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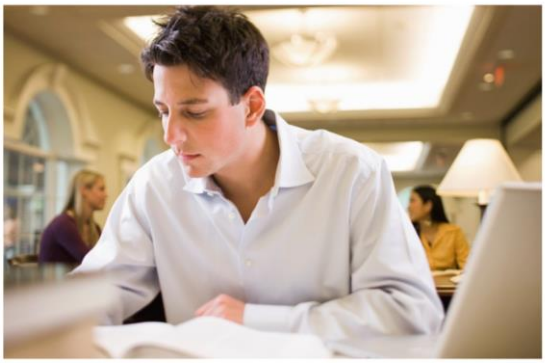
Java Fundamentals

4-3

Data Types and Operators



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Objectives

- This lesson covers the following objectives:
  - Use primitive data types in Java code
  - Specify literals for the primitive types and for Strings
  - Demonstrate how to initialize variables
  - Describe the scope rules of a method
  - Recognize when an expression requires a type conversion

Overview

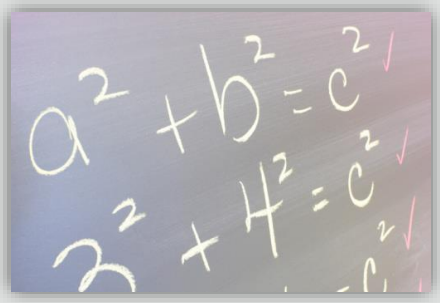
- This lesson covers the following topics:
  - Apply casting in Java code
  - Use arithmetic operators
  - Use the assignment operator
  - Use a method from the Math class
  - Access a Math class method from the Java API

Java Programming Types

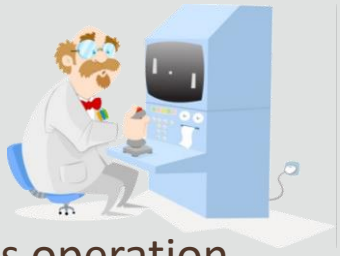
- In Java, data types:
  - Are used to define the kind of data that can be stored inside a variable
  - Ensure that only correct data is stored
  - Are either declared or inferred
  - Can be created by the programmer

Variables Must Have Data Types

- All variables must have a data type for security reasons
- The program will not compile if the user attempts to store data that is not the correct type
- Programs must adhere to type constraints to execute
  - Incorrect types in expressions or data are flagged as errors at compile time



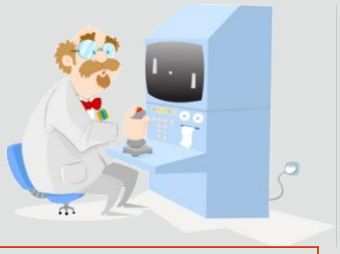
Primitive Data Types



- Java has eight primitive data types that are used to store data during a program's operation
- Primitive data types are a special group of data types that do not use the keyword new when initialized
- Java creates them as automatic variables that are not references, which are stored in memory with the name of the variable
- The most common primitive types used in this course are int (integers) and double (decimals)

The primitive types are simple and store just one value while an object is more complex and may store many values (fields).
int and double are the most common primitive types used in Java. boolean is also used extensively.

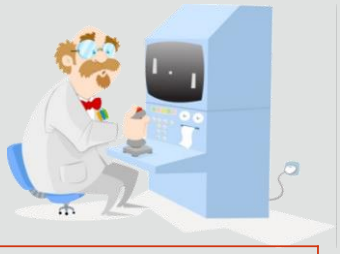
Primitive Data Types



Data Type	Size	Example Data	Data Description
boolean	1 bit	true, false	Stores true and false flags
byte	1 byte (8 bits)	12, 128	Stores integers from -128 to 127
char	2 bytes	'A', '5', '#'	Stores a 16-bit Unicode character from 0 to 65,535
short	2 bytes	6, -14, 2345	Stores integers from -32,768 to 32,767

Depending on the computer operating system that Java is being used with, the smaller data types may actually use 4 or even 8 bytes of actual memory.

Primitive Data Types



Data Type	Size	Example Data	Data Description
int	4 bytes	6, -14, 2345	Stores integers from: -2,147,483,648 to 2,147,483,647
long	8 bytes	3459111, 2	Stores integers from: -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
float	4 bytes	3.145, .077	Stores a positive or negative decimal number from: 1.4023x10-45 to 3.4028x10+38
double	8 bytes	.0000456, 3.7	Stores a positive or negative decimal number from: 4.9406x10-324 to 1.7977x10308

Declaring Variables and Using Literals

- The keyword new is not used when initializing a variable of a primitive type
- Instead, a literal value should be assigned to each variable upon initialization
- A literal can be any number, text, or other information that represents a value
- Examples of declaring a variable and assigning it a literal value:

```
boolean result = true;
char capitalC = 'C';
byte b = 100;
short s = 10000;
int i = 100000;
```

Declaring Variables and Using Literals Example

- The values of d1 and d2 are the same
- The initialization of d2 shows how scientific notation can be used to set the value
- Total and ss_num are assigned the same value
- The initialization of ss_num shows that underscores can be used to separate numbers for readability

```
long total=999999999;
long ss_num = 999_99_9999;
double d1 = 123.4;
double d2 = 1.234e2;
float f1  = 123.4f;
```


Usually Java is very case sensitive. However, you can use upper or lower case e, f, or l when working with literal values and scientific notation.

Numeric Literal Examples

- 0x and 0b are used to denote a literal hexadecimal value or a literal binary value
- Literals will improve processing performance

```
long creditCardNumber = 1234_5678_9012_3456L;
long socialSecurityNumber = 999_99_9999L;
float pi = 3.14_15F;
long hexBytes = 0xFF_EC_DE_5E;
long hexWords = 0xCAFE_BABE;
long maxLong = 0x7fff_fff_fff_ffffL;
byte nybbles = 0b0010_0101;
long bytes = 0b11010010_01101001_10010100_10010010;
```

For fun, what other Hex words (only the letters A-F), like DEAD_BEEF, can you come up with?

Binary Literals

- Binary literals can be expressed using the binary system by adding the prefixes 0b or 0B to the number
- Binary literals are Java int values
- Java byte and short values require a cast to prevent a precision loss error from the compiler

A cast signals a type conversion. If you cast one type as another type, you are explicitly converting the item from its original type to the type that you specify. A cast does not round a decimal number, but instead, will truncate it. An example of casting a double as an int is:

```
double x = 5.745;
int y = (int)x;  //y is now equal to 5
```


Note that casting from float or double to an integer type truncates the value. It does not round the value.

Purpose of Java Binary Literals

- Binary Literals are used for:
  - Calculations
  - Comparisons
  - Low-level programming, such as:
    - Writing device drivers
    - Low-level graphics
    - Communications protocol packet assembly
    - Decoding

Why Use Binary Literals?

- Using Binary Literals to represent values for comparisons and calculations is substantially faster than using values of the actual data type
- Modern high-performance processors usually perform calculations on integers as fast as using binary literals, so why use literals?
- It is still optimal to use literals for overall power and performance because they use less resources

Casting Example

```
// An 8-bit 'byte' value:
byte aByte = (byte)0b00100001;

// A 16-bit 'short' value:
short aShort = (short)0b1010_0001_0100_0101;

// Some 32-bit 'int' values:
int anInt1=0b1010_0001_0100_0101_1010_0001_0100_0101;
int anInt2=0b101;
int anInt3=0B101;   //The B can be upper or lower case
```

This is an example of casting. In this example, the binary value is cast to a byte type.

Rules for Variable Names

- You must follow the following rules when choosing the name for a variable:
  - Do not use a Java keyword or reserved word
  - Do not use a space in the variable name
  - Use a combination of letters or a combination of letters and numbers
  - Cannot start with a number
  - The only symbols allowed are the underscore (_) and the dollar sign (**$**)

Using _ and $ in Java identifiers is rarely used and should be discouraged.

Conventions for Variable Names

- While conventions are not rules, most Java programmers follow these conventions:
  - Use full words instead of cryptic abbreviations
  - Do not use single letter variables
  - If all of the variables are single letter, the code may look very confusing
    - An exception to this convention is for loop control variables, which are often letters i, j, or k
  - If a variable name consists of one word, spell that word in all lowercase letters
  - If a variable name consists of more than one word, use lowerCamelCase

Use good variable names!

Additional Naming Conventions for Variable Names

- Additional naming conventions:
  - If a variable will be a constant value, use all capital letters and separate words with the underscore
  - Use names that express the purpose of the variable
  - In the example below, PI is a good choice for naming this number because it allows you to recall what the variable is

```
double PI = 3.14159;
```

Variable Scope

- Scope is used to describe the block of code where a variable exists in a program
- It is possible for multiple variables with the same name to exist in a Java program
  - In most cases, the innermost variable has precedence
- A variable exists only inside the code block in which it is declared
- Once the final brace of the block } is reached:
  - The variable goes out of scope
  - It is no longer recognized as a declared variable

When a variable is declared, memory is allocated for it. When the variable goes out of scope, the memory is freed up and the value is lost.

Variable Scope Example 1

- In the following example, name will not print out because it stops existing once the brace marked Point B is reached

```
public void someMethod()
{
   if(gameOver && score>highScore)
   {
      String name;                  //Point A
      System.out.println("Please enter your name:");
      name=reader.next();
   }//end if                        //Point B

   System.out.println("Thank you " + name + ", ");
   System.out.println("your high score has been saved.");
}//end method someMethod
```


Not only will name not be printed, the program will not compile.

Variable Scope Example 2

- In this example, the variable name has been moved outside of the if statement block to allow name to be used throughout the method

```
public void someMethod()
{
   String name;                    //Point A
   if(gameOver && score>highScore)
   {
      System.out.println("Please enter your name:");
      name=reader.next();
   }//end if                       //Point B
   System.out.println("Thank you " + name + ", ");
   System.out.println("your high score has been saved.");
} //end method someMethod
```

Variable Scope Example 3

- Java will allow a class variable and a method variable with the same name to exist in a program
- Can you predict what this program will print?

```
public class Counting{
  public static int counter=5;
  public static void main(String[] args){
    System.out.println("At the start of this program, counter is "+ counter);
    count();
    System.out.println("At the end of this program, counter is "+ counter);
  }//end method main
  public static void count(){
    int counter=10;
    System.out.println("At the end of this method, counter is "+ counter);
  }//end method count
}//end class Counting
```


While this example compiles and runs, it can be very confusing. If you must have local variables and field with the same name, their scope should be heavily documented with comments. Better yet, used different names and avoid the confusion.

Variable Scope Example 3 Solution

- Solution:
  - 5, 10, 5
- The program starts main() and prints the global class variable counter
- The method count() is called and a new local variable counter is created for that method call
- It is given a value of 10 and then prints
- When the brace at the end of count() is reached, the local variable goes out of scope (ceases to exist)
- The program returns to the main() method and prints the global variable counter which has not changed it's value

Boolean Operators

- Boolean operators are a set of operators that can be used to compare expressions to either true or false

Operator	Operator	Description	Example
&&	AND	If both are true, returns true	(A&&B)
||	OR	If any are true, returns true	(A||B)
!	NOT	Reverses the logical state(T to F, F to T)	!(A&&B)
==	equal to	If both are equal, returns true	(A==B)
!=	NOT equal to	If both are not equal, returns true	(A!=B)
>	greater than	If left is greater than right, return true	(A>B)
>=	Greater than or equal to	If left is greater than or equals right, return true	(A>=B)
<	less than	If left is less than right, return true	(A<B)
<=	less than or equal to	If left is less than or equals right, return true	(A<=B)

Arithmetic Operators

- Java has several arithmetic operators to perform math operations

Symbol	Operator Description
+	Addition operator
-	Subtraction operator
*	Multiplication operator
/	Division operator (finds the quotient)
%	Modular operator (finds the remainder)
+ +	Increment operator (adds one) Is a unary operator
- -	Decrement operator (subtracts one) Is a unary operator

In Java code, there is no space between the + or -.

Arithmetic Operators Precedence

- All math expressions are evaluated following the order of precedence:
  - Expressions in parenthesis are handled first
  - All multiplication, division, and modular operations are handled next, working from left to right
  - Finally, all addition and subtraction operations are handled, working from left to right

Full precedence table:

https://docs.oracle.com/javase/tutorial/java/nutsandbolts/operators.html

Increments and Decrements

- Increments and decrements are handled first for pre-increment notation and last for post-increment notation
- Increment in Java means to add one to the variable value
- Decrement in Java means to subtract one from the variable
- Pre-increment notation:

```
++x;
```

- Post-increment notation:

```
x++;
```

Increment and Decrement Precedence Example

- Pre-increment notation:

```
int x = 3;
++x;          //x is equal to 4
z = ++x;      //x is equal to 4, THEN z is equal to 5
```

- Post-increment notation:

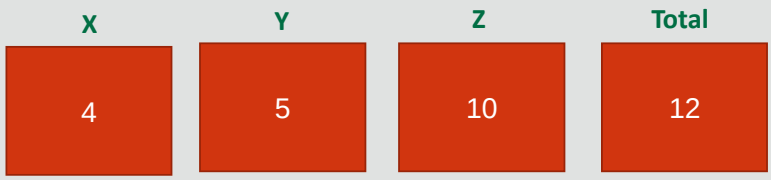
```
int x = 3;
x++;          //x is equal to 4
z = x++;      //z is equal to 4, THEN x is equal to 5
```


Can you do the same statements on this slide without using the ++ operator?

Assignment Operator

- Java uses the = (equal sign) as the assignment operator The evaluation of the expression on the right is assigned to the memory location on the left

```
int x = 4;
int y = 5;
int z = 10;
int total = 12;
```



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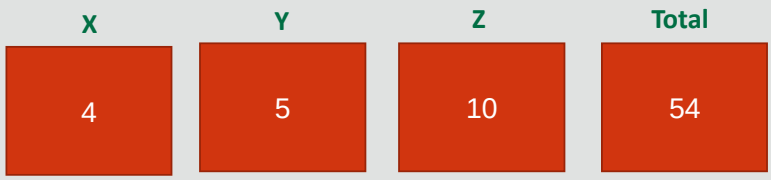
Assignment Operator Example 1

- When this line of code is executed, the value for total changes
- The boxes show what is in each memory location for x, y, z, and total
- Now the memory location total is assigned the value of 4 + 5 * 10, which is 54

```
int x = 4, y = 5, z = 10;
int total = x + y * z;
```



Assignment Operator Example 2

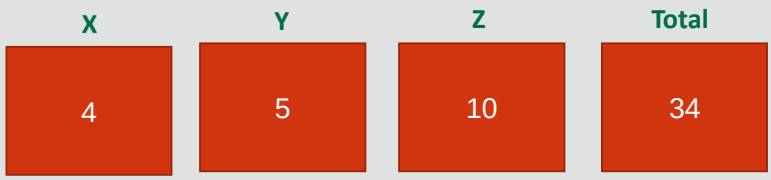
- Think of the assignment operator like an arrow pointing to the left
- Everything on the right will go into the memory location on the left
- How will memory change when this code is executed?

```
int x = 4, y = 5, z = 10;
int total = x + y * (z - x);
```

Assignment Operator Example 2 Solution

- The answer is that total will be assigned the value of the expression
- This means that the value of the expression will be stored in the memory address associated with the variable total

```
int x = 4, y = 5, z = 10;
int total = x + y * (z - x);
```



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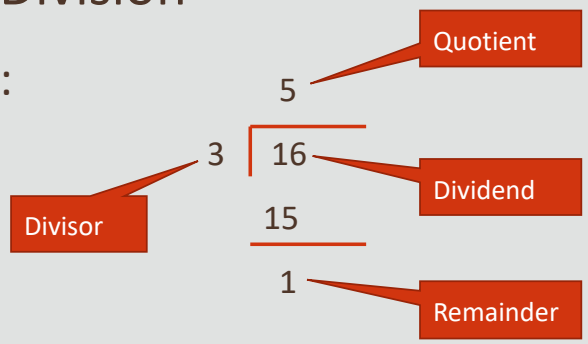
Truncation and Integer Division

- Division of two integers will ALWAYS produce an integer
- For example, the formula for the volume of a cone from Geometry is:
  - V = ⅓ r2 h
  - If 1/3 is used in a Java expression, it is evaluated as 0 because of integer division
  - Integer division results are the quotient without decimals

Truncation is the concept of removing the fractional or decimal part of a number. For example: Truncating 7.8 would produce a result of 7 and truncating -3.2 would produce a result of -3.

Truncation and Integer Division

- Integer Division Examples:
  - 16 / 3 = 5 (Truncation)
  - 10 / 3 = 3 (Truncation)
  - 16 % 3 = 1
  - 12 % 3 = 0
  - 11 % 3 = 2



- To calculate a quotient without truncation (decimal results), convert either the dividend or the divisor to a decimal
- For example:
  - 11 / 5.0 = 2.2 and likewise, 11.0 / 5 = 2.2

In addition to adding a .0 to integer literals to make them doubles, the integers could also be cast.

Truncation and Integer Division Example 1

- What prints when the code below is executed?

```
int x = 4, y = 5, z = 10;
int total = z / (x * y);

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

- The answer is 0
- Why doesn't 0.5 display?
- Since total is an integer, the system will store an integer value as the result of the calculation
- The decimal portion of the answer is truncated rather than rounded to produce the final integer answer of 0

Truncation and Integer Division Example 2

- A programmer might write the following code to create a program to calculate volume
- The Java program will incorrectly calculate the answer as 0
- Working from left to right, the program divides 1 by 3
- Java considers 1 and 3 to be literal integers and does integer division where .33... is truncated to 0
- How would you correct this?

```
double height = 4, radius = 10, volume;
volume = 1 / 3 * 3.14 * radius * radius * height;
System.out.println("The volume is " + volume + ".");
```

Understanding Types and Conversions

- There are a few ways to force a formula to not truncate a value:
  - Move the fraction to the end so that Java will always use a double and an integer and will implicitly convert the answer to a double, not truncate

```
double volume = 3.14 * radius * radius * height * 1 / 3;
```

  - Make one of the literal integers into a literal double so that Java will always use a double and an integer and will implicitly convert the answer to a double, not truncate

```
double volume = 1 / 3.0 * 3.14 * radius * radius * height;
```

Implicit Type Conversions

- In the previous example, Java did implicit type conversions
- This happens whenever a smaller data type (like int) is placed into a larger type (like double)
- Java realizes the types are different and converts to the larger size automatically for you
- However, Java will not convert from a larger (like double) to a smaller (like int) size automatically

Using Type Casting

- Using the random method from the Math library, we can generate a random number from 1 to 10
- The random method generates a double between 0 and (not including) 1
- Values such as 0, 0.4567 or 0.901306 might be generated

```
int number;
number = Math.random() * 10;
System.out.println("The random number is " + number + ".");
```

Using Type Casting

- Multiplying these values by 10 and then truncating the extra would yield values 0, 4 or 9
- However, Java will not let this program compile in its current state
- Data is lost by going from a larger value (double) to a smaller value (int)
- Thus, type casting is required for this type conversion

```
int number;
number = Math.random() * 10;
System.out.println("The random number is " + number + ".");
```

Type Casting Operator

- To cast a double value to an int, use (int) in front of the value
- To get the double result from our formula to go into the integer container, use the type casting operator (int) in front of the value
- Casting to the int data type will truncate the value
- Thus, casting the double literal 4.567 to an int will result in 4, and 9.01306 will result in 9

```
int number;
number = (int)(Math.random() * 10);
System.out.println("The random number is " + number + ".");
```

Converting Data Types

- You can convert a data type (primitive or reference) to another data type by simply placing the name of the data type in parenthesis in front of the value or variable, as shown in the example below

```
int number;
Object o;
char firstInitial = 'A';
number = (int)firstInitial;
o = (Object)firstInitial;
```


Objects related via inheritance may also be cast. This will be covered later in this course.

Converting String Data Types

- Note that casting will not work in all situations
- For example
  - Casting a char to a String results in a compiler error
  - In situations such as this, you would need to resort to making the type conversion in another way
  - There are methods in the java.lang library to convert characters to strings

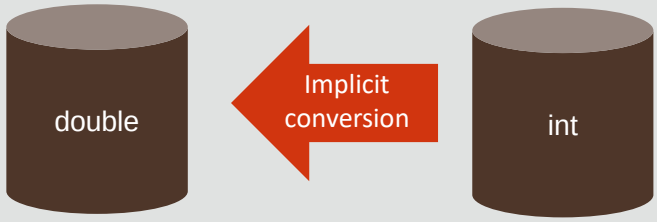
Using Type Conversions

- Using type conversions is another option to fixing the truncation issue with the volume formula shown previously
- Use type casting to make one of the literal integers a double

```
double volume = (double) 1 / 3 * 3.14 * radius * radius * height;
```

Understanding Types and Conversions

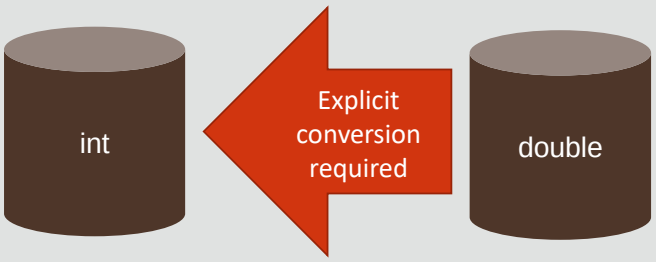
- When Java is converting from a smaller primitive type to a larger primitive type, the conversion is implicit




```
double d1  = 5;
```

Understanding Types and Conversions

- However, when Java converts from a larger primitive type to a smaller primitive type, the conversion must be explicit via type casting
- Java will not implicitly cast a larger type to a smaller type because of loss of precision




```
int x  =
(int)12.95;
```

Searching Through the Java API

- Examples and exercises in this course will require the use of the methods in the Java Math and String classes
- You can find a description of all Java methods in the online Java API
- Understanding how to navigate this vast library of standard methods and classes will aid you in writing Java programs and reusing code blocks that have already been created by others

Why Use the Java API?

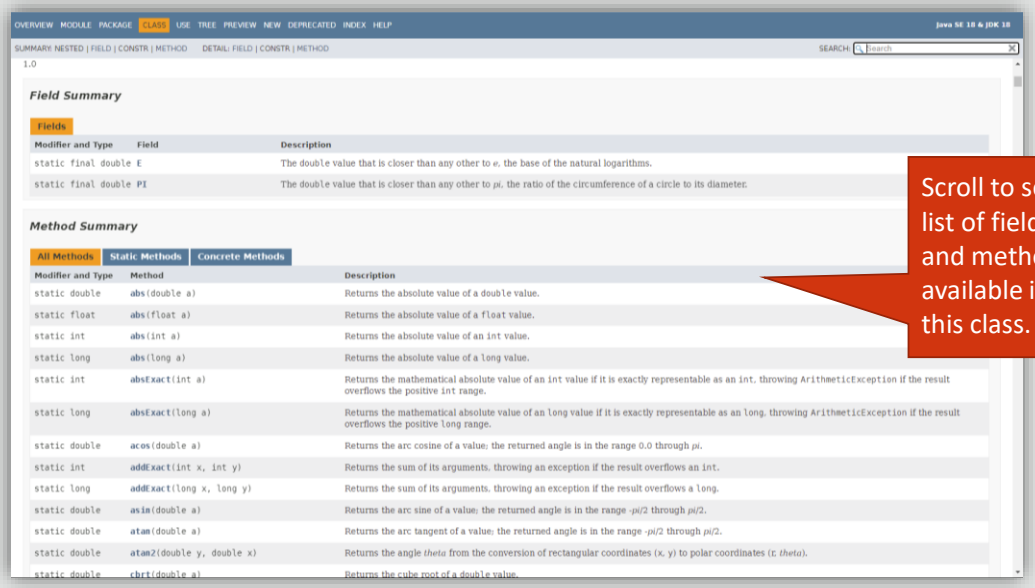
- One major benefit to having access to the Java API is a common concept for programmers called code reuse
- Rather than coding excess items, you may use the API to find how to access existing code that does exactly what you want
- This will reduce spending time on reproducing already existing code and make your programming much more efficient

Review the Java API

- Go back to the Java API by using a search engine to search for it
- There are many editions
- Review the Standard Edition for Java 18: https://docs.oracle.com/en/java/javase/18/docs/api/allclasses-index.html
  - Examine the Math class
  - See if you can find a value for PI and a method for computing the square root of a number?

Math Class

- Find the Math Class in the class frame window

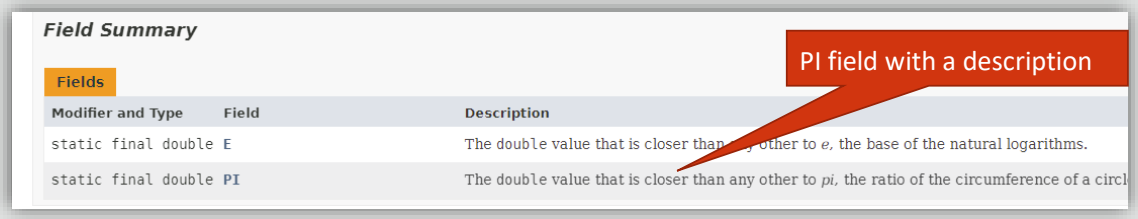


Scroll to see a list of fields and methods available in this class.

PI Field

- Scroll to find the PI field
- To use PI in a program, specify the class name (Math) and PI separated by the dot operator
- For example, this field would yield a more accurate volume calculation in our earlier example if it is used as follows:

```
double volume = (double) 1 / 3 * Math.PI * radius * radius * height;
```



Calculating Square Roots

- The method for calculating square roots:

`static double`	**`sqrt`**`(double a)` Returns the correctly rounded positive square root of a `double` value.

- To calculate the square root of 625, use the class name and the method separated again by the dot operator

```
double answer = Math.sqrt(625);
```

- The sqrt method requires a double
- Why does the literal integer 625 not give an error?

If you have time, explore what happens when Java is asked to calculate the square root of a negative number. Exceptions will be covered in Section 6.

Calculating Square Roots Solution

- Question:
  - The sqrt method requires a double
  - Why does the literal integer 625 not give an error?
- Solution:
  - Implicit conversion
  - The int 625 is implicitly converted to a double and thus no error occurs

Data Types and Operators Practice

- On paper, evaluate the following Java statements and record the result

```
double x = 3.25;
double y = -4.5;
int m = 23;
int n = 9;
System.out.println(x + m * y - (y + n) * x);
System.out.println(m / n + m % n);
System.out.println(5 * x - n / 5);
System.out.println(Math.sqrt(Math.sqrt(n)));
System.out.println((int)x);
System.out.println(Math.round(y));
double x = 3.25;
double y = -4.5;
int m = 23;
int n = 9;
System.out.println((int)Math.round(x) + (int)Math.round(y));
System.out.println(m + n);
System.out.println(1-1-((1-(1-(1-n)))));
```

Terminology

- Key terms used in this lesson included:
  - Arithmetic operator
  - Assignment operator
  - boolean
  - char
  - Conventions
  - Declaration
  - Double
  - float
  - Initialization
  - int
  - Literals

Terminology

- Key terms used in this lesson included:
  - long
  - Order of Operation
  - Primitive data types
  - Scope
  - Short
  - Truncation
  - Type casting
  - Type conversion
  - Variables

Summary

- In this lesson, you should have learned how to:
  - Use primitive data types in Java code
  - Specify literals for the primitive types and for Strings
  - Demonstrate how to initialize variables
  - Describe the scope rules of a method
  - Recognize when an expression requires a type conversion
  - Apply casting in Java code
  - Use arithmetic operators
  - Use the assignment operator
  - Use a method from the Math class
  - Access a Math class method from the Java API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