Chapter 2: Data and Expressions
CS 121

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Chapter 2

- Part 1: Data Types
  
- Part 2: Expressions and Scanner
Part 1: Data Types

- Character Strings
  - Concatenation
  - Escape Sequences
- Java Primitive Data Types
- Declaring and Using Variables
A sequence of characters can be represented as a string literal by putting double quotes around it.

"This is a string literal." "So is this."

What about the string literal? ""

A character string is an object in Java, defined by the String class.

Every string literal represents a String object.

The `System.out` object represents a destination (the monitor) to which we can send output.

We can invoke the `println` and `print` methods of the `System.out` object to print a character string.

- `println` – prints a new line character (`\n`) after the string.
- `print` – does NOT print a new line character (`\n`) after the string.

Example: `Countdown.java`
The string concatenation operator (+) appends one string to the end of another.

"Peanut butter " + "and jelly"

Allows strings to be broken across multiple lines.

"If this was a long string, we may want it on " + "two lines so we can see it more easily"

Also used to append numbers to a string.

"We will have " + 8 + " quizzes this semester."
String Concatenation (2)

- The + operator is also used for addition.
- The function it performs depends on the context.
  - **String concatenation**
    - Both operands are strings.
    - One operand is a string and one is a number.
  - **Addition**
    - Both operands are numeric.
  - **Example:** Addition.java
- Precedence: evaluated left to right, but can use parenthesis to force order (more about this later).
What if we wanted to actually print the " character??

Let's try it.

```java
System.out.println("I said "Hello" to you");
```

Our compiler is confused! Do you know why?

We can fix it with an escape sequence – a series of characters that represents a special character.

Begins with a backslash character (\).

```java
System.out.println("I said \"Hello\" to you");
```
Some Java Escape Sequences

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>\b</td>
<td>backspace</td>
</tr>
<tr>
<td>\t</td>
<td>tab</td>
</tr>
<tr>
<td>\n</td>
<td>newline</td>
</tr>
<tr>
<td>\r</td>
<td>carriage return</td>
</tr>
<tr>
<td>&quot;</td>
<td>double quote</td>
</tr>
<tr>
<td>'</td>
<td>single quote</td>
</tr>
<tr>
<td>\</td>
<td>backslash</td>
</tr>
</tbody>
</table>
Using Java Escape Sequences

- **Example:** BlankOrDark.java
- **Example:** CarriageReturnDemo.java (must run from command-line)
There are 8 primitive data types in Java (varies in other languages)

Integers
- byte, short, int, long

Floating point types
- float, double

Characters
- char

Boolean values (true/false)
- boolean
## Numeric Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Space (#bits)</th>
<th>Minimum value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>8</td>
<td>-128</td>
<td>127</td>
</tr>
<tr>
<td>short</td>
<td>16</td>
<td>-32768</td>
<td>32767</td>
</tr>
<tr>
<td>int</td>
<td>32</td>
<td>-2147483648</td>
<td>2147483647</td>
</tr>
<tr>
<td>long</td>
<td>64</td>
<td>-9223372036854775808</td>
<td>9223372036854775807</td>
</tr>
<tr>
<td>float</td>
<td>32</td>
<td>1.4E-45</td>
<td>3.4028235E38</td>
</tr>
<tr>
<td>double</td>
<td>64</td>
<td>4.9E-324</td>
<td>1.7976931348623157E308</td>
</tr>
</tbody>
</table>

- **float** has 6-9 significant digits
- **double** has 15-17 significant digits
A decimal literal value is an int by default. To write a long literal value, we have to use the L suffix.

```java
int answer = 42;
long neuronsInBrain = 100000000000L;
```

A floating point literal value is double by default. To write a float literal value, we have to use the F suffix.

```java
double delta = 453.234343443;
float ratio = 0.2363F;
```
A **char** stores a *single* character delimited by single quotes.

```java
char topGrade = 'A';
char comma = ',';
char tab = '\t';
```

A **char** variable in Java can store any character from the **Unicode** character set.

- Each character corresponds to a unique 16-bit number.
- We typically use characters from the **ASCII** character set.
  - Older and smaller subset of Unicode (only 8-bits).

See Appendix C on page 951 of your textbook.

Boolean values only have two valid values for the `boolean` type: `true` or `false`. Reserved words `true` and `false`.

```java
boolean done = false;
```

Commonly used to represent two states (e.g. on/off).
Identifiers are words a programmer uses in a program.

- Consists of a combination of A-Z, a-z, 0-9, _, and $
- Can’t begin with digit.
- Case sensitive.
- Total, total, and TOTAL are different

Good practice to use different case style for different types of identifiers.

- title case for class names – Lincoln, HelloClass
- camel case for variables – count, nextCount
- upper case for constants – MAXIMUM, MINIMUM
Reserved Words

- **Reserved words** are special identifiers that have pre-defined meaning. They can’t be used in any other way.
- Some examples – `public`, `static`, `void`, `class`
- See page 7 (Chapter 1) in textbook for full list of reserved words.
Variables

- A **variable** is just a name for a location in memory.
- Variable names are **identifiers**. They must be unique.
- Variables must be **declared** by specifying a **name** and the **type** of information it will hold.
  
  ```java
  String name;
  int radius, area, circumference;
  ```
- When a variable is used in a program, the current value is used.
Assignment

- An assignment statement changes the value of a variable.
- The assignment operator is the equals sign (=).

```java
int radius;
radius = 10;
```

- The value on the right-hand side is stored in the variable on the left.
- The previous value in `radius` is overwritten.
- Variables can also be initialized when they are declared.

```java
int count = 0;
```

- The type of the right-hand side must be compatible with the type of the variable.
The right-hand side can be an expression.
The expression will be evaluated \textit{first} and \textit{then} stored in the variable.

\begin{verbatim}
radius = 10;
radius = radius * 2; // double the radius
\end{verbatim}

What is the new value of \texttt{radius}? 20
A constant is an identifier (similar to a variable) that holds the *same* value during its entire existence.

It is constant, not variable.

The compiler will issue an error if you try to change the value of a constant.

In Java, we use the `final` modifier to declare a constant.

We typically use all caps to name constants.

```java
final int MAX_RADIUS = 1000;
```
Why do we need constants?

- Readability – give meaning to arbitrary literals.
- Program maintenance – only need to change value once.
- Program protection – establishes that a value should not change; less chance for error.
In-class Exercises

▶ EX 2.2. What output is produced by the following code fragment? Explain.

```java
System.out.print("Here we go!");
System.out.println("12345");
System.out.print("Another.");
System.out.println(""");
System.out.println("All done.");
```

▶ EX 2.4. What output is produced by the following statement? Explain.

```java
System.out.println("50 plus 25 is " + 50 + 25);
```

▶ PP 2.1. Create a revised version of the Lincoln application from Chapter 1 such that quotes appear around the quotation.
Part 2: Expressions and Scanner

- Expressions
- Data conversions
- The Scanner class for interactive programs

Go to index.
In-class Exercises

Which data type would you use to represent each of the following items?

- The name of a restaurant.
- The maximum number of occupants a restaurant can hold.
- The current number of occupants.
- The price of a meal.
- Whether or not the restaurant is open.

Write a variable declaration for each of the above items. Make sure to give your variables descriptive names.
Expressions

- An **expression** is a combination of one or more **operators** and **operands**.
- We focus on **arithmetic** expressions that produce numeric results.
Arithmetic Expressions

- Arithmetic expressions use the arithmetic operators.

  - Addition $+$
  - Subtraction $-$
  - Multiplication $*$
  - Division $/$
  - Remainder (modulo) $\%$
Arithmetic Expressions and Data Types

▶ If *any one* of the operands used by an arithmetic operator is *floating point* (*float* or *double*), then the result will be a floating point.

▶ For example:

```java
int radius = 10;
final double PI = 3.14159265358979323;
double area = PI * radius * radius;
```

▶ If *both* operands used by an arithmetic operator are *floating point*, then the result will be a floating point

▶ If *both* operands used by an arithmetic operator are *integer*, then the result will be an integer. *Be careful!!*
Division and Data Types

▶ If both operands of the division operator are integers, then the result will be an integer.
▶ This means we lose the fractional part of the result.
▶ For example, let’s assume we want to divide a wall into equal sections.

```java
int length = 15;
int sections = 2;
double newLength = length / sections;
```
▶ Let’s try this.
▶ How can we fix it?
▶ Data conversion – we’ll get to this soon.
Given two positive numbers, \( a \) (the dividend) and \( b \) (the divisor), \( a \% n \) (\( a \mod n \)) is the remainder of the Euclidean division of \( a \) by \( n \).

\[
\begin{array}{ccc}
14 / 3 &=& 4 \\
8 / 12 &=& 0 \\
10 / 2 &=& 5 \\
7 / 6 &=& 1 \\
9 / 0 &=& \text{error}
\end{array}
\]

\[
\begin{array}{ccc}
14 \% 3 &=& 2 \\
8 \% 12 &=& 8 \\
10 \% 2 &=& 0 \\
7 \% 6 &=& 1 \\
9 \% 0 &=& \text{error}
\end{array}
\]
Remainder Operator (modulo)

- Typically used to determine if a number is odd or even.
- How?
Just like in Mathematics, operators can be combined into complex expressions.

\[
\text{result} = \text{total} + \frac{\text{count}}{\text{max}} - \text{offset};
\]

Operators have well-defined precedence to determine order of evaluation.

\[
\text{result} = \text{total} + \frac{\text{count}}{\text{max}} - \text{offset};
\]

Expressions are evaluated from left to right in order of operator precedence.
### Operator Precedence

<table>
<thead>
<tr>
<th>Precedence</th>
<th>Operator</th>
<th>Operation</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>()</td>
<td>parenthesis</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>+</td>
<td>unary plus</td>
<td>R to L</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>unary minus</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>*</td>
<td>multiplication</td>
<td>L to R</td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>division</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>modulo (remainder)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>addition</td>
<td>L to R</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>subtraction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>string concatenation</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>=</td>
<td>assignment</td>
<td>R to L</td>
</tr>
</tbody>
</table>

See the full precedence table in Figure D.1 on page 956 of your textbook.
Determine the order of evaluation in the following expressions.

1) \( a + b + c + d + e \)
2) \( a + b * c - d / e \)
3) \( a / (b + c) - d \% e \)
4) \( a / (b * (c + (d - e))) \)
In-Class Exercise

- Determine the order of evaluation in the following expressions.

1) \( a + b + c + d + e \)
   1 2 3 4

2) \( a + b * c - d / e \)
   3 1 4 2

3) \( a / (b + c) - d % e \)
   2 1 4 3

4) \( a / (b * (c + (d - e))) \)
   4 3 2 1
Order of Evaluations and Integer Division

- Expressions are evaluated from left to right in order of operator precedence.
- This order can change the results of an expression, especially where possible integer division is involved, which can easily lead to bugs in code.

```java
final double PI = 3.14159;
double radiusCubed = 1.0;
double volume1 = 4 / 3 * PI * radiusCubed;
double volume2 = PI * radiusCubed * 4 / 3;
```

- Does `volume1` equal `volume2`?
- Example: Volume.java
Evaluation order of an expression can also be shown using an expression tree.

The operators lower in the tree have higher precedence for that expression.

\[ a + (b - c) / d \]

\[ \begin{array}{c}
\text{a} \\
\downarrow \\
\text{b} \\
\downarrow \\
\text{c} \\
\end{array} \quad \begin{array}{c}
\downarrow \\
\text{d} \\
\end{array} \quad + \\
\text{a} \\
\downarrow \\
\text{b} \\
\downarrow \\
\text{c} \]
The assignment operator has the lowest operator precedence. The entire right-hand side expression is evaluated first, then the result is stored in the original variable. It is common for the right hand side and left hand sides of an assignment statement to contain the same variable.

```cpp
count = count + 1;
```
The increment operator (++) adds one to its operand. The following statements produce the same result.

```c
count++; 
count = count + 1;
```

The decrement operator (--) subtracts one from its operand. The following statements produce the same result.

```c
count--; 
count = count - 1;
```

The increment ++ and decrement – operators have the same level of precedence as the unary + and unary – operators.
Postfix vs. Prefix

- The increment and decrement operators can be applied in postfix form
  
  ```
  count++; count--;
  ```

  or prefix form
  
  ```
  ++count; --count;
  ```

- When used as part of a larger expression, the two can have different effects. Use with care!!
Java provides assignment operators to simplify expressions where we perform an operation on an expression then store the result back into that variable.

Consider the following expression.

```java
num = num + count;
```

We can simplify this using the addition assignment operator.

```java
num += count;
```

Java provides the following assignment operators.

- `+=` (string concatenation or addition), `-=` method, `*=` method, `/=` method, `%=` method
Sometimes we need to convert from one data type to another (e.g. `double` to `int`).

These conversions do not change the type of a variable, they just convert it temporarily as part of a computation.

**Widening conversions.** Safest. Go from small data type to large one.
- e.g. `short` to `int`, `int` to `double`

**Narrowing conversions.** Not so safe. Go from large data type to smaller one. Must be used carefully as we can lose information!
- e.g. `int` to `short`, `double` to `int`

By default, Java will not allow narrowing conversions unless we force it (shown later)
- `int count = 3.14; //won’t compile!`
Data Conversions

- Assignment conversion.
- Promotion.
- Casting.
Assignment Conversion

- **Assignment conversion** occurs when one type is assigned to a variable of another.
- Only *widening conversions* can happen via assignment.
- For example:
  ```java
  double totalCost;
  int dollars;
  totalCost = dollars;
  ```
  - The *value* stored in `dollars` is converted to a `double` before it is assigned to the `totalCost` variable.
  - The `dollars` variable and the value stored in it are still `int` after the assignment.
Promotion happens automatically when operators in expressions convert their operands.

For example:

```java
double sum;
int count;
double result = sum / count;
```

The value of `count` is converted to a `double` before the division occurs.

Note that a widening conversion also occurs when the result is assigned to `result`.

Casting

- Casting is the most powerful and potentially dangerous conversion technique.
- Explicitly perform narrowing and widening conversions.
- Recall our example from earlier:
  ```java
  int length = 15, sections = 2;
  double newLength = length / sections;
  ```
  
  - Recall: *If both operands of the division operator are integers, then the result will be an integer. If either or both operands used by an arithmetic operator are floating point, then the result will be a floating point.*
  
  - By casting one of the operands (**length** in this case), we get the desired result:
  ```java
  double newLength = ((double) length) / sections;
  ```
Will the following program produce an accurate conversion (why or why not)?

```java
/**
 * Computes the Fahrenheit equivalent of a specific Celsius value using the formula:
 * F = (9/5) * C + 32.
 */
public class TempConverter
{
    public static void main (String[] args)
    {
        final int BASE = 32;

        double fahrenheitTemp;
        int celsiusTemp = 24; // value to convert

        fahrenheitTemp = celsiusTemp * 9 / 5 + BASE;

        System.out.println("Celsius Temperature: " + celsiusTemp);
        System.out.println("Fahrenheit Equivalent: " + fahrenheitTemp);
    }
}
```

1. Yes.
2. Sometimes.
3. Nope.
4. I have no idea.
The Scanner class

- Typically, we want our programs to interact with our users.
- The **Scanner** class is part of the **java.util** class library. It must be imported.
  
  ```java
  import java.util.Scanner;
  ```
- It provides methods for reading input values of various types.
- A **Scanner** object can read input from various sources (e.g. keyboard, file)
- See Java 8 API docs: [http://docs.oracle.com/javase/8/docs/api/java/util/Scanner.html](http://docs.oracle.com/javase/8/docs/api/java/util/Scanner.html)
Create a new `Scanner` object that reads from the keyboard.

```java
Scanner scan = new Scanner(System.in);
```

- The `new` operator creates a new `Scanner` object.
- The `System.in` object represents keyboard input.
- After the object is created, we can invoke various input methods it provides.
Example

- Example: Convert TempConverter.java to interactive program.
- Example: Echo.java
By default, white space is used to separate input elements (called tokens).

White space includes

- Space characters (‘ ‘)
- Tab characters (‘\t’)
- New line characters (‘\n’ and ‘\r’)

The next, nextInt, nextDouble, etc. methods of the Scanner class read and return the next input tokens.

See Scanner documentation for more details.
Example

Example: GasMileage.java
Exercises

Recommended Homework:
- Exercises: EX 2.5, 2.7, 2.8, 2.9, 2.10 (a, b, c, d), 2.11 (e, f, g, i, j).
- Projects: PP 2.3, 2.4, 2.8.

Browse Chapter 3 of textbook.