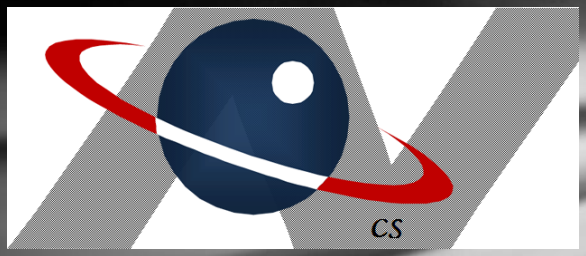
O(N) CS LESSONS

Lesson 2A – Intro to Data Types, Variables and Constants – Identifier Creation Rules, Range and Precision Limits



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Objectives

- The student will understand the basics of standard data types, and how to create, initialize, declare, assign and output variables and constants.
- The student will also gain an in-depth understanding of the numerical representations and limits of integers and decimals.

DATA TYPES AND EXPRESSIONS

- In the previous lesson group, the three most commonly used types of data were introduced:
- Strings
- Integers
- Decimals

Primitive data types – int and double

- The official JAVA data type designation for an integer is *int,* and for a decimal value, *double*.
- These are called *primitive* data types, because they are *simple*.
- There is a bit more to it than that, but for now this explanation will suffice.

Object data type - String

- A String is not a primitive because it is not simple, but more complex.
- Instead it is called an object.
- Again, later on we'll go into more detail regarding the distinction between primitives and objects.

Other primitives - boolean and char

- The two other commonly used primitive data types are boolean and char.
- The boolean data type represents *true/false* values, which are used quite a bit in logic processing, as you will soon see.

Other primitives - boolean and char

- char is short for character (rhymes with "car"), and can be any single character you find on the keyboard, plus a few more as you will see later on.
- A complete listing of all Java primitives is on the next page.

All eight primitive data types

Integer types:

byte, char, short, int, long

Decimal types:

float, double

Boolean type:

boolean

As your programming grows in sophistication, you will explore these other types, but for now we'll stick with int, double, char and boolean.

Data expressions – int, double

Each type of data is expressed in its own way.

- int values are expressed as whole numbers like `7` or `-83`.
- double values are expressed as decimals like `5.95` or `-12.0`

Data expressions – String, char

- String values are always enclosed within double quotes, like "Hello World" , "A" , or even "", the empty string.
- char values are always enclosed within single quotes, like `'A'` , `'7'` , or `'$'` .

'A' is NOT "A"

- Note that 'A' is NOT the same as "A". The first is a char (inside single quotes), and the other a String (inside double quotes).
- The more significant difference is in how they are stored in the computer's memory (more on that later).

Data expressions – char, boolean

- A char is never empty! It must always contain a single character.
- A *blank space* is a character and can be contained in a char variable…' '.
- boolean values are simply the two words true and false; they are NOT enclosed in quotes, and they are NOT Strings.

VARIABLES and CONSTANTS

Let's talk more about variables and constants:

- How to create and assign values to them
- How to output them
- What they really are
- Some limits

Outputting data expressions

In an earlier lesson, you learned how to output literal values like this:

- `System.out.println("Hello");`
- `System.out.println(45);`
- `System.out.println(3.14);`
- `System.out.println('A');`
- `System.out.println(true);`

Initializing variables

You also got a brief glimpse into the world of variables, where data literals can be stored in memory, and then used in output statements. Here are some examples:

- `String name = "John Owen";`
- `int age = 55;`
- `double wage = 54.65;`
- `char initial = 'B';`
- `boolean sailor = true;`

Initializing variables

There are five parts to a variable initialization statement:

- The data type
- The ***identifier***
- The "=" sign (called the ***assignment operator***)
- The actual value
- A semi-colon to mark the end of the statement.


```
String name = "John Owen";
```

Separate declare and assign

It is also possible to separately declare and then assign variables.

The five parts are still there, but you must restate the identifier in the second part.

- `String name;`
- `name = "John Owen";`

Separate declare and assign

You can actually do this with a constant when you first create one, but once assigned the first time, it cannot be changed later *(more about constants later in this lesson)*.

The word "final" at the front is what makes it a constant.

- `final String name;`
- `name = "John Owen";`

Outputting variables

Here is how you would output the variables:

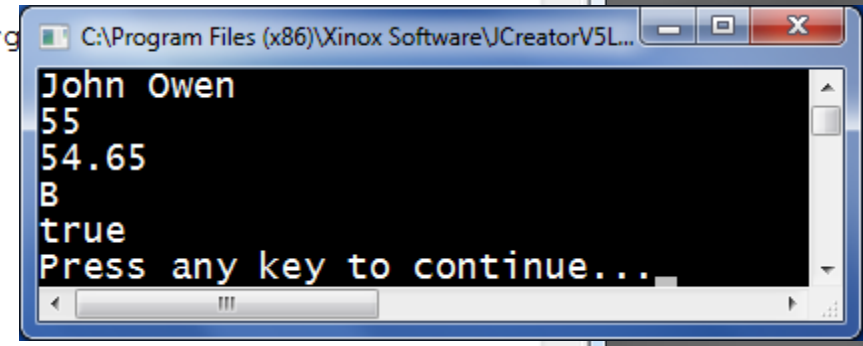
- `System.out.println(name);`
- `System.out.println(age);`
- `System.out.println(wage);`
- `System.out.println(initial);`
- `System.out.println(sailor);`

Variable assignment and output

This program demonstrates how to ***initialize*** (declare and give beginning values to) and output variables.

output.java

```
1  public class output
2  {
3    public static void main (String [] arg
4    {
5      String name = "John Owen";
6      int age = 55;
7      double wage = 54.65;
8      char initial = 'B';
9      boolean sailor = true;
10     System.out.println(name);
11     System.out.println(age);
12     System.out.println(wage);
13     System.out.println(initial);
14     System.out.println(sailor);
15   }
16 }
17
```



Variables are memory locations

Variables are simply *locations in the computer's RAM*, or memory.

When you declare a variable, like

```
int age = 55;
```

the JAVA compiler finds some available memory, carves out enough room for an int value, marks that memory location with the ***identifier*** (variable name) `age`, and places the value `55` into that memory location.

Primitives vs objects

```
int age = 55;
```

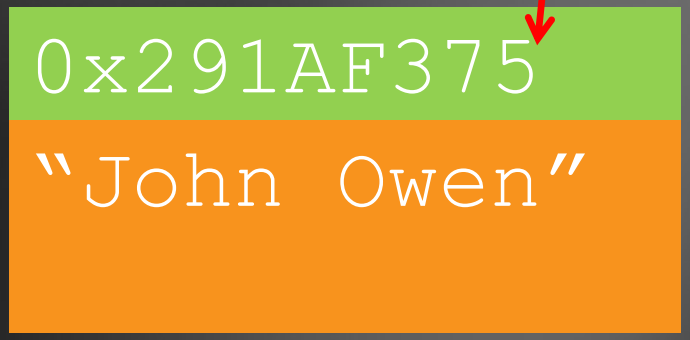
- The main reason this is called a ***primitive*** is that the memory location actually contains the value.
- Objects are stored in a different way than primitives…see next slide.

Object storage

This String object is not stored like a primitive.

The memory location indicated by the variable does not contain the String itself, but instead a ***reference*** to another memory location, which DOES contain the String. This may seem redundant, but later on you will see a reason for it more clearly.

```
String name =
"John Owen";
```



Memory Locations…

Other primitive types work the same way as an int, in that the memory location actually stores the data value.

Each type of data requires different amounts of memory to store…more on that later in this lesson.

- `double wage = 54.65;`
- `char initial = 'B';`
- `boolean sailor = true;`

Constants

Constants work just like variables, in that they store values in memory.

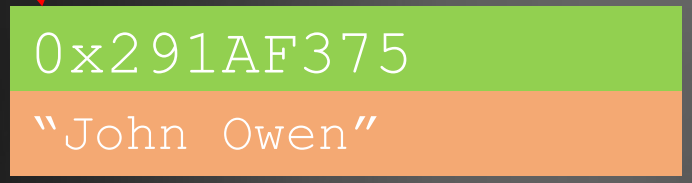
- `final String NAME = "John Owen";`
- `final double WAGE = 54.65;`
- `final char INITIAL = 'B';`
- `final boolean SAILOR = true;`

Constants

The difference is that once they are given a beginning value in the execution of a program, they CANNOT BE CHANGED!

- `final String NAME = "John Owen";`
- `final double WAGE;`
- `WAGE = 54.65;`
- `final char INITIAL = 'B';`
- `final boolean married = true;`

Notice the separate "declare" and "assign" parts for this constant. This is legal the first time it receives a value, but you can't change it later in the program.



Rules for creating JAVA identifiers

Before we proceed to a discussion of memory requirements, let's discuss some basic rules for creating ***identifiers***.

`Identifiers` are simply words YOU create as a programmer to represent variables, constants, methods and class names.

Rules for creating JAVA identifiers

Identifiers can be created for just about anything you need in programming, but there are certain restrictions on how to do this.

The main restriction is that Java reserved words, what I call ***"magic words"***, CANNOT be used as identifiers, for obvious reasons…

Rules for creating JAVA identifiers

…the compiler would not consider the reserved word as an identifier, but would instead try to use it as a command, get very confused, and throw a "fit" (a compile error).

Now, let's move on to what you CAN do to create identifiers…

Rules for creating JAVA identifiers

1. Always use descriptive names for identifiers. If you are creating a variable to store total pay, then name it something like
   - double totalPay;
2. Avoid non-descriptive single letter identifiers, like *double a;* or *int x;* (for utility purposes, such as loop control, these are generally OK to use…more on this later)
3. Always start with a letter or an underscore, never a digit.

Rules for creating JAVA identifiers

4. Use only letters, digits, and the underscore character…no symbols allowed!
5. Do not use spaces, but instead use the underscore if you want separation between words.

Valid and invalid examples

Can you tell which of these are valid identifiers?

- `name`
- `My name`
- `_address`
- `$amount`
- `num1`
- `1st_num`

Valid and invalid examples

Answers

- `name` OK
- `My name` not OK…has a space
- `_address` OK
- `$amount` not OK…has a symbol
- `num1` OK
- `1st_num` not OK…starts with digit

Agreements or "conventions"

- There are several agreements or "conventions" in programming related to creating identifiers which, although not required, are strongly suggested.
- *Some software development companies DO require these conventions, perhaps others, and strongly enforce them, or you could get fired!*
- We will follow these conventions, shown on the next few slides.

Agreements or "conventions"

- **Multiple word** identifiers will lowercase the first word and capitalize all remaining words, or put underscore characters between words
- Examples: myName, hourlyWage, startTime, my_street_address

Agreements or "conventions"

- Variable and method identifiers will always begin with lowercase letters, like sum or getName.
- Constant identifiers will always be in all CAPS, like PI and MAX_VALUE.
- Class identifiers will always be capitalized….the String and System classes are two you have already seen.

Agreements or "conventions"

- **Multiple word** constant names will capitalize everything and separate words with the underscore character
- Examples: MY_WAGE, ZIP_CODE, COMPANY_NAME

Examples of multi-word variables and constants

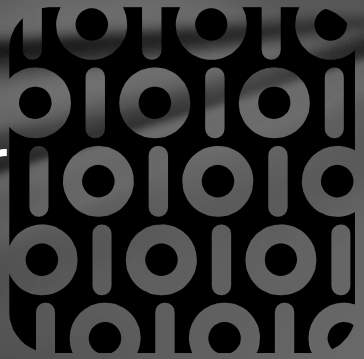
```
number1
streetAddress
hourlyWage
surface_area
PI
NICKEL_VALUE
E
MAX_VALUE
```

MEMORY STORAGE

And now it is time to talk about the various memory requirements and limits of the different data types, specifically integers and decimals.

Bit – binary digit

One bit, or ***b***inary dig***it***, of memory is the smallest unit of memory in a computer. It is an electronic signal, either around 5 volts in strength, or virtually zero volts.



Typically a bit is represented as a **1** (5 volt signal) or a **0**, also sometimes represented as on/off, or true/false.

Binary system, boolean logic

These two values, `1` and `0`, (`true` and `false`) are the foundation of the ***binary number system*** and the ***Boolean logic*** field of mathematics, on which all of computing and logical processing is based.

We'll explore the binary numbers and Boolean logic systems in much greater depth later on.

Bits, bytes, etc.

- Memory consists of bits, bytes, kilobytes(KB), megabytes(MB), gigabytes(GB), terabytes(TB), petabytes(PB), exabytes(EB), zettabytes(ZB), yottabytes(YB), etc….
- Bits are typically grouped in series of 8 bits called bytes.

Bits, bytes, etc.

- An int variable requires 32 bits, or 4 bytes of memory to store it.
- On the next page you will see all the *integer family* of primitive data types along with the memory requirements and range limits for each.

Memory and range limits – integer family of data types

DATA TYPE	MEMORY SIZE	RANGE LIMITS	MAXIMUM VALUE EXPRESSION
byte	8 bits	-128…127	2^7-1
short	16 bits	-32768…32767	2^15-1
char	16 bits	0…65535	2^16-1
int	32 bits	-2147483648 …2147483647 (approx 2 billion)	2^31-1
long	64 bits	-9223372036854775808 … 9223372036854775807 (approx 9 quintillion)	2^63-1

Although the char data type is technically an integer data type, has minimum and maximum values, and is truly stored as an integer value, it represents characters and is output as letters, digits, and numerous other symbols in the ***Unicode system***, which we'll explore later on.

MIN_VALUE
MAX_VALUE

Each data type has its maximum and minimum values stored in special constant memory locations called MIN_VALUE and MAX_VALUE. Below is how you can output those values.

JCreator

File Edit View Project Build Run Tools Configure

limits.java * | Calendar.html

```
1  public class limits
2  {
3    public static void main (String [] args)
4    {
5      System.out.println(Byte.MIN_VALUE);
6      System.out.println(Byte.MAX_VALUE);
7      System.out.println(Short.MIN_VALUE);
8      System.out.println(Short.MAX_VALUE);
9      System.out.println(Integer.MIN_VALUE);
10     System.out.println(Integer.MAX_VALUE);
11     System.out.println(Long.MIN_VALUE);
12     System.out.println(Long.MAX_VALUE);
13   }
14 }
```

```
-128
127
-32768
32767
-2147483648
2147483647
-9223372036854775808
9223372036854775807
Press any key to continu
```

General Output | Task View | Build Output

For Help, press F1 Ln 14 Col 2 Char 2 OVR NU

MIN_VALUE
MAX_VALUE

These values can also be stored in variables and output using the ***%d*** format specifier of the ***printf*** output command, as we discussed in Lesson 1.

JCreator

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limits.java | Calendar.html

```
1  public class limits
2  {
3    public static void main (String [] args)
4    {
5      byte b = Byte.MIN_VALUE;     System.out.printf("%+28d\n",b);
6      b = Byte.MAX_VALUE;          System.out.printf("%+28d\n",b);
7      short s = Short.MIN_VALUE;   System.out.printf("%+,28d\n",s);
8      s = Short.MAX_VALUE;         System.out.printf("%+,28d\n",s);
9      int i = Integer.MIN_VALUE;   System.out.printf("%+,28d\n",i);
10     i = Integer.MAX_VALUE;       System.out.printf("%+,28d\n",i);
11     long l = Long.MIN_VALUE;     System.out.printf("%,+28d\n",l);
12     l = Long.MAX_VALUE;          System.out.printf("%,+28d\n",l);
13
14   }
15 }
```

General Output | Task View | Build Output

For Help, press F1

OVR Read CAP NUM

```
                        -128
                        +127
                     -32,768
                     +32,767
                -2,147,483,648
                +2,147,483,647
  -9,223,372,036,854,775,808
  +9,223,372,036,854,775,807
Press any key to continue...
```

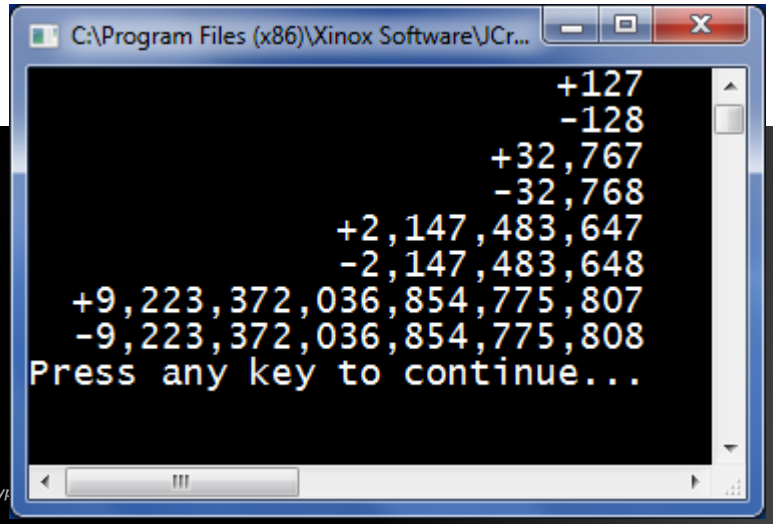
Out of bounds?

Now look carefully at this code.

After each variable is ***initialized*** (declared and assigned a beginning value), it is either decreased by 1 (b--), or increased by 1 (b++), seemingly causing it to "step out of bounds", beyond it's normal range limit.

However, observe what really happens!!!

```
public class limits
{
  public static void main (
  {
    byte b = Byte.MIN_VALUE;     b--;System.out.printf("%+28d\n",b);
    b = Byte.MAX_VALUE;          b++;System.out.printf("%+28d\n",b);
    short s = Short.MIN_VALUE;   s--;System.out.printf("%+,28d\n",s);
    s = Short.MAX_VALUE;         s++;System.out.printf("%+,28d\n",s);
    int i = Integer.MIN_VALUE;   i--;System.out.printf("%+,28d\n",i);
    i = Integer.MAX_VALUE;       i++;System.out.printf("%+,28d\n",i);
    long l = Long.MIN_VALUE;     l--;System.out.printf("%,+28d\n",l);
    l = Long.MAX_VALUE;          l++;System.out.printf("%,+28d\n",l);
  }
}
```



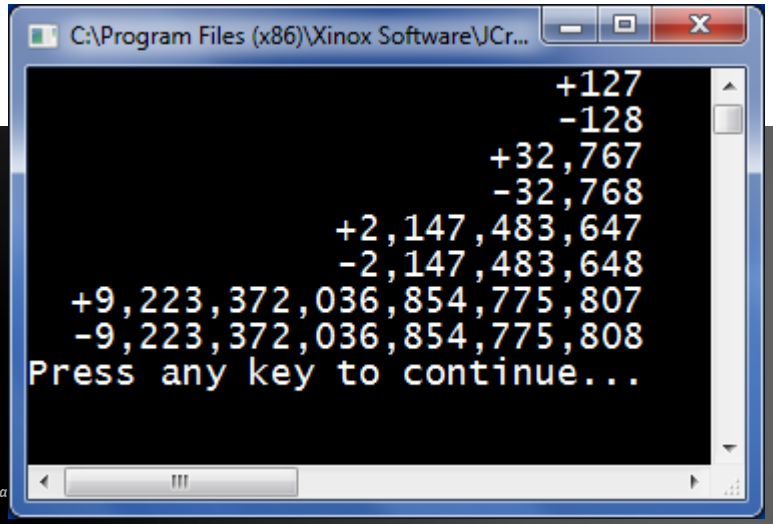
Wrap around!

In the first line, b is assigned `-128`, the minimum value for a byte. It is then decreased by `1`, which seems like it should be the value `-129`. However, since that is "out of range" for a byte, the compiler "wraps around" to the other side of the range and assigns it the maximum value instead!!!

The same is true for all of the other examples.

```
public class limits
{
  public static void main
  {
    byte b = Byte.MIN_VALUE;     b--;System.out.printf("%+28d\n",b);
    b = Byte.MAX_VALUE;          b++;System.out.printf("%+28d\n",b);
    short s = Short.MIN_VALUE;   s--;System.out.printf("%+,28d\n",s);
    s = Short.MAX_VALUE;         s++;System.out.printf("%+,28d\n",s);
    int i = Integer.MIN_VALUE;   i--;System.out.printf("%+,28d\n",i);
    i = Integer.MAX_VALUE;       i++;System.out.printf("%+,28d\n",i);
    long l = Long.MIN_VALUE      l--;System.out.printf("%,+28d\n",l);
    l = Long.MAX_VALUE;          l++;System.out.printf("%,+28d\n",l);
  }
}
```

THIS IS CRAZY!!!

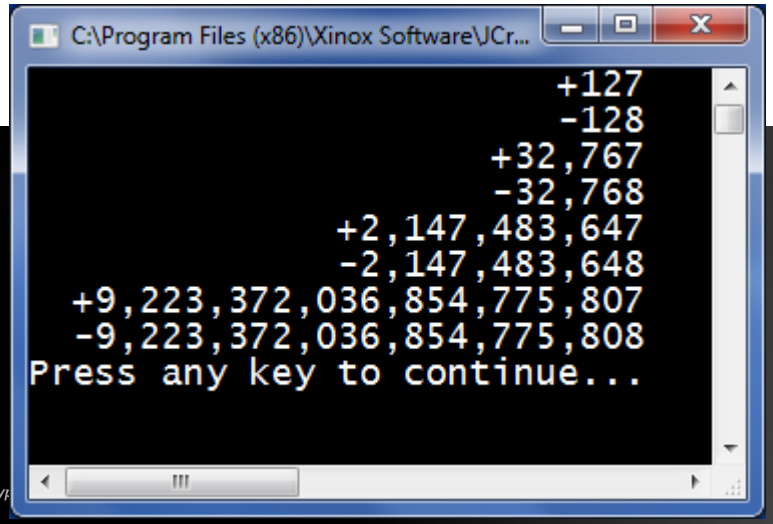


Wrap around!

The same phenomenon occurs in all of the other lines.

Study them carefully to fully understand what is happening.

```
public class limits
{
  public static void main (String [] args)
  {
    byte b = Byte.MIN_VALUE;     b--;System.out.printf("%+28d\n",b);
    b = Byte.MAX_VALUE;          b++;System.out.printf("%+28d\n",b);
    short s = Short.MIN_VALUE;   s--;System.out.printf("%+,28d\n",s);
    s = Short.MAX_VALUE;         s++;System.out.printf("%+,28d\n",s);
    int i = Integer.MIN_VALUE;   i--;System.out.printf("%+,28d\n",i);
    i = Integer.MAX_VALUE;       i++;System.out.printf("%+,28d\n",i);
    long l = Long.MIN_VALUE;     l--;System.out.printf("%,+28d\n",l);
    l = Long.MAX_VALUE;          l++;System.out.printf("%,+28d\n",l);
  }
}
```

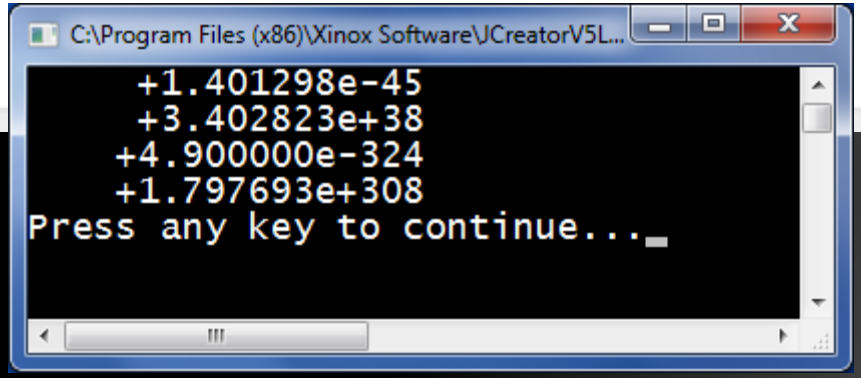


Decimal max and min

The decimal data types also have maximum and minimum values as you can see below, but the ***precision*** of the values they can hold is more significant in programming, rather than the max or min values.

```
public class limits
{
  public static void main (String [] args)
  {
    float f = Float.MIN_VALUE;        System.out.printf("%+18e\n",f);
    f = Float.MAX_VALUE;              System.out.printf("%+18e\n",f);
    double d = Double.MIN_VALUE;      System.out.printf("%+18e\n",d);
    d = Double.MAX_VALUE;             System.out.printf("%+18e\n",d);

  }
}
```



Decimal precision

Below you can see the limits of the decimal data types.

The most significant item and the easiest to observe is the number of decimal places of precision.

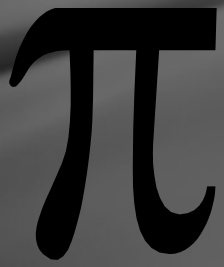
On the next few slides, a brief case study is shown to take a closer look at this.

DATA TYPE	MEMORY SIZE	MAX AND MIN +1.401298e-45 +3.402823e+38 +4.900000e-324 +1.797693e+308	PRECISION LIMITS IN BITS	PRECISION LIMITS IN DECIMAL PLACES
float	32 bits		23 bits	**7 places**
double	64 bits		52 bits	**15 places**

Decimal precision – a brief case study

Let's take a quick look at the two most famous irrational and transcendental numbers in mathematics – PI and E.

PI is the ratio of a circle's circumference to its diameter – `3.1415...`



E is the approximate base of the natural logarithms – `2.71828...`

Math.PI and Math.E

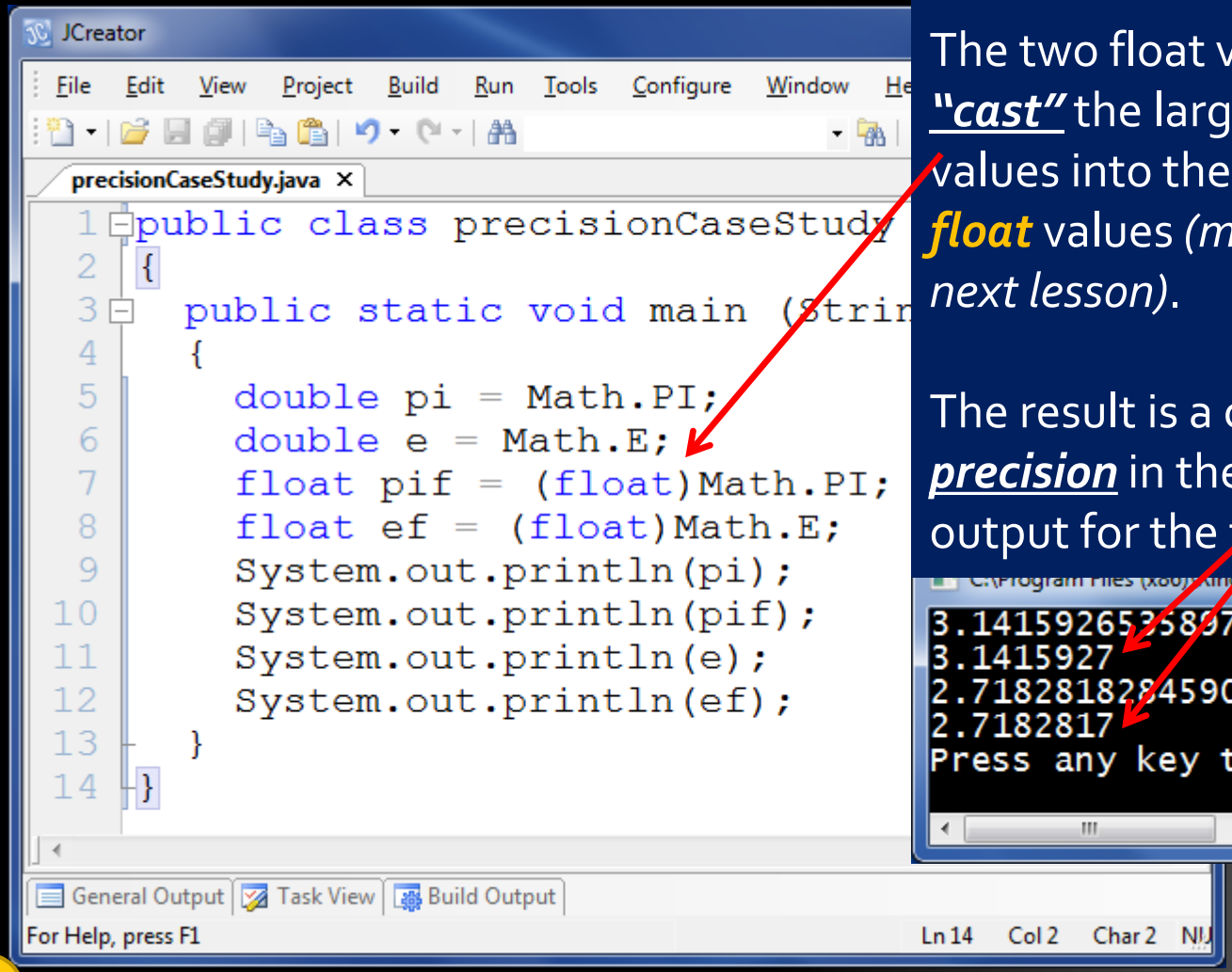
The JAVA Math class defines the two values, PI and E, as constants.

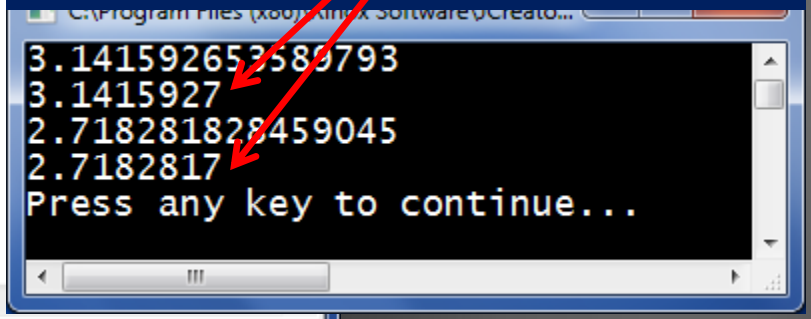
As you can see, each one is a double, and each is defined up to 15 places of precision.

static double	E The double value that is closer than any other to *e*, the base of the natural logarithms.
static double	PI The double value that is closer than any other to *pi*, the ratio of the circumference of a circle to its diameter.

java.lang.Math		
public static final double	E	2.71828182845904 5
public static final double	PI	3.14159265358979 3

Math.PI and Math.E





The two double variables receive the constant values of PI and E from the Math class.

The two float variables must ***"cast"*** the larger memory ***double*** values into the smaller memory ***float*** values *(more on casting in the next lesson)*.

The result is a clear ***loss of precision*** in the storage and output for the float values.

Lesson Summary

- This lesson introduced the basics of standard data types, and how to create, initialize, declare, assign, and output variables and constants.
- It also explored the numerical representations, ranges and limits of integers and decimals.

Lab 2A-1

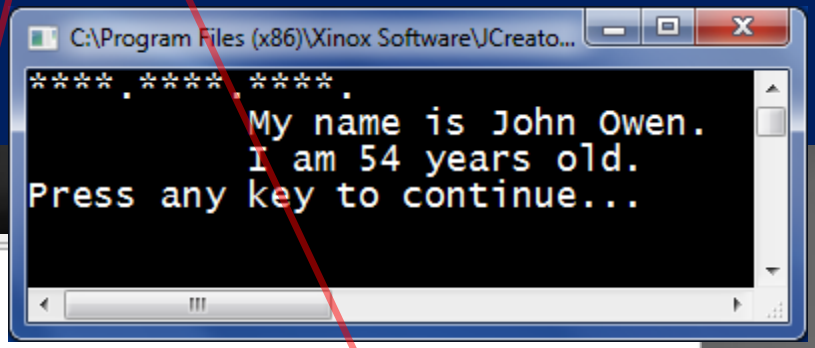
Create the following output using a constant for YOUR full name and a variable for YOUR age. Indent output 10 spaces from left margin (first character in column 11).

Study carefully the new indent technique demonstrated in the source code. This technique will be especially useful later on when flexibility is important.

Be sure to use the correct format specifier for each variable.

Hint: %s will work for an integer, but there is a better one to use.

"%"+10+"s"
=
"%10s"




```
1  public class varConst
2  {
3     public static void main (String [] args)
4     {
5        final String name = "John Owen";
6        int age = 54;
7        System.out.println("****.****.****.");
8        System.out.printf("%"+10+"sMy name is %s.\n","",name);
9        //output statement for age goes here
0     }
1  }
```

2A-2 - Receipt Lab - Revisited

- Repeat this lab from Lesson 1D, but this time use variables instead.
- Initialize each value to be used BEFORE the output statements, and then use the variables in the output, NOT the literal values.
- The partial solution for my receipt is shown on the next slide. Be sure to use your own receipt, not mine!

Lab 2A-2 Receipt Lab - Revisited

```
import java.util.*;
public class receiptLab2A2
{
  public static void main (String [] args)
  {
    Calendar cal = Calendar.getInstance();
    System.out.printf("John B. Owen - %tc\n",cal);
    System.out.println("\"Receipt\" lab");
    System.out.print("\t\tAce Hardware\n");
    System.out.println("Item\t\t\tAmount");
    String item1 = "Grass Trimmer";
    String item2 = "Gas Can";
    String item3 = "Work Gloves";
    double price1 = 84.99;
    //initialize price2
    //initialize price3
    double subtotal = price1+price2+price3;
    double tax = subtotal*.0825;
    //initialize total with sum of subtotal and tax
    System.out.printf("%-24s$%6.2f\n",item1,price1);
    //output price2
    //output price3
    //output subtotal
    //output tax
    //output total
  }
```

```
John B. Owen - Sun May 29 07:11:43
"Receipt" lab
                Ace Hardware

Item                        Amount
Grass Trimmer               $ 84.99
Gas Can                     $  5.91
Work Gloves                 $  4.99

Subtotal                    $ 95.89
Tax                         $  7.91

Total                       $103.80
Press any key to continue...
```

The output is the same, but variables are now used instead. Part of the solution source code is shown. You provide the rest.

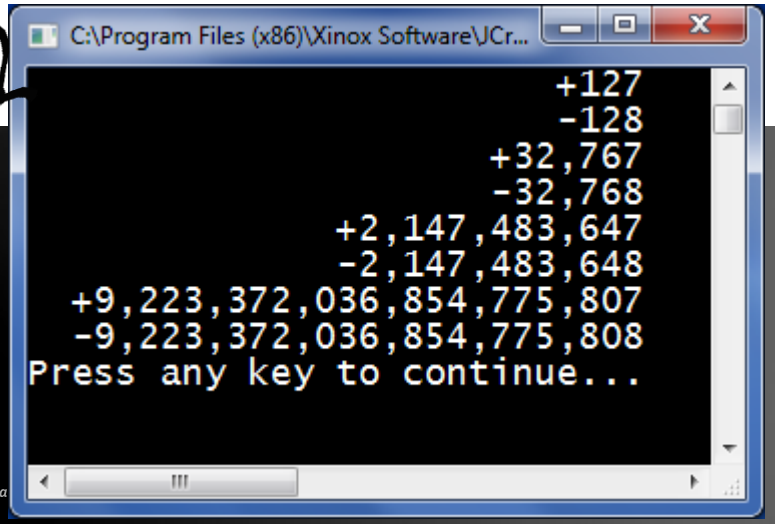
Pay close attention to the format specifier in the output statement. Three tabs have been replaced with a field width of 24, with a **negative sign** to provide left alignment. Don't forget…USE YOUR OWN RECEIPT!!!

Lab 2A-3

Type in the source code for this lab, shown earlier in the lesson, exactly as you see it. Experiment with the - - and ++ statements, using more than just one to see what happens.
Show and explain to your instructor your final version of this program, with at least three "experiments" you tried.

```
public class limits
{
  public static void main (String [] args)
  {
    byte b = Byte.MIN_VALUE;     b--;System.out.printf("%+28d\n",b);
    b = Byte.MAX_VALUE;          b++;System.out.printf("%+28d\n",b);
    short s = Short.MIN_VALUE;   s--;System.out.printf("%+,28d\n",s);
    s = Short.MAX_VALUE;         s++;System.out.printf("%+,28d\n",s);
    int i = Integer.MIN_VALUE;   i--;System.out.printf("%+,28d\n",i);
    i = Integer.MAX_VALUE;       i++;System.out.printf("%+,28d\n",i);
    long l = Long.MIN_VALUE;     l--;System.out.printf("%,+28d\n",l);
    l = Long.MAX_VALUE;          l++;System.out.printf("%,+28d\n",l);
  }
}
```

Do at least three "experiments" with this madness!!!



CONGRATULATIONS!

- You now have a greater understanding of the data types used in JAVA, as well as how to create and use variables and constants.
- *It is now time to move on to Lesson 2B, which talks more about characters and Strings, math operations, and some standard Math class methods.*

Thanks, and have fun!

To order supplementary materials for all the lessons in this package, including lesson examples, lab solutions, quizzes, tests, and unit reviews, visit the O(N)CS Lessons website, or contact me at

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