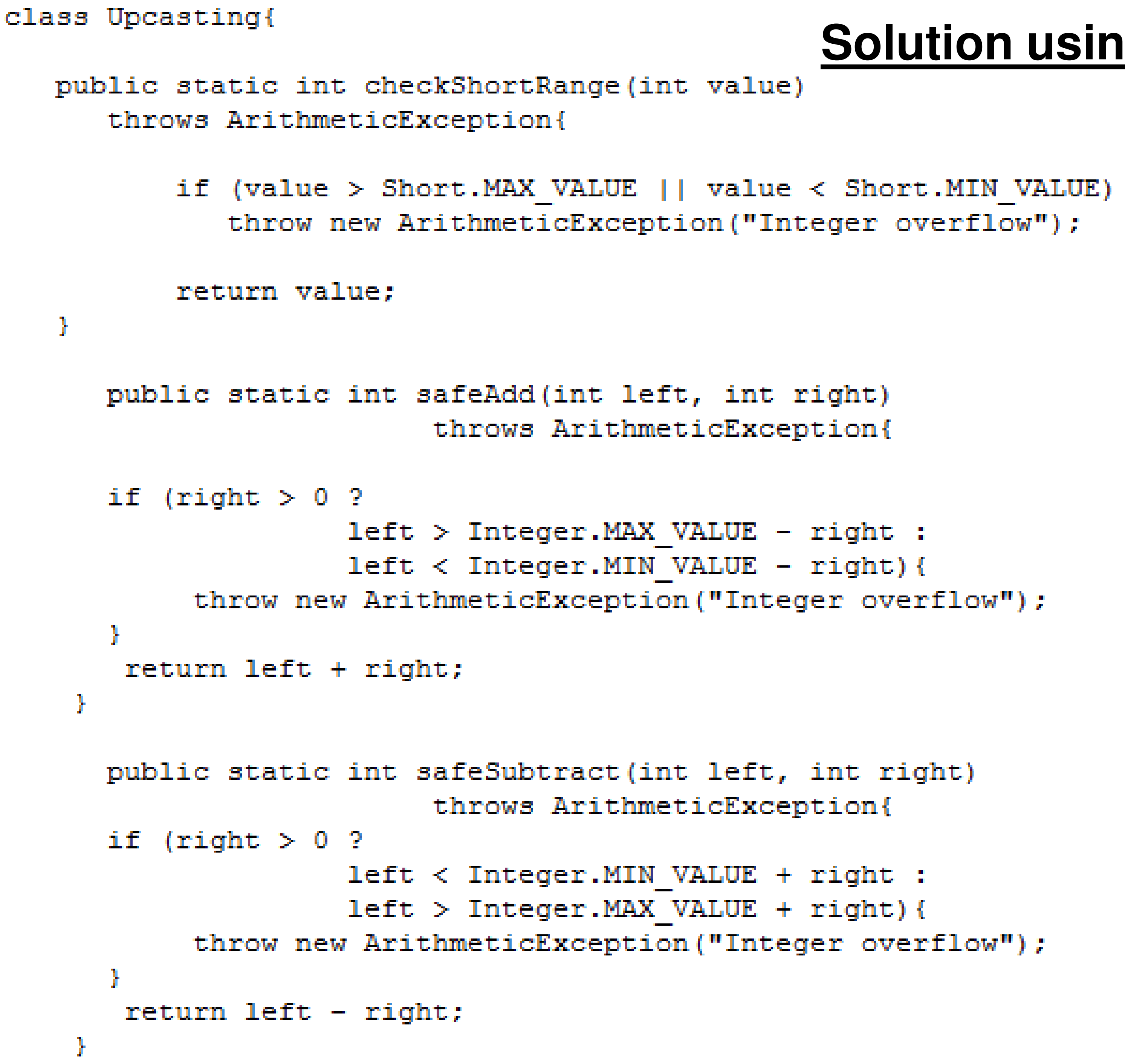
```
class Upcasting{

   // Evaluating the expression (a + b - c)
   // where a, b and c are of type short

   public static void main(String[] args){

    short short_a = Short.parseShort(args[0]);
    short short_b = Short.parseShort(args[1]);
    short short_c = Short.parseShort(args[2]);

    short result = (short) (short_a + short_b - short_c);

    System.out.println("result in short: "+ result);

    }

}
```



```
C:\res\SCA\8-intOverflow>java Upcasting 3 4 5
result in short: 2

C:\res\SCA\8-intOverflow>java Upcasting 32760 10 5
result in short: 32765

C:\res\SCA\8-intOverflow>java Upcasting 32760 100 5
result in short: -32681
```

How is this possible???

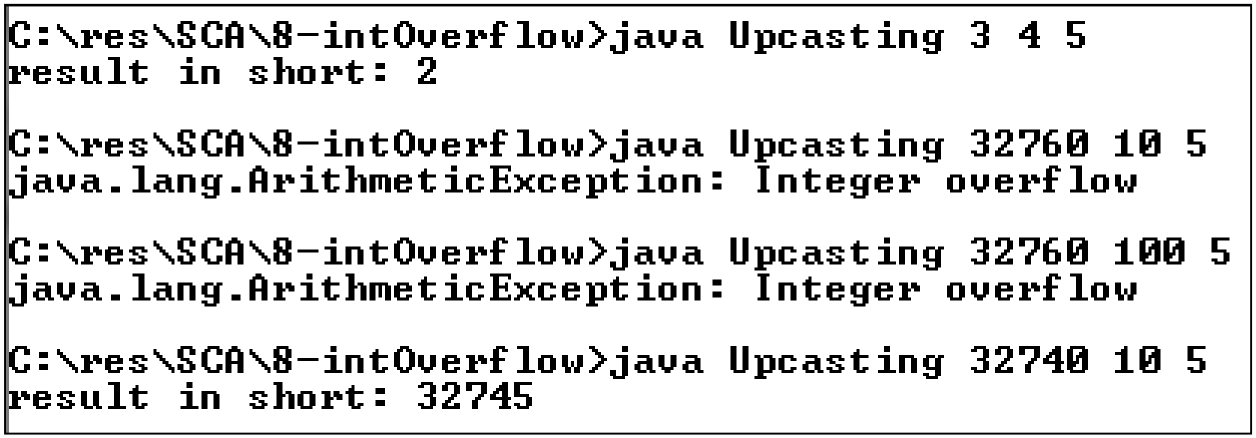
Solution using Upcasting



```
class Upcasting{

   public static int checkShortRange(int value)
      throws ArithmeticException{

          if (value > Short.MAX_VALUE || value < Short.MIN_VALUE)
             throw new ArithmeticException("Integer overflow");

          return value;
   }

      public static int safeAdd(int left, int right)
                         throws ArithmeticException{

      if (right > 0 ?
                    left > Integer.MAX_VALUE - right :
                    left < Integer.MIN_VALUE - right){
           throw new ArithmeticException("Integer overflow");
      }
       return left + right;
    }

      public static int safeSubtract(int left, int right)
                         throws ArithmeticException{
      if (right > 0 ?
                    left < Integer.MIN_VALUE + right :
                    left > Integer.MAX_VALUE + right){
           throw new ArithmeticException("Integer overflow");
      }
       return left - right;
    }
```

Continued…..

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

   try{
    short short_a = Short.parseShort(args[0]);
    short short_b = Short.parseShort(args[1]);
    short short_c = Short.parseShort(args[2]);

    short result = (short)
                    checkShortRange(
                       safeSubtract(
                          checkShortRange( safeAdd(short_a, short_b) ),
                          short_c  )
                                 );

    System.out.println("result in short: "+ result);
  }
  catch(ArithmeticException ae){
     System.out.println(ae);
  }

 }

}
```

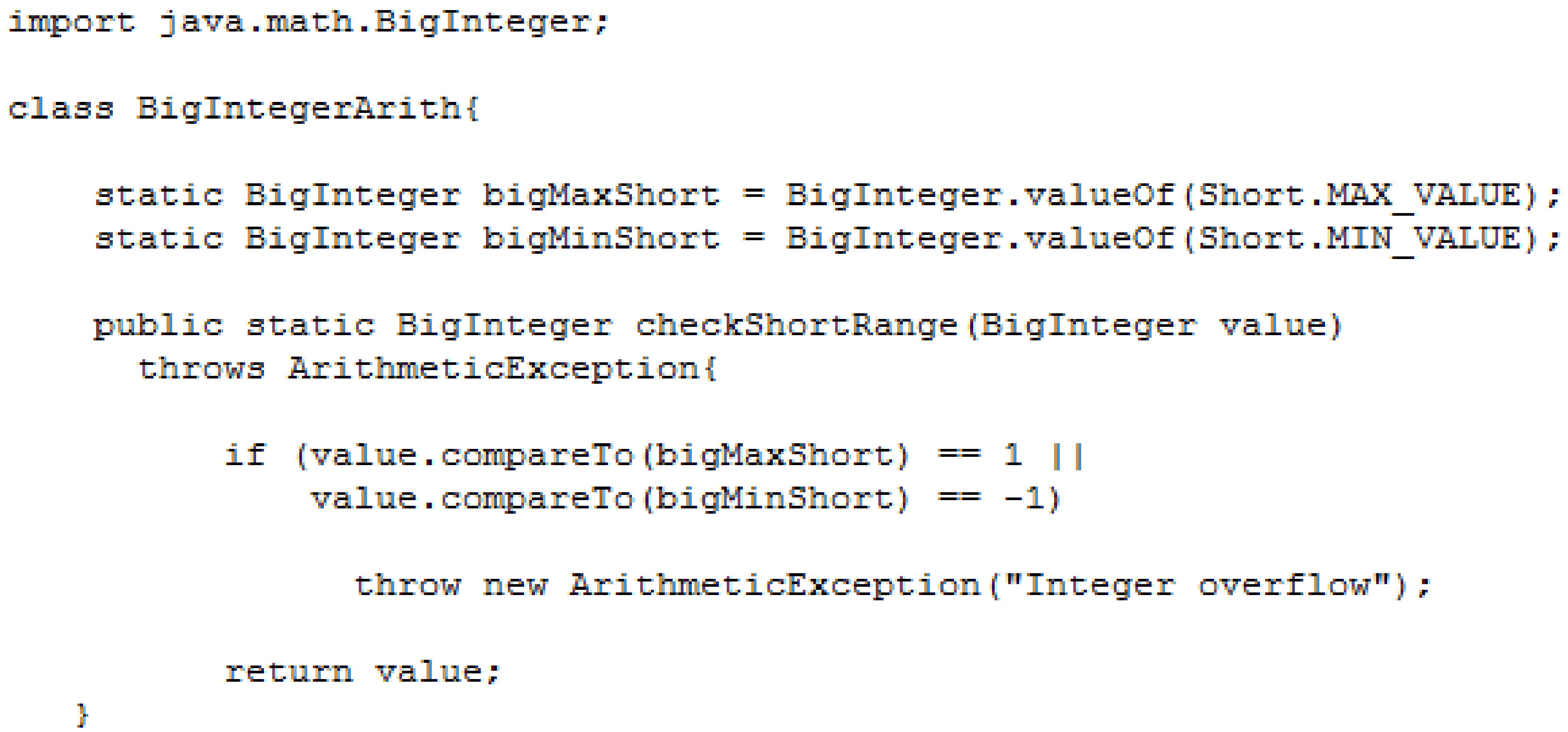


```
C:\res\SCA\8-intOverflow>java Upcasting 3 4 5
result in short: 2

C:\res\SCA\8-intOverflow>java Upcasting 32760 10 5
java.lang.ArithmeticException: Integer overflow

C:\res\SCA\8-intOverflow>java Upcasting 32760 100 5
java.lang.ArithmeticException: Integer overflow

C:\res\SCA\8-intOverflow>java Upcasting 32740 10 5
result in short: 32745
```

Solution # 3: Use BigInteger Class

- Idea:
  - Convert the inputs into objects of type BigInteger and perform all arithmetic using BigInteger methods.
  - Type BigInteger is the standard arbitrary-precision integer type provided by the Java standard libraries.
  - The arithmetic operations implemented as methods of this type cannot overflow; instead, they produce the numerically correct result.
  - Consequently, compliant code performs only a single range check just before converting the final result to the original smaller type and throws an ArithmeticException if the final result is outside the range of the original smaller type.

Solution using BigInteger

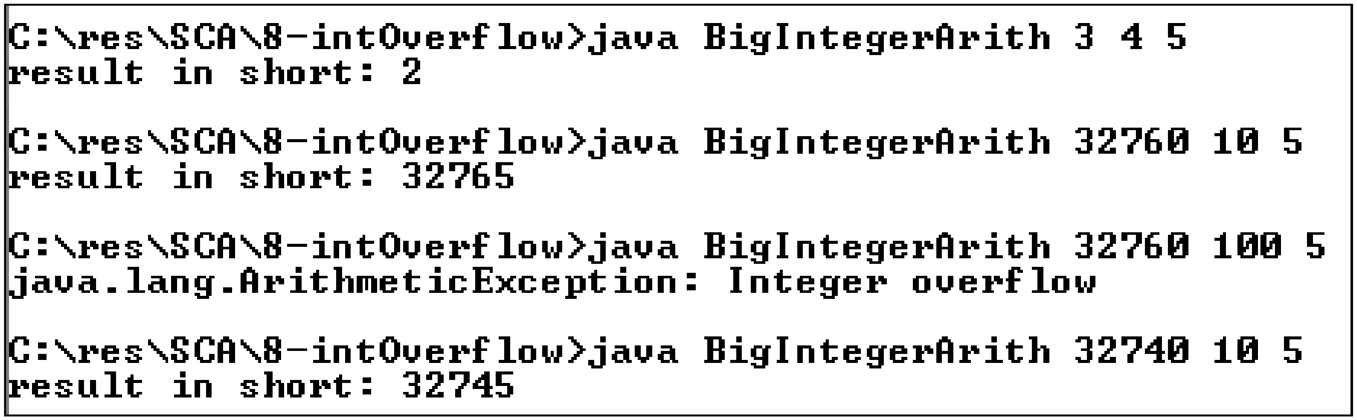


```
import java.math.BigInteger;

class BigIntegerArith{

    static BigInteger bigMaxShort = BigInteger.valueOf(Short.MAX_VALUE);
    static BigInteger bigMinShort = BigInteger.valueOf(Short.MIN_VALUE);

    public static BigInteger checkShortRange(BigInteger value)
      throws ArithmeticException{

          if (value.compareTo(bigMaxShort) == 1 ||
              value.compareTo(bigMinShort) == -1)

                throw new ArithmeticException("Integer overflow");

          return value;
   }
```

Continued…..

Solution using BigInteger

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

   try{
    short short_a = Short.parseShort(args[0]);
    short short_b = Short.parseShort(args[1]);
    short short_c = Short.parseShort(args[2]);

    BigInteger big_a = new BigInteger(""+short_a);
    BigInteger big_b = new BigInteger(""+short_b);
    BigInteger big_c = new BigInteger(""+short_c);

    BigInteger big_result = big_a.add(big_b).subtract(big_c);

    short result = (short) ( checkShortRange(big_result) ).intValue();

    System.out.println("result in short: "+ result);
  }
  catch(ArithmeticException ae){
     System.out.println(ae);
  }

 }

}
```



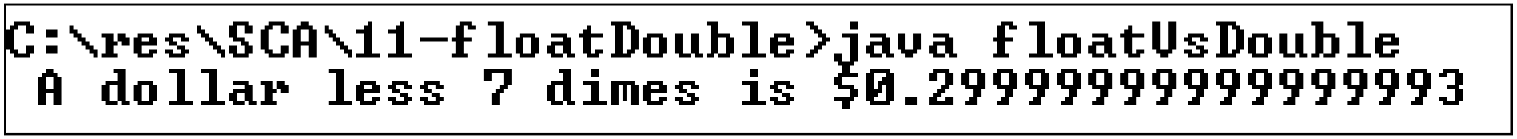
```
C:\res\SCA\8-intOverflow>java BigIntegerArith 3 4 5
result in short: 2

C:\res\SCA\8-intOverflow>java BigIntegerArith 32760 10 5
result in short: 32765

C:\res\SCA\8-intOverflow>java BigIntegerArith 32760 100 5
java.lang.ArithmeticException: Integer overflow

C:\res\SCA\8-intOverflow>java BigIntegerArith 32740 10 5
result in short: 32745
```

Standard 2: Floating Point Values

- When precise computation is necessary, such as when performing currency calculations, floating-point types must not be used. Instead, use an alternative representation that can completely represent the necessary values.

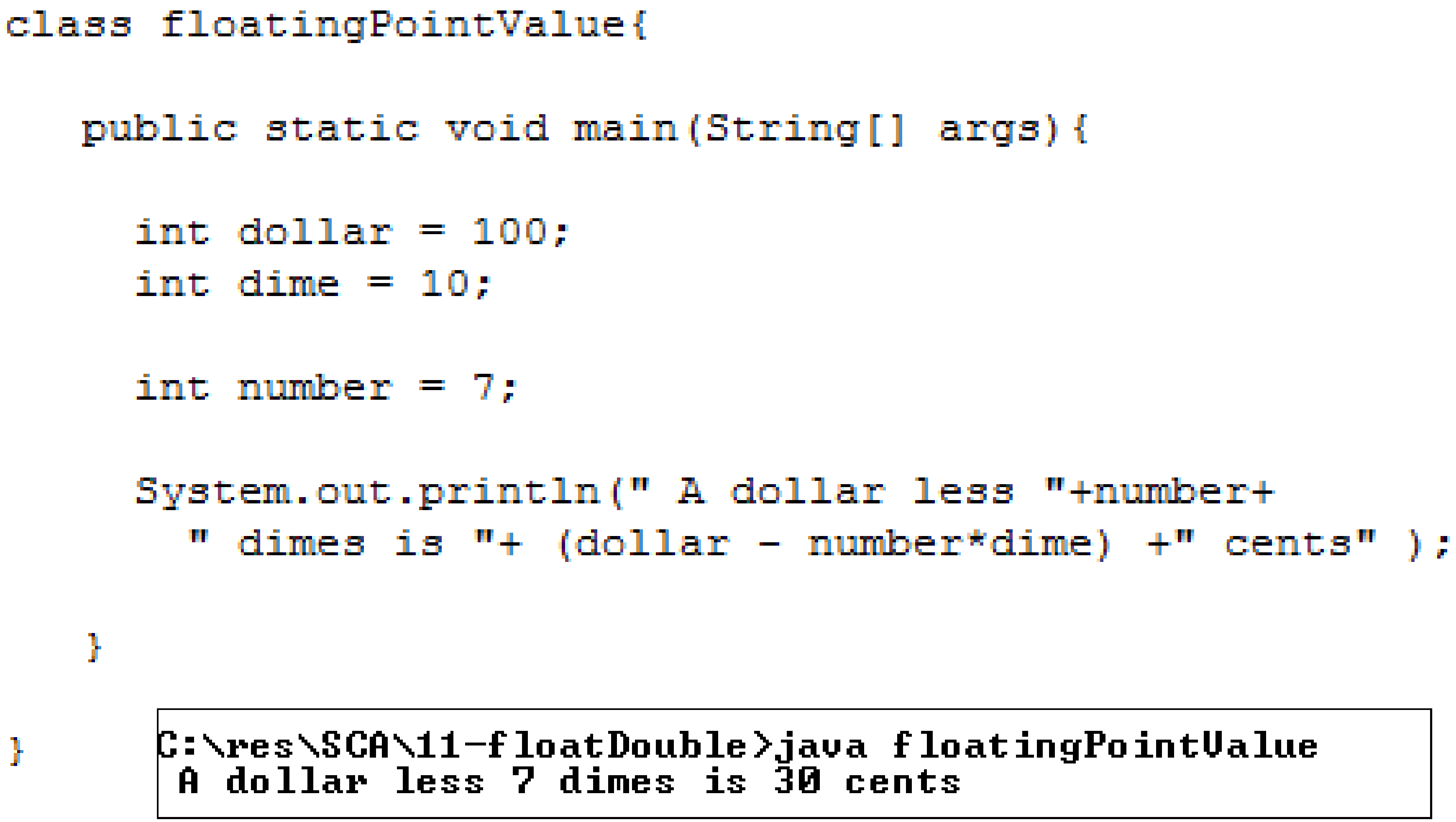
Vulnerable Code: Program requiring Precise Computation

```
class floatingPointValue{

   public static void main(String[] args){

     double dollar = 1.00;
     double dime = 0.10;

     int number = 7;

     System.out.println(" A dollar less "+number+" dimes is $"+
(dollar - number*dime) );

   }
}
```



```
C:\res\SCA\11-floatDouble>java floatVsDouble
 A dollar less 7 dimes is $0.29999999999999993
```

Solution 1: Use Integer types

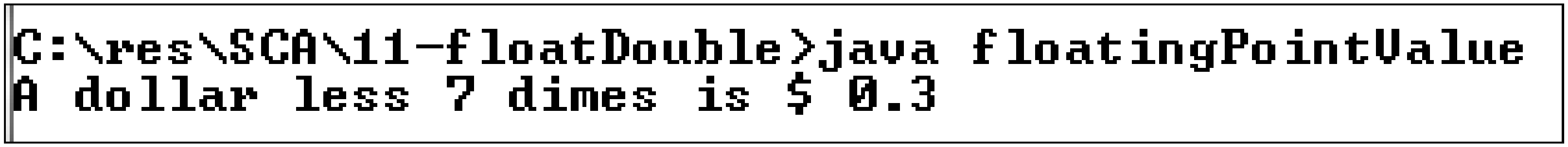


```
class floatingPointValue{

   public static void main(String[] args){

     int dollar = 100;
     int dime = 10;

     int number = 7;

     System.out.println(" A dollar less "+number+
       " dimes is "+ (dollar - number*dime) +" cents" );

   }

}
```

```
C:\res\SCA\11-floatDouble>java floatingPointValue
 A dollar less 7 dimes is 30 cents
```

Solution 2: Use BigDecimal

```
import java.math.BigDecimal;

class floatingPointValue{

   public static void main(String[] args){

       BigDecimal dollar = new BigDecimal("1.0");
       BigDecimal dime = new BigDecimal("0.1");
       int number = 7;

       System.out.println( "A dollar less " + number + " dimes
is $ " +( dollar.subtract( dime.multiply(new BigDecimal(number))
) ) );

   }
}
```

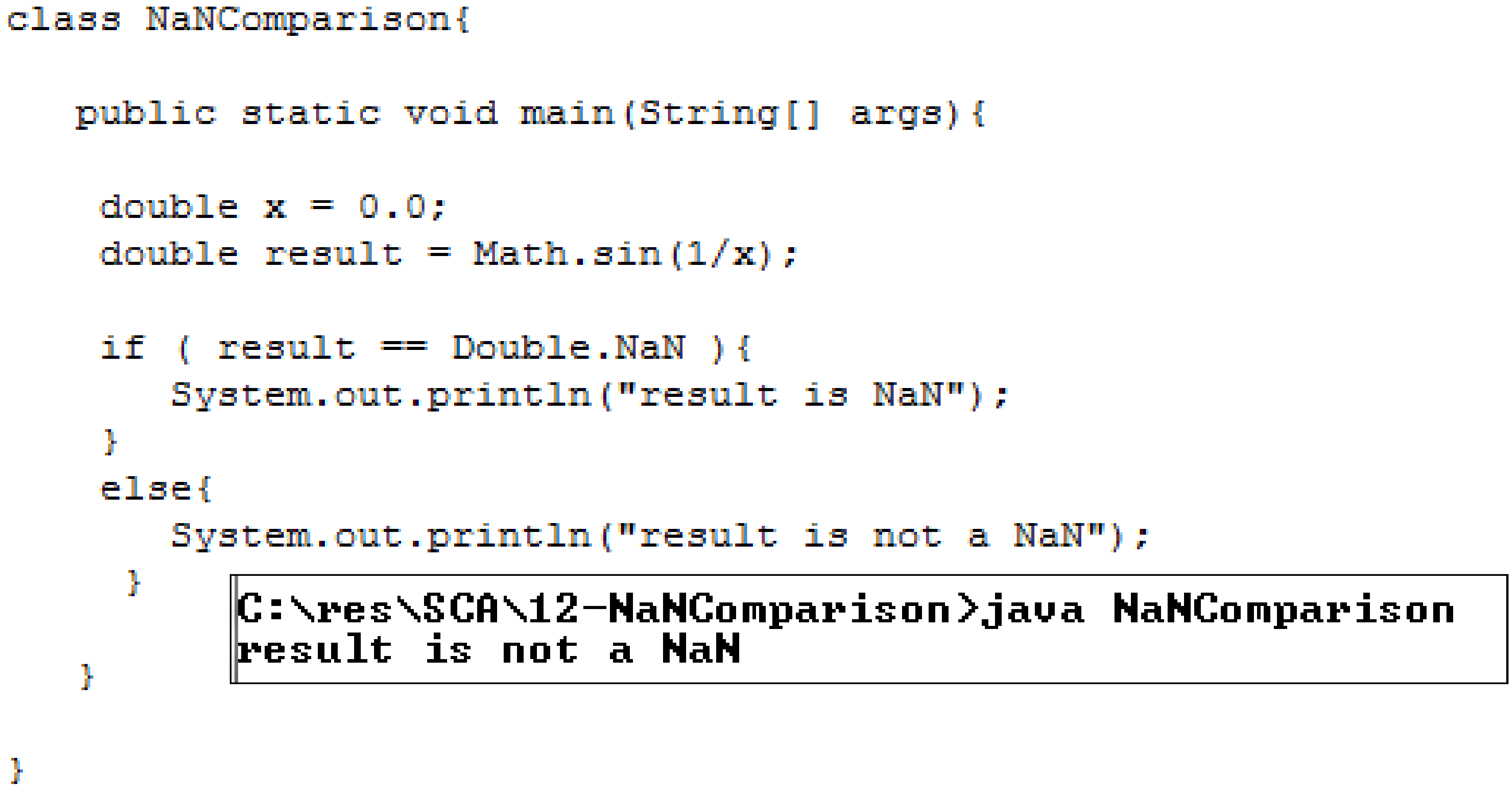


```
C:\res\SCA\11-floatDouble>java floatingPointValue
A dollar less 7 dimes is $ 0.3
```

Note: Do not construct BigDecimal objects from floating point literals like:
BigDecimal dollar = new BigDecimal(1.0);
Instead use string-based BigDecimal constructors.

Standard 3: Do not Attempt Comparisons with NaN

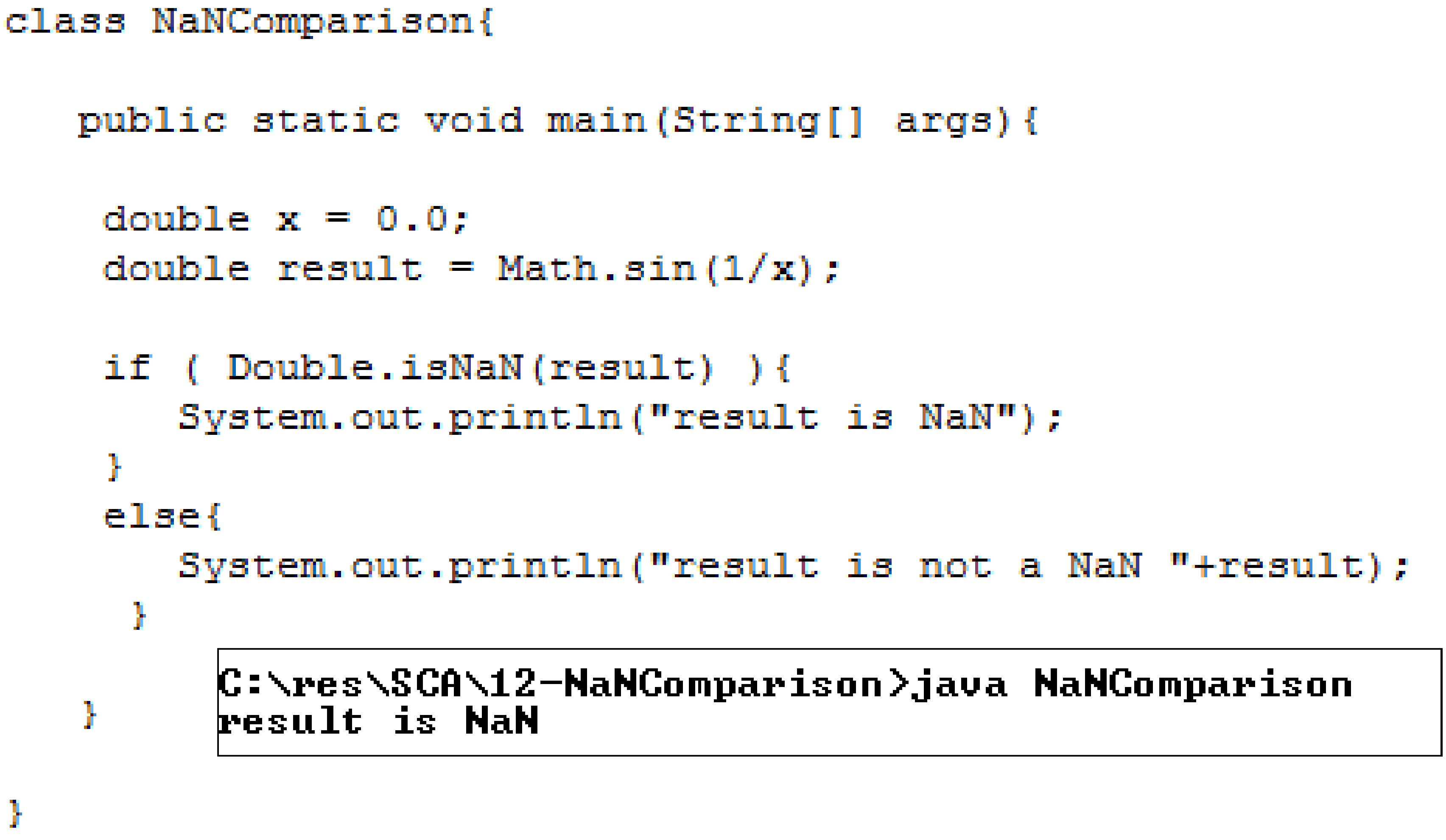
- Use of the numerical comparison operators (<, <=, >, >=, ==) with NaN (not a number) returns false, if either or both operands are NaN.
- Use of the inequality operator (!=) returns true, if either operand is NaN.



```
class NaNComparison{

   public static void main(String[] args){

    double x = 0.0;
    double result = Math.sin(1/x);

    if ( result == Double.NaN ){
       System.out.println("result is NaN");
    }
    else{
       System.out.println("result is not a NaN");
     }
   }

}
```

```
C:\res\SCA\12-NaNComparison>java NaNComparison
result is not a NaN
```

Solution: Use the Double.isNaN(double) Method

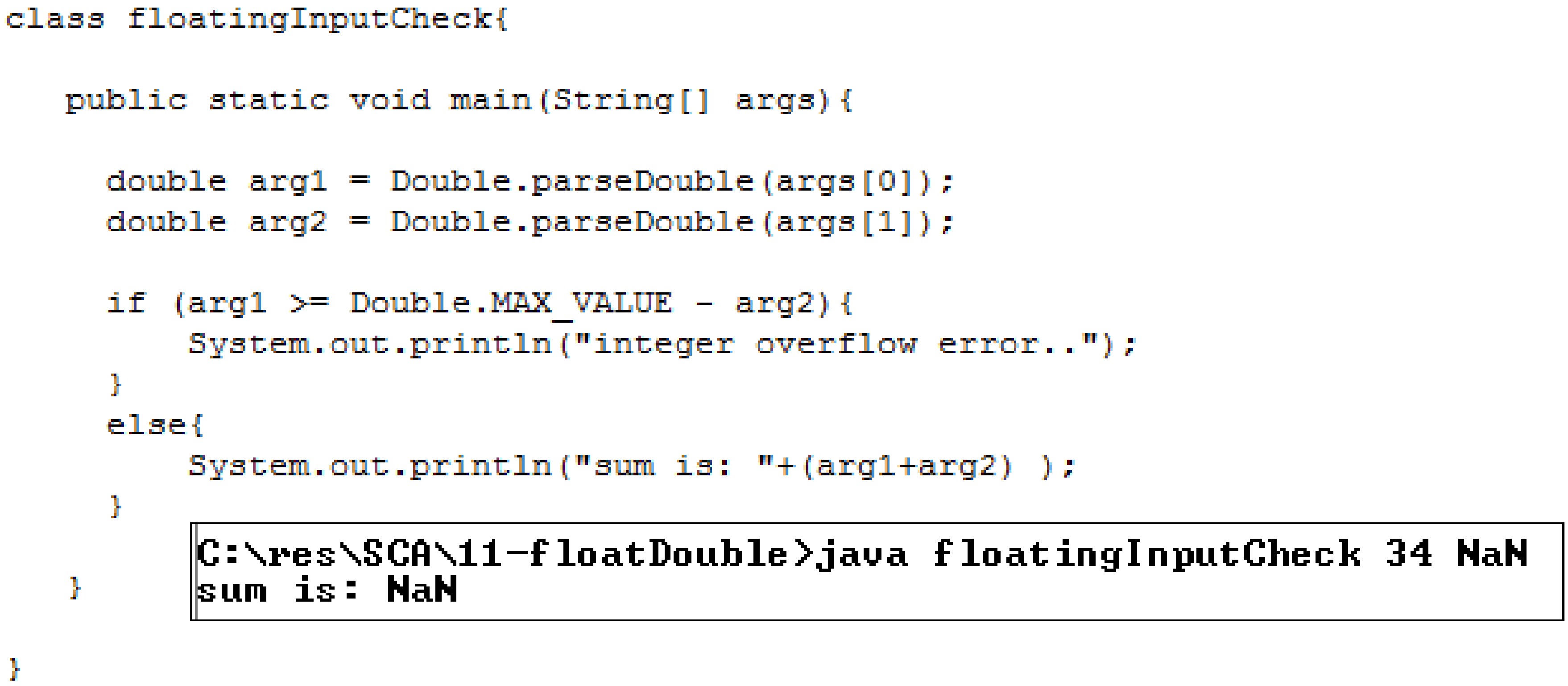


```
class NaNComparison{

   public static void main(String[] args){

    double x = 0.0;
    double result = Math.sin(1/x);

    if ( Double.isNaN(result) ){
       System.out.println("result is NaN");
    }
    else{
       System.out.println("result is not a NaN "+result);
     }

   }

}
```

```
C:\res\SCA\12-NaNComparison>java NaNComparison
result is NaN
```

Standard 4: Check Floating Point Inputs for Exceptional Values

- Floating-point numbers can take on three exceptional values: infinity, -infinity, and NaN (not-a-number). These values are produced as a result of exceptional or otherwise unresolvable floating-point operations, such as division by zero, or can be input by the user.

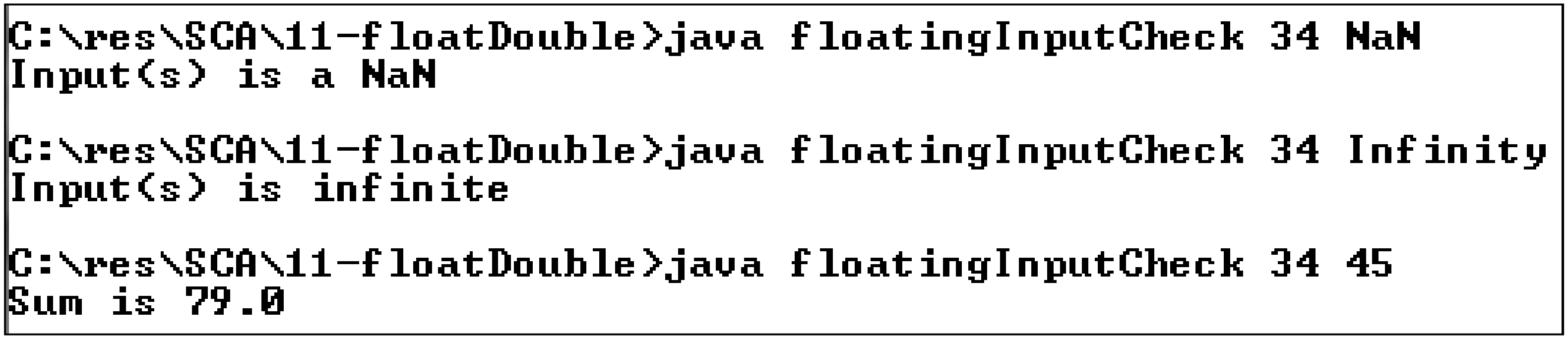


```
class floatingInputCheck{

   public static void main(String[] args){

     double arg1 = Double.parseDouble(args[0]);
     double arg2 = Double.parseDouble(args[1]);

     if (arg1 >= Double.MAX_VALUE - arg2){
         System.out.println("integer overflow error..");
     }
     else{
         System.out.println("sum is: "+(arg1+arg2) );
     }
   }

}
```

```
C:\res\SCA\11-floatDouble>java floatingInputCheck 34 NaN
sum is: NaN
```

Solution: Check Values before Use

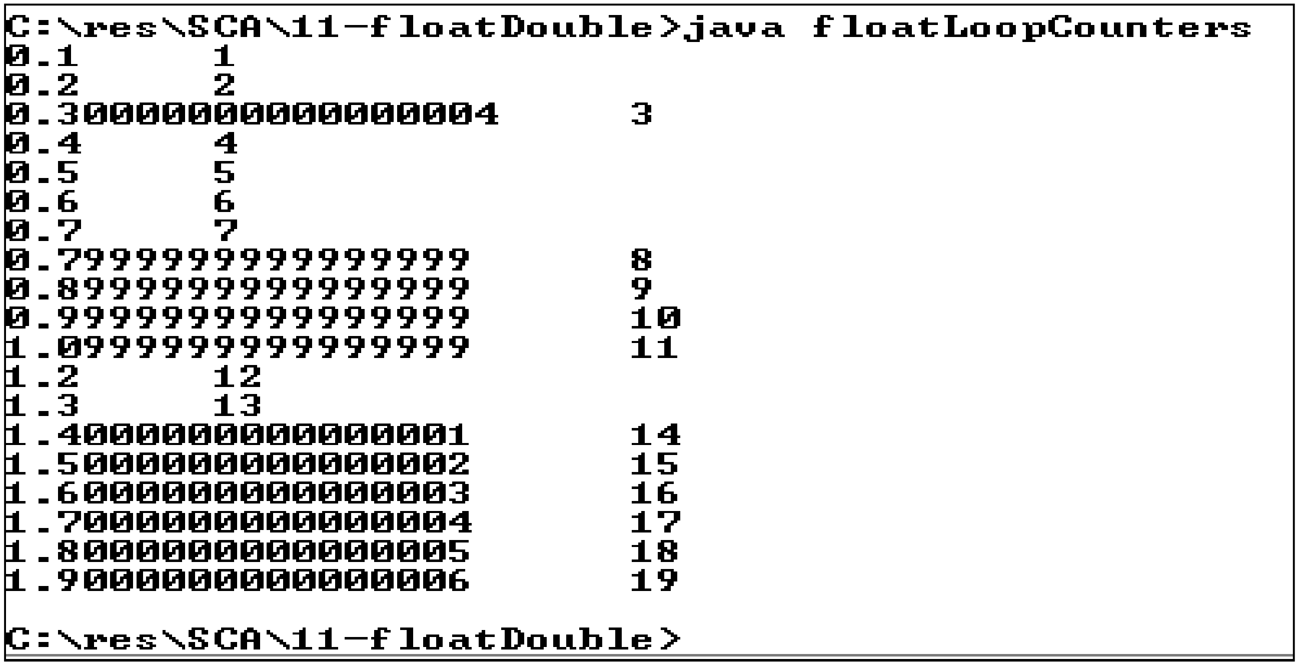
```
class floatingInputCheck{

   public static void main(String[] args){

     double arg1 = Double.parseDouble(args[0]);
     double arg2 = Double.parseDouble(args[1]);

     if (Double.isNaN(arg1) || Double.isNaN(arg2) ){
         System.out.println("Input(s) is a NaN");
         return;
     }

     if (Double.isInfinite(arg1) || Double.isInfinite(arg2) ){
         System.out.println("Input(s) is infinite");
         return;
     }

     if (arg1 >= Double.MAX_VALUE - arg2){
         System.out.println("integer overflow error..");
         return;
     }

     System.out.println("Sum is "+(arg1+arg2) );
   }
}
```



```
C:\res\SCA\11-floatDouble>java floatingInputCheck 34 NaN
Input(s) is a NaN

C:\res\SCA\11-floatDouble>java floatingInputCheck 34 Infinity
Input(s) is infinite

C:\res\SCA\11-floatDouble>java floatingInputCheck 34 45
Sum is 79.0
```

Standard 5: Do not use Floating Point Values as Loop Counters

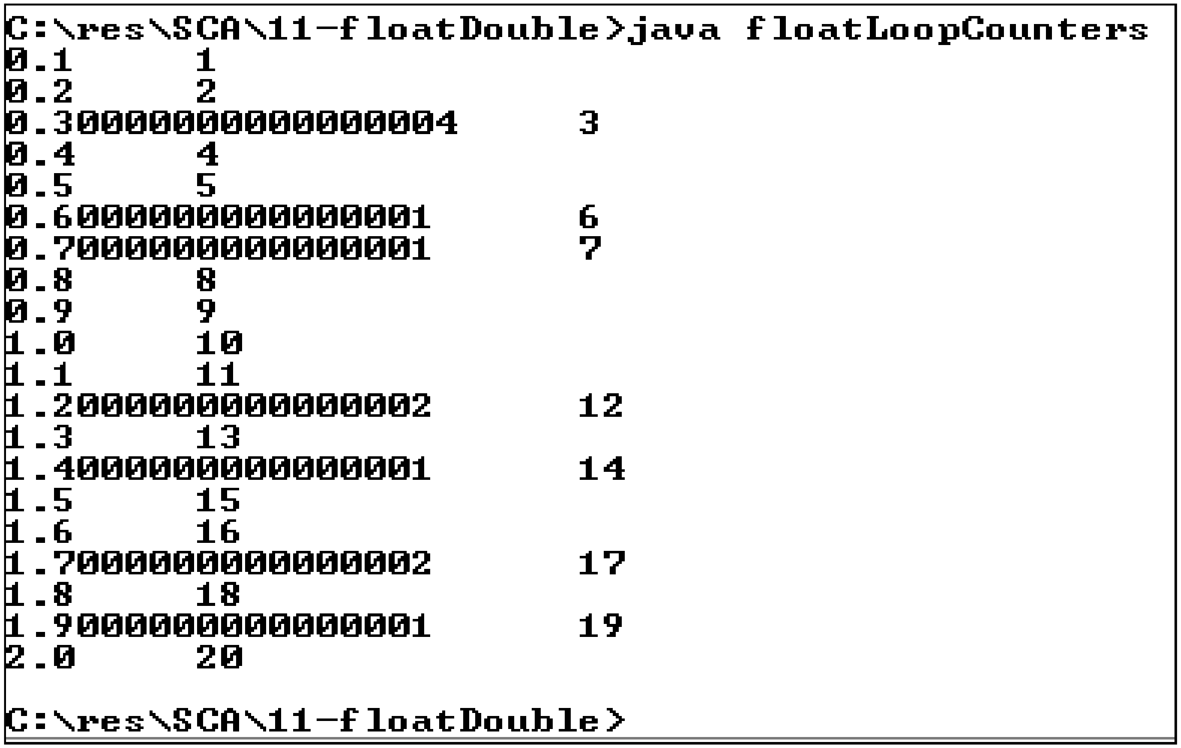
```
class floatLoopCounters{

    public static void main(String[] args){

        int counter = 1;

        for (double i = 0.1; i <= 2.0; i += 0.1){
            System.out.println(i+"\t"+counter);
            counter++;
        }

    }

}
```



```
C:\res\SCA\11-floatDouble>java floatLoopCounters
0.1     1
0.2     2
0.30000000000000004     3
0.4     4
0.5     5
0.6     6
0.7     7
0.7999999999999999      8
0.8999999999999999      9
0.9999999999999999      10
1.0999999999999999      11
1.2     12
1.3     13
1.4000000000000001      14
1.5000000000000002      15
1.6000000000000003      16
1.7000000000000004      17
1.8000000000000005      18
1.9000000000000006      19

C:\res\SCA\11-floatDouble>
```

Solution: Use Integer Loop Counter

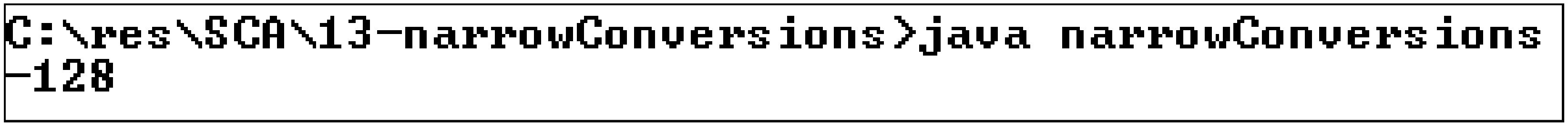
```
class floatLoopCounters{

    public static void main(String[] args){

        for (int counter = 1; counter <= 20; counter++){
            System.out.println((counter*0.1)+"\t"+counter);
        }

    }

}
```



```
C:\res\SCA\11-floatDouble>java floatLoopCounters
0.1     1
0.2     2
0.30000000000000004     3
0.4     4
0.5     5
0.6000000000000001      6
0.7000000000000001      7
0.8     8
0.9     9
1.0     10
1.1     11
1.2000000000000002      12
1.3     13
1.4000000000000001      14
1.5     15
1.6     16
1.7000000000000002      17
1.8     18
1.9000000000000001      19
2.0     20

C:\res\SCA\11-floatDouble>
```

Standard 6: Conversions of Numeric Types to Narrower Types should not result in Lost or Misinterpreted Data

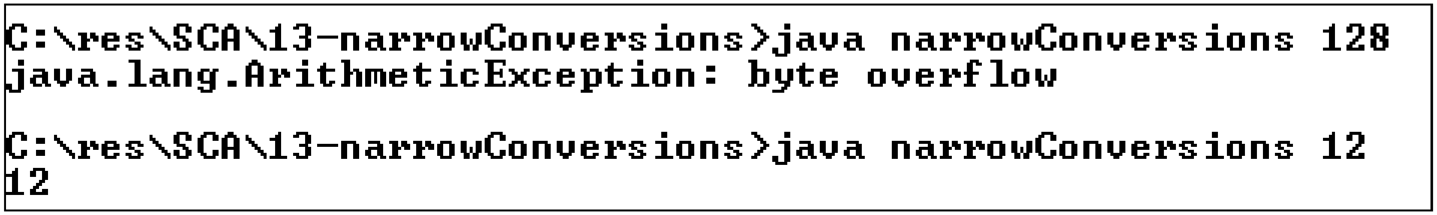
```
class narrowConversions{

   public static byte castByte(int x){
      return (byte) x;
   }

   public static void main(String[] args){

     int x = 128;
     byte b_x = castByte(x);
     System.out.println(b_x);
   }
}
```



```
C:\res\SCA\13-narrowConversions>java narrowConversions
-128
```

Solution: Range Check the Values before Conversion

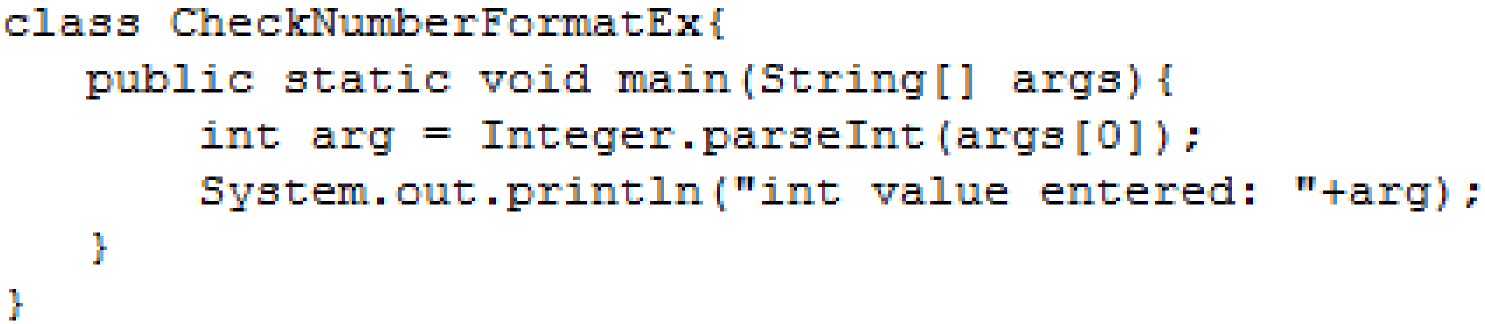
```
class narrowConversions{

   public static byte castByte(int x) throws ArithmeticException{
      if (x > Byte.MAX_VALUE || x < Byte.MIN_VALUE)
         throw new ArithmeticException("byte overflow");

      return (byte) x;
   }

   public static void main(String[] args){

     int x = Integer.parseInt(args[0]);

     try{
       byte b_x = castByte(x);
       System.out.println(b_x);
     }
     catch(ArithmeticException ae){
        System.out.println(ae);
     }

   }

}
```



```
C:\res\SCA\13-narrowConversions>java narrowConversions 128
java.lang.ArithmeticException: byte overflow

C:\res\SCA\13-narrowConversions>java narrowConversions 12
12
```

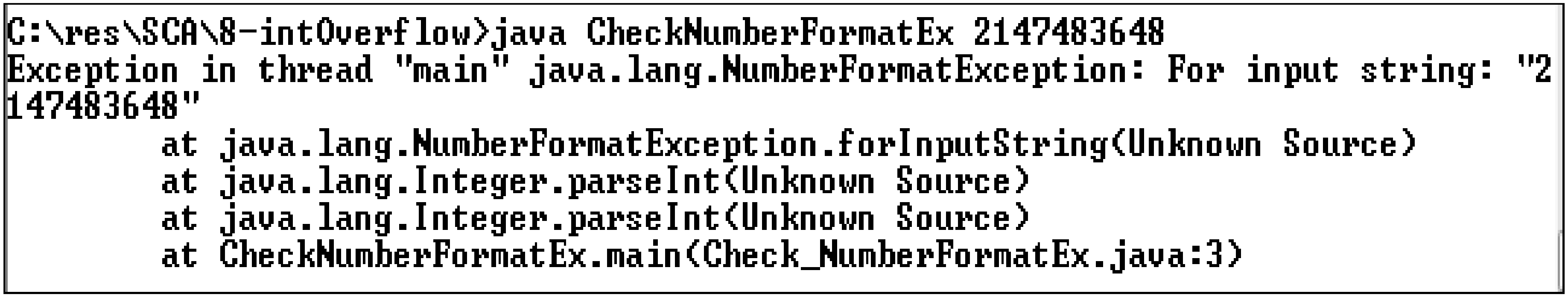
Issue 1: Handling Number Format Exception

Vulnerable Program



```
class CheckNumberFormatEx{
   public static void main(String[] args){
        int arg = Integer.parseInt(args[0]);
        System.out.println("int value entered: "+arg);
   }
}
```

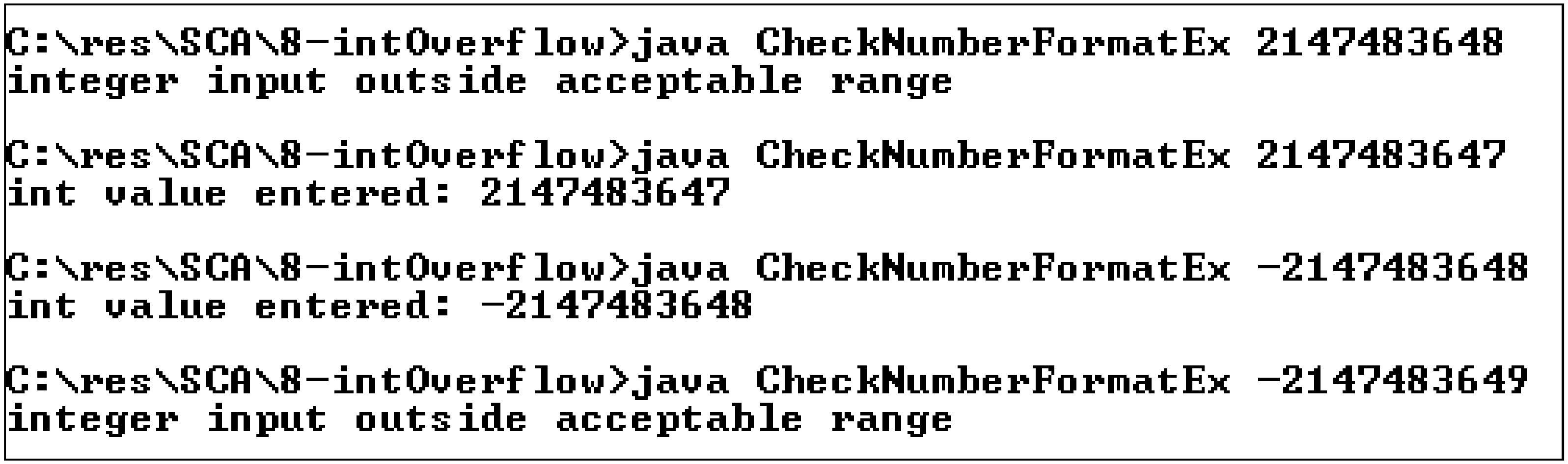
Note: Acceptable range of 32-bit integers (considering 2’s complement)
-2147483648 to 2147483647



```
C:\res\SCA\8-intOverflow>java CheckNumberFormatEx 2147483648
Exception in thread "main" java.lang.NumberFormatException: For input string: "2
147483648"
        at java.lang.NumberFormatException.forInputString(Unknown Source)
        at java.lang.Integer.parseInt(Unknown Source)
        at java.lang.Integer.parseInt(Unknown Source)
        at CheckNumberFormatEx.main(Check_NumberFormatEx.java:3)
```

Code to Handle Number Format Exception

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

     try{
       int arg = Integer.parseInt(args[0]);
       System.out.println("int value entered: "+arg);
      }
     catch(NumberFormatException nfe){
       System.out.println("integer input outside acceptable range");
     }

   }
}
```



```
C:\res\SCA\8-intOverflow>java CheckNumberFormatEx 2147483648
integer input outside acceptable range

C:\res\SCA\8-intOverflow>java CheckNumberFormatEx 2147483647
int value entered: 2147483647

C:\res\SCA\8-intOverflow>java CheckNumberFormatEx -2147483648
int value entered: -2147483648

C:\res\SCA\8-intOverflow>java CheckNumberFormatEx -2147483649
integer input outside acceptable range
```