Chapter 2: Data and Expressions
CS 121

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Chapter 1 Terminology Review

- algorithm
- program (aka. application)
- programming language
- JDK, JRE
- main method
- compiler (compiling)
- execution
- debugging
- syntax
- semantics
- compile-time error
- run-time error
- logical error
Chapter 2

- Part 1: Data Types
  Go to part 1

- Part 2: Expressions
  Go to part 2
Part 1: Data Types

- What is a data type?
- Character Strings
  - Concatenation
  - Escape Sequences
- Java Primitive Data Types
- Declaring and Using Variables

Go to index.
What is a data type?

- Programs represent all kinds of data.
- What types of data might the following programs need to represent?
  - A calculator program.
  - A word processor.
  - An address book.

- A data type is a classification identifying various types of data, such as real, integer, Boolean, words, etc.
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.

See javadoc for String here: [http://docs.oracle.com/javase/8/docs/api/java/lang/String.html](http://docs.oracle.com/javase/8/docs/api/java/lang/String.html).
Printing Strings

- The `System.out` object represents a destination (the console) 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.
In-Class Exercise

- Example: Countdown.java
- Predict the output of the program before we run it.
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."
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).
Escape Sequences

▶ What if we wanted to actually print the " character??
▶ Let’s try it.
    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 (\).
    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:** Roses.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 \texttt{int} by default. To write a long literal value, we have to use the \texttt{L} suffix.

\begin{itemize}
\item 42 (\texttt{int})
\item 100000000000L (\texttt{long})
\end{itemize}

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

\begin{itemize}
\item 453.234343443 (\texttt{double})
\item 0.2363F (\texttt{float})
\end{itemize}
A `char` stores a `single` character delimited by single quotes.

`'A'`, `' ', `	` A `char` variable in Java can store any character from the Unicode character set.

- Each character corresponds to a unique 16-bit number.
- The `Character` class supports the full Unicode Standard.
- English speakers typically use characters from the ASCII character set.
  - Older and smaller subset of Unicode (only 7-bits per character).

See Appendix C on page 951 of your textbook.


To print a special character in a string, use `"\u"` followed by the code.

```java
System.out.println("Are you happy? \u263A");
```

Here is a handy table of characters:

Booleans

- Only two valid values for the boolean type: true or false.
- Reserved words true and false.
- Commonly used to represent two states (e.g. on/off)
In-Class Exercise

What are the 8 primitive data types available in Java?

- Integers (byte, short, int, long)
- Floating Point (float, double)
- Character (char)
- Boolean (boolean)

How do we represent a sequence of characters?

- Strings (the String object).

Give an example of an int, double, char, boolean, and String, and when each could be used.
Declaring and Using Variables

- We know we can represent different types of data in our programs using the data types we just discussed, but we need a way to keep track of all of this data.

- Variables allow us to define and reference the data we use in our programs.
A variable is just a name for a location in memory. Variables must be declared by specifying the type of information it will hold and a unique name.

```java
String name;
char letter;
int radius, circumference;
double area;
boolean done;
```

The value of the variable should be set before it is used.
Variable names are **identifiers**. Identifiers are words a programmer uses in a program. There are certain rules we must follow for identifiers.

- They must be unique.
- They can’t be reserved words.
  - e.g. `public`, `void`, `main` (see pg. 7 of book for complete list)
- Consist of a combination of `A-Z`, `a-z`, `0-9`, `_`, and `$`
- Can’t begin with a digit.
- Examples
  - Valid: `octopus`, `octopus_10`, `and` `sharkBait`
  - Invalid: `10octopus`, `sharkBait!`, `and` `shrimp()`
- 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`, `nextCountTwo`
  - **upper case** for constants – `MAXIMUM`, `MINIMUM`
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 radius = 10;
```

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
In-Class Exercise

1. **Declare** a variable to represent the number of students in this class.
   - What type will it be?
   - What name will you give it?

2. **Initialize** the variable to the number of students in class right now.

3. Suppose one new student enrolls in this class. Write a statement that will **update** the value of your variable with the new number of students in this class.

4. **Declare and initialize** a variable that will store the name of the new student, **Bugs Bunny**.

5. Finally, **declare** a variable to represent whether or not we are having fun in this class.
A constant is an identifier (similar to a variable) that holds the same value during its entire existence.

It is constant, not variable.

We can only assign a value one time.

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 – by giving a value a name, you help explain it’s role in the program.
  - 38 vs. `MAX_ROOM_OCCUPANCY`
  - `true` vs. `HAS_VACANCY`
- Program maintenance – if a constant is used throughout a program and its value has to be modified, then you only need to update it in one place.
- Program protection – establishes that a value should not change; less chance for error.
Part 2: Expressions

- Expressions
- Data conversions
1. 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.

2. Write a variable declaration for each of the above items. Make sure to give your variables descriptive names. (Don’t worry about initializing your variables.)
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.
- In-Class Exercise: 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), $a \% b$ ($a \mod b$) is the remainder of the Euclidean division of $a$ by $b$.

<table>
<thead>
<tr>
<th>$a$</th>
<th>$b$</th>
<th>$a \div b$</th>
<th>$a % b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>error</td>
<td>error</td>
</tr>
</tbody>
</table>
The modulo operator is typically used to determine if a number is odd or even.

How would this be accomplished?

What if we want to determine if a number is a multiple 5? 10? 32?
Just like in math, 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>L to R</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.
In-Class Exercise

Determine the order of evaluation in the following expressions.

1) \( a + b + c + d + e \)

2) \( a + b \times c - d / e \)

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

4) \( a / (b \times (c + (d - e))) \)
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
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`
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.

```c
  count = count + 1;
```
The increment operator (++) adds one to its operand.

- The following statements produce the same result.
  
  ```
  count++;
  count = count + 1;
  ```

The decrement operator (--) subtracts one from its operand.

- The following statements produce the same result.
  
  ```
  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
int x = 10;
int y = ++x;
System.out.println("++x: "+ y); // prints 11

int a = 10;
int b = a++;  
System.out.println("a++: "+ b); // prints 10
```
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), `-=` *, `*=` /=` %=`
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

- **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: " + celsiusTemp);
        System.out.println("Fahrenheit: " + fahrenheitTemp);
    }
}
```

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