Chapter 2

Primitive Types, Strings, and Console I/O

- Primitive Data types
- Strings: a class
- Assignment
- Expressions
- Keyboard and Screen I/O
- Documentation & Style

What is a program variable?

- A named location to store data
  - » a container for data

- One variable can hold only one type of data
  - » for example only an integer, only a floating point (real) number, or only a character

Creating Variables

- All program variables **must** be *declared* before using them
- A variable declaration associates a name with a storage location in memory and specifies the type of data it will store:

  Type variable_1, variable_2, …;

- For example, to create three integer variables to store the number of baskets, number of eggs per basket, and total number of eggs:

```
int numberOfBaskets, eggsPerBasket, totalEggs;
```

Changing the Value of a Variable

Usually a variable is changed (assigned a different value) somewhere in the program

- May be calculated from other values:

```
totalEggs = numberOfBaskets * eggsPerBasket;
```

- or read from keyboard input:

```
totalEggs = SavitchIn.readLineInt();
```

Two Main Kinds of *Types* in Java

primitive data types

- the simplest types
- cannot decompose into other types
- values only, no methods
- Examples:
  `int` - integer
  `double` - floating point (real)
  `char` - character

class types

- more complex
- composed of other types (primitive or class types)
- both data and methods
- Examples:
  `SavitchIn`
  `String`

Identifiers

- An identifier is the name of something (for example, a variable, object, or method) used in a Java program.
- Syntax rules for identifiers tell what names are allowed.
- Naming conventions are not required by the compiler but are good practice.

Syntax Rules for Identifiers

Identifiers

- cannot be reserved words (e.g. “if,” “for”, etc.– see Appendix 1)
- must contain only letters, digits, and the underscore character, _.
- cannot have a digit for the first character.
  - » **`$`** is allowed but has special meaning, so do not use it.
- have no official length limit (there is always a finite limit, but it is very large and big enough for reasonable names)
- ***are case sensitive!***
  - » **`junk`**, **`JUNK`**, and **`Junk`** are three valid and *different* identifiers, so be sure to be careful in your typing!
- Note that no spaces or dots are allowed.

Naming Conventions

- Always use meaningful names, e.g. **`finalExamScore`**, instead of something like `x`, or even just **`score`**.
- Use only letters and digits.
- Capitalize interior words in multi-word names, e.g. **`answerLetter`**.
- Names of classes start with an uppercase letter, e.g. **`Automobile`**.
  - » ***every program in Java is a class as well as a program***.
- Names of variables, objects, and methods start with a lowercase letter.

Primitive Numeric Data Types

- integer—whole number

  examples: 0, 1, -1, 497, -6902
  - » four data types: **`byte, short, int, long`**
  - » **`Do not use a leading zero (0423)`**

- floating-point number—includes fractional part

  examples: 9.99, 3.14159, -5.63, 5.0
  - » Note: 5.0 is a floating-point number even though the fractional part happens to be zero.
  - » two data types: **`float, double`**

The **`char`** Data Type

- The **`char`** data type stores a single “printable” character

- For example:

```
char answer = `y`;
System.out.println(answer);
```

  prints (displays) the letter **`y`**

Primitive Data Types

Type Name	Kind of Value	Memory Used	Size Range
byte	integer	1 byte	-128 to 127
short	integer	2 bytes	-32768 to 32767
int	integer	4 bytes	-2,147,483,648 to 2,147,483,647
long	integer	8 bytes	-9,223,372,036,854,775,808 to 9,223,374,036,854,775,808
float	floating point	4 bytes	+/- 3.4028… x 10^{+38} to +/- 1.4023… x 10^{-45}
double	floating point	8 bytes	+/- 1.767… x 10^{+308} to +/- 4.940… x 10^{-324}
char	single character (Unicode)	2 bytes	all Unicode characters
boolean	*true* or *false*	1 bit	not applicable

Which Ones to Know for Now

Display in text is for reference; for now stick to these simple primitive types:

- **`int`**
  - » just whole numbers
  - » may be positive or negative
  - » no decimal point
- **`char`**
  - » just a single character
  - » uses ***single*** quotes
  - » for example
    `char letterGrade = 'A';`
- **`double`**
  - » real numbers, both positive and negative
  - » has a decimal point (fractional part)
  - » two formats
    - – number with decimal point, e.g. 514.061
    - – e (or *scientific*, or *floating-point)* notation, e.g. 5.14061 e2, which means 5.14061 x 10^2

Assignment Statements

- most straightforward way to change value of a variable

  Variable = Expression;

  answer = 42;

- = is assignment operator

- evaluate expression on right-hand side of the assignment operator
- variable on the left-hand side of the assignment operator gets expression value as new value

Assignment Operator =

- The assignment operator is not the same as the equals sign in algebra.
- It means -

  "Assign the value of the expression on the right side to the variable on the left side."

- Can have the same variable on both sides of the assignment operator:

```
int count = 10;// initialize counter to ten
count = count - 1;// decrement counter
```

  new value of **`count`** = 10 - 1 = 9

Specialized Assignment Operators

- A shorthand notation for performing an operation on and assigning a new value to a variable
- General form: ***var <op>= expression;***
  - » equivalent to: ***var = var <op> (expression);***
  - » <op> is +, -, *, /, or %
- Examples:

```
amount += 5;
    //amount = amount + 5;

amount *= 1 + interestRate;
    //amount = amount * (1 + interestRate);
```

- Note that the right side is treated as a unit (put parentheses around the entire expression)

Returned Value

- Expressions *return* values: the number produced by an expression is "returned", i.e. it is the "return value."

```
int numberOfBaskets, eggsPerBasket, totalEggs;
numberOfBaskets = 5;
eggsPerBasket = 8;
totalEggs = numberOfBaskets * eggsPerBasket;
```

  - » in the last line **`numberOfBaskets`** returns the value 5 and **`eggsPerBasket`** returns the value 8
  - » **`numberOfBaskets * eggsPerBasket`** is an expression that returns the integer value 40
- Similarly, methods return values

  `SavitchIn.readLine()` is a method that returns a string read from the keyboard

Assignment Compatibility

- Can't put a square peg into a round hole
- Can't put a **`double`** value into an **`int`** variable
- In order to copy a value of one type to a variable of a different type, there must be a conversion.
- Converting a value from one type to another is called ***casting***.
- Two kinds of casting:
  - » automatic or implicit casting
  - » explicit casting

Casting: changing the data type of the *returned* value

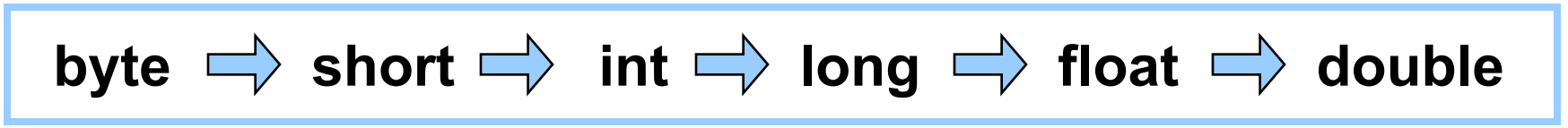
- Casting only changes the type of the *returned value* (the single instance where the cast is done), not the type of the variable
- For example:

```
double x;
int n = 5;
x = n;
```

- Since **`n`** is an integer and **`x`** is a double, the value returned by **`n`** must be converted to type double before it is assigned to **`x`**

Implicit Casting

- Casting is done implicitly (automatically) when a “lower” type is assigned to a “higher” type
- The data type hierarchy (from lowest to highest):

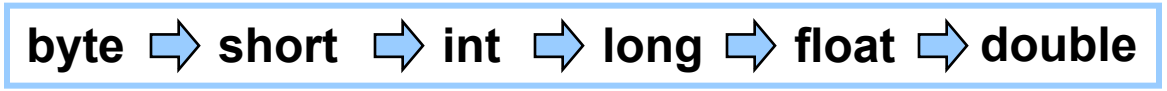


- An **`int`** value will automatically be cast to a **`double`** value.
- A **`double`** value will **not** automatically be cast to an **`int`** value.

Implicit Casting Example: `int` to `double`

```
double x;
int n = 5;
x = n;
```

data type hierarchy:



- the value returned by `n` is *cast* to a double,then assigned to `x`
- `x` contains 5.000… (as accurately as it can be encoded as a floating point number)
- This casting is done automatically because `int` is lower than `double` in the data type hierarchy
- The data type of the variable `n` is unchanged; it is still an `int`

Data Types in an Expression: More Implicit Casting

- Some expressions have a mix of data types
- All values are automatically advanced (implicitly cast) to the highest level before the calculation
- For example:

```
double a;
int n = 2;
float x = 5.1;
double y = 1.33;
a = n * x/y;
```

n and **x** are automatically cast to type double before performing the multiplication and division

Explicit Casting

- Explicit casting changes the data type of the *value* for a single use of the variable
- Precede the variable name with the new data type in parentheses:

  (<data type>) variableName

  » The type is changed to <data type> only for the single use of the returned value where it is cast.

- For example:

```
int n;
double x = 2.0;
n = (int)x;
```

  the value of **x** is converted from double to integer before assigning the value to **n**

Explicit casting is required to assign a higher type to a lower

- ILLEGAL: *Implicit* casting to a *lower* data type

```
int n;
double x = 2.1;
n = x;  //illegal in java
```

  It is illegal since **x** is double, **n** is an int, and double is a higher data type than integer

data type hierarchy: **byte** ⇨ **short** ⇨ **int** ⇨ **long** ⇨ **float** ⇨ **double**

- LEGAL: *Explicit* casting to a lower data type **int n;**

```
double x = 2.1;
n = (int)x;  //legal in java
```

- You can always use an explicit cast where an implicit one will be done automatically, but it is not necessary

Truncation When Casting a **`double`** to an Integer

- Converting (casting) a double to integer does not round; it ***truncates***
  - » the fractional part is lost (discarded, ignored, thrown away)
- For example:

```
int n;
double x = 2.99999;
n = (int)x;
```

  - » the value of **`n`** is now 2 (truncated value of **`x`**)
  - » the cast is required
- This behavior is useful for some calculations, as demonstrated in *Case Study: Vending Machine Change*

Characters as Integers

- Characters are actually stored as integers according to a special code
  - » each printable character (letter, number, punctuation mark, space, and tab) is assigned a different integer code
  - » the codes are different for upper and lower case
  - » for example 97 may be the integer value for ‘a’ and 65 for ‘A’
- ASCII (Appendix 3) and Unicode are common character codes
- Unicode includes all the ASCII codes plus additional ones for languages with an alphabet other than English
- Java uses Unicode

Casting a **`char`** to an **`int`**

- Casting a char value to int produces the ASCII/Unicode value
- For example, what would the following display?

```
char answer = `y`;
System.out.println(answer);
System.out.println((int)answer);
```

- Answer: the letter ‘y’ on one line followed by the ASCII code for ‘y’ (lower case) on the next line:

```
y
121
```

Assigning Initial Values to Variables

- Initial values *may or may not* be assigned when variables are declared:

```
//These are not initialized when declared
//and have unknown values
int totalEggs, numberOfBaskets, eggsPerBasket;

//These are initialized when declared
int totalEggs = 0;  // total eggs in all baskets
int numberOfBaskets = 10;  // baskets available
int eggsPerBasket = 25;  // basket capacity
```

- Programming tip: it is good programming practice always to initialize variables -- either in declarations (as above), assignments, or read methods.

GOTCHA: Imprecision of Floating Point Numbers

- Computers store numbers using a fixed number of bits, so not every real (floating point) number can be encoded precisely
  - » an infinite number of bits would be required to precisely represent any real number
- For example, if a computer can represent up to 10 decimal digits, the number 2.5 may be stored as 2.499999999 if that is the closest it can come to 2.5
- Integers, on the other hand, are encoded precisely
  - » if the value 2 is assigned to an int variable, its value is precisely 2
- This is important in programming situations you will see later in the course

Arithmetic Operators

- addition (+), subtraction (-), multiplication (*), division (/)
- can be performed with numbers of any integer type, floating-point type, or combination of types
- result will be the highest type that is in the expression
- Example:

```
amount - adjustment
```

  - » result will be **`int`** if both **`amount`** and **`adjustment`** are **`int`**
  - » result will be float if amount is **`int`** and adjustment is **`float`**

data type hierarchy: **byte** ⇨ **short** ⇨ **int** ⇨ **long** ⇨ **float** ⇨ **double**

Truncation When Doing Integer Division

- No truncation occurs if at least one of the values in a division is type **`float`** or **`double`** (all values are promoted to the highest data type).
- Truncation occurs if *all* the values in a division are integers.
- For example:

```
int a = 4, b = 5, c;
double x = 1.5, y;
y = b/x;  //value returned by b is cast to double
          //value of y is approximately 3.33333
c = b/a;  //all values are ints so the division
          //truncates: the value of c is 1!
```

The Modulo Operator: `a % b`

- Used with integer types
- Returns the remainder of the division of `b` by `a`
- For example:

```
int a = 57; b = 16, c;
c = a % b;
```

  `c` now has the value 9, the remainder when 57 is divided by 16
- A very useful operation: see *Case Study: Vending Machine Change*

Vending Machine Change

Excerpt from the **`ChangeMaker.java`** program:

```
int amount, originalAmount,
            quarters, dimes, nickels, pennies;
. . . // code that gets amount from user not shown
originalAmount = amount;
quarters = amount/25;
amount = amount%25;
dimes = amount/10;
amount = amount%10;
nickels = amount/5;
amount = amount%5;
pennies = amount;
```

If `amount` is 90 then 90/25 will be 3, so there are three quarters.

If `amount` is 90 then the remainder of 90/25 will be 15, so 15 cents change is made up of other coins.

Arithmetic Operator Precedence and Parentheses

- Java expressions follow rules similar to real-number algebra.
- Use parentheses to force precedence.
- Do not clutter expressions with parentheses when the precedence is correct and obvious.

Examples of Expressions

Ordinary Math Expression	Java Expression (preferred form)	Java Fully Parenthesized Expression
$rate^2 + delta$	rate*rate + delta	(rate*rate) + delta
2(salary + bonus)	2 * (salary + bonus)	2 * (salary + bonus)
$\frac{1}{time + 3mass}$	1/(time + 3 * mass)	1/(time + (3 * mass))
$\frac{a - 7}{t + 9v}$	(a - 7) / (t + 9 * v)	(a - 7) / (t +(9 * v))

Increment and Decrement Operators

- Shorthand notation for common arithmetic operations on variables used for counting
- Some counters count up, some count down, but they are integer variables
- The counter can be incremented (or decremented) before or after using its current value

```
int count;
```

...

`++count` preincrement count: count = count + 1 before using it

`count++` postincrement count: count = count + 1 after using it

`--count` predecrement count: count = count -1 before using it

`count--` postdecrement count: count = count -1 after using it

Increment and Decrement Operator Examples

common code

```
int n = 3;
int m = 4;
int result;
```

What will be the value of `m` and result after each of these executes?

(a) `result = n * ++m;  //preincrement m`

(b) `result = n * m++;  //postincrement m`

(c) `result = n * --m;  //predecrement m`

(d) `result = n * m--;  //postdecrement m`

Answers to Increment/Decrement Operator Questions

(a) 1) `m = m + 1;  //m = 4 + 1 = 5`
2) `result = n * m;  //result = 3 * 5 = 15`

(b) 1) `result = n * m;  //result = 3 * 4 = 12`
2) `m = m + 1;  //m = 4 + 1 = 5`

(c) 1) `m = m - 1;  //m = 4 - 1 = 3`
2) `result = n * m;  //result = 3 * 3 = 9`

(b) 1) `result = n * m;  //result = 3 * 4 = 12`
2) `m = m - 1;  //m = 4 - 1 = 3`

The *String* Class

- A string is a sequence of characters
- The String class is used to store strings
- The String class has methods to operate on strings
- String constant: one or more characters in *double* quotes
- Examples:

```
char charVariable = `a`;  //single quotes
String stgVariable = "a";  //double quotes
String sentence = "Hello, world";
```

String Variables

- Declare a String variable:

```
String greeting;
```

- Assign a value to the variable

```
greeting = "Hello!";
```

- Use the variable as a String argument in a method:

```
System.out.println(greeting);
```

  causes the string **`Hello!`** to be displayed on the screen

Concatenating (Appending) Strings

Stringing together strings -- the “+” operator for Strings:

```
String name = "Mondo";
String greeting = "Hi, there!";
System.out.println(greeting + name + "Welcome");
```

causes the following to display on the screen:

```
Hi, there!MondoWelcome
```

Note that you have to remember to include spaces if you want it to look right:

```
System.out.println(greeting + " " + name
                           + " Welcome");
```

causes the following to display on the screen:

```
Hi, there! Mondo Welcome
```

Indexing Characters within a String

- The index of a character within a string is an integer starting at 0 for the first character and gives the position of the character
- The **`charAt`*`(Position)`*** method returns the char at the specified position
- **`substring`*`(Start, End)`*** method returns the string from position ***`Start`*** to position (***`End`*** – 1)
- For example:

```
String greeting = "Hi, there!";
```

`greeting.charAt(0)` returns **`'H'`**

`greeting.charAt(2)` returns **`','`**

`greeting.substring(4,7)` returns **`"the"`**

H	i	,		t	h	e	r	e	!
0	1	2	3	4	5	6	7	8	9

Escape Characters

- How do you print characters that have special meaning?
  For example, how do you print the following string?

  `The word "hard"`

  Would this do it?

  `System.out.println("The word "hard"");`

  No, it would give a compiler error - it sees the string **`The word`** between the first set of double quotes and is confused by what comes after

- Use the backslash character, "\", to escape the special meaning of the internal double quotes:

  `System.out.println("The word \"hard\""); //this works`

More Escape Characters

Use the following escape characters to include the character listed in a quoted string:

`\"` Double quote.

`\'` Single quote.

`\\` Backslash.

`\n` New line. Go to the beginning of the next line.

`\r` carriage return. Go to the beginning of the current line.

`\t` Tab. White space up to the next tab stop.

Screen Output: `print` and `println`

- Sometimes you want to print part of a line and not go to the next line when you print again
- Two methods, one that goes to a new line and one that does not

```
System.out.println(…);//ends with a new line
System.out.print(…);//stays on the same line
```

- For example:

```
System.out.print("This will all ");
System.out.println("appear on one line");
```

- `System.out.print()` works similar to the "+" operator:

```
System.out.println("This will all "
                   + "appear on one line, too");
```

Program I/O

- I/O - Input/Output
- Keyboard is the normal input device
- Screen is the normal output device
- Classes are used for I/O
- They are generally add-on classes (not actually part of Java)
- Some I/O classes are always provided with Java, others are not

I/O Classes

- We have been using an output method from a class that automatically comes with Java:

  `System.out.println()`

- But Java does not automatically have an input class, so one must be added
  - » ***`SavitchIn`*** **is a class specially written to do keyboard input**
- **`SavitchIn.java`** is provided with the text - see Appendix 4
- Examples of **`SavitchIn`** methods for keyboard input:
  `readLineInt()`
  `readLineDouble()`
  `readLineNonwhiteChar()`
- Gotcha: remember Java is case sensitive, for example **`readLineNonWhiteChar()`** will **not** work

Input Example from Vending Machine Change Program

Excerpt from the **`ChangeMaker.java`** program:

```
int amount, originalAmount,
            quarters, dimes, nickels, pennies;
System.out.println("Enter a whole number...");
System.out.println("I will output ... coins");
System.out.println("that equals that amount ...");

amount = SavitchIn.readLineInt();
originalAmount = amount;
```

Prompts so that user knows what they need to type.

Lets the user type in an integer and stores the number in **`amount`**.

Keyboard Input Gotchas

Note the two variations for reading each type of number

`readLine` variation

- reads a whole line
- asks the user to reenter if it is not the right format
- Try to use these
- Examples:
  `readLineInt()`
  `readLineDouble()`

`read` variation

- reads just the number
- aborts the program if it is not the right format
- Avoid using these
- Examples:
  `readInt()`
  `readDouble()`

User-Friendly Input

- Print a prompt so that the user knows what kind of information is expected.
- Echo the information that the user typed in so that it can be verified.

```
System.out.println("Enter the number of trolls:");
int trolls = SavitchIn.readLineInt();
System.out.println(trolls + " trolls");
```

Prints prompt

Echoes user input

Sample output with user input in italic:

```
Enter the number of trolls:
38
38 trolls
```

A little practical matter: If the screen goes away too quickly …

If the output (screen display) of your programs does not stay on the screen, use this code:

```
System.out.println("Press any key to end program.");
String junk;
junk = SavitchIn.readLine();
```

- The display stops until you enter something
- Whatever you enter is stored in variable **`junk`** but is never used
  - it is "thrown away"

Documentation and Style

- Use meaningful names for variables, classes, etc.
- Use indentation and line spacing as shown in the CS 180 Java Programming Standards
- Always include a “prologue” (JavaDoc block) at the beginning of the file
- Use all lower case for variables, except capitalize internal words (**`eggsPerBasket`**)
- Use all upper case for variables that have a constant value, **`PI`** for the value of pi (3.14159…)

Comments

- *Comment*—text in a program that the compiler ignores
- Does not change what the program does, only explains the program
- Write meaningful and useful comments
- Comment the *non*-obvious
- Assume a *reasonably*-knowledgeable reader
- `//` for single-line comments
- `/*` … `*/` for multi-line comments

Named Constants

- *Named constant*—using a name instead of a value
- Example: use **`INTEREST_RATE`** instead of **`0.05`**
- Advantages of using named constants
  - » Easier to understand program because reader can tell how the value is being used
  - » Easier to modify program because value can be changed in one place (the definition) instead of being changed everywhere in the program.
  - » Avoids mistake of changing same value used for a different purpose

Defining Named Constants

```
public static final double PI = 3.14159;
```

`public`—no restrictions on where this name can be used

`static`—must be included, but explanation has to wait

`final`—the program is not allowed to change the value (after it is given a value)

- The remainder of the definition is similar to a variable declaration and gives the type, name, and initial value.
- A declaration like this is usually at the beginning of the file and is not inside the main method definition (that is, it is “global”).

Summary
Part 1

- Variables hold values and have a *type*
  - » The type of a Java variable is either a primitive type or a class
  - » Common primitive types in Java include **`int`**, **`double`**, and **`char`**
  - » A common class type in Java is **`String`**
  - » Variables must be declared
- Parentheses in arithmetic expressions ensure correct execution order
- Use **`SavitchIn`** methods for keyboard input
  - » **`SavitchIn`** is not part of standard Java

Summary
Part 2

- Good programming practice:
  - » Use meaningful names for variables
  - » Initialize variables
  - » Use variable names (in upper case) for constants
  - » Use comments sparingly but wisely, e.g. to explain non-obvious code
  - » Output a prompt when the user is expected to enter data from the keyboard
  - » Echo the data entered by the user