

2. Data and Expressions

- Objectives - when we have completed this set of notes, you should be familiar with:
 - character strings and escape sequences
 - variables and assignment
 - primitive data
 - if and if-else statements
 - expressions and operator precedence
 - Accepting standard input from the user
 - data conversions

Character Strings

- A string of characters can be represented as a *string literal* by putting double quotes around the text:
- Examples:
 - "This is a string literal."
 - "Pat Doe, 123 Main Street"
 - "7"
- When your program is running, a character string is an object in Java, defined by the `String` class
- Every string literal represents a `String` object

The println Method

- Recall that the `println` method prints a character string and then advances to the next line
- The `System.out` object is an output stream corresponding to a display destination (the monitor screen)

```
System.out.println ("War Eagle from the Auburn Plains!");
```

The diagram illustrates the components of the `println` method call. A red bracket under `System.out` is labeled "object". A red arrow points from the label "method name" to `println`. A red bracket under the string argument is labeled "information provided to the method (argument or parameter)".

The print Method

- The `print` method for the `system.out` object is similar to the `println` method, except that it does not advance to the next line after it prints
- Therefore anything printed after a `print` statement will appear on the same line
- See [CountOff.java](#)

String Concatenation

- The *string concatenation operator* (+) appends one string to the end of another

"Peanut butter " + "and jelly"

- A string literal cannot be broken across two lines in a program
- It can also append a **number** to a **string**
- See [ConcatenationExample1](#)

String Concatenation

- The + operator is a binary operator applied to two operands; if at least one the operands is a String then string concatenation is done

5 + " years" results in "5 years"

- The + operator also used for addition if both operands are numeric

5 + 10 results in 15

- The + operator is evaluated left to right, but parentheses can be used to force the order
- See [ConcatenationExample2](#)
(Experiment with String expressions in the interactions pane in jGRASP)

Escape Sequences

- What if we wanted to print a quotation mark " (a.k.a. double quote)?
- The following line would cause a compile-time error - it would interpret the second quote as the end of the string

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



- An *escape sequence* represents a special character
- An escape sequence begins with a backslash character (\)

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



Escape Sequences

- Some Java escape sequences:

<u>Escape Sequence</u>	<u>Meaning</u>
<code>\t</code>	tab
<code>\n</code>	newline
<code>\r</code>	carriage return
<code>\"</code>	double quote
<code>\'</code>	single quote
<code>\\</code>	backslash

- `\r\n` are used together by `println` in Windows to move to the next line
- See [EscapeSeq.java](#)

Variables

- A *variable* is a name for a “location” in memory that holds a value
- There are many types of values or data...
 - integers values (e.g., -60, 0, 1, 7, 23)
 - floating point values (e.g., -5.6, 0.0, 2.4, 35.2)
 - characters values (e.g., 'j', 'P', '5')
 - boolean values (**true**, **false**)
 - references to objects
- We'll focus on `int` types (integer values) for now and then examine the other types later

Variables

- A variable must be *declared* with the type of information that it will hold or reference

type (integer)

variable name



```
int total;
```

Multiple variables can be created in one declaration

```
int count, temp, result;
```

Variable Initialization

- A variable can be “initialized” to a particular value

```
int sum = 0;  
int base = 32, max = 149;
```

- When a variable is referenced in a program, its current value is used


```
System.out.println("base is " + base);
```



would print...

base is 32

Assignment

- An *assignment statement* changes value of variable

`total = 55;`


- The *assignment operator* `=`
- How does it work?
 - Evaluate the expression on the right side
 - Store the result in the variable on the left side
(previous value is overwritten)
- Java is *strongly typed*: variable type and expression type must be compatible!
- See [VariablesExample.java](#) (Run in Canvas , )

Primitive Data

- There are 8 primitive data types in Java

- Integer types:

- byte, short, **int**, long

```
int age = 19;
```

- Floating point types:

- float, **double**

```
double avg = 94.8;
```

- Character type:

- char

```
char letter = 'A';
```

- Boolean type:

- boolean

```
boolean isCold = false;
```

Expressions

- An *expression* is a construct made up of one or more variables, operators, and method invocations that evaluates to a single value
- *Arithmetic expressions* compute numeric results and make use of the *arithmetic operators*:

Addition	+
Subtraction	-
Multiplication	*
Division	/
Remainder (Modulus)	%

- If either operand is a floating point value, then the result is a floating point value

Division and Remainder

- If both operands to the division operator (/) are integer types, the result is an integer (the fractional part is discarded)

14 / 3 equals 4

8 / 12 equals 0

- The remainder (or mod) operator (%) returns the remainder after dividing the first operand by the second

14 % 3 equals 2

8 % 12 equals 8

[RemainderCheck.java](#)

Assignment Revisited

- The right and left hand sides of an assignment statement can contain the same variable

First, one is added to the
original value of count

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



Then the result is stored back into count
(overwriting the original value)

Increment and Decrement

- The increment and decrement operators use only one operand
- The *increment operator* (++) adds one to its operand
- The *decrement operator* (--) subtracts one from its operand
- The statement

```
count++;
```

is functionally equivalent to

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

Assignment Operators

- Often we perform an operation on a variable, and then store the result back into that variable
- Java provides *assignment operators* to simplify that process
- For example, the statement

```
num += count;
```

is equivalent to

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

Characters

- A `char` variable stores a single character
- *Character literals* are in single quotes:

`'a'` `'x'` `'7'` `'$'` `','` `'\n'`

- Example declarations:

```
char topGrade = 'A';
```

```
char terminator = ';', separator = ' ';
```

- A primitive character variable holds only one character, while a `String` object holds multiple characters

Boolean

- A `boolean` value represents a true or false condition
- The reserved words `true` and `false` are the only valid values for a boolean type

```
boolean done = false;
```

- A `boolean` variable can also be used to represent any two states, such as a light bulb being *on* or *off*

Relational Operators

- Boolean values can be calculated using relational operators

Operator	Meaning
==	Equal
!=	Not equal
<	Less than
<=	Less than or equal
>	Greater than
>=	Greater than or equal

- Example:

```
boolean greater = 89 > 50; // greater set to true
int temp = 99;
boolean isCold = temp < 50; // isCold set to false
```

if Statements

- Allows a program to execute a statement or block { } only under certain conditions:

```
int temp = 39;  
if (temp < 50) {  
    System.out.println("It's cold!");  
}  
System.out.println("Temp = " + temp);
```

[IfExample.java](#)

if Statements

- You can also use a boolean variable:

```
int temp = 39;  
boolean isCold = temp < 50;  
if (isCold) {  
    System.out.println("It's cold!");  
}  
System.out.println("Temp = " + temp);
```

[IfExample2.java](#)

if-else Statements

- What if you wanted to execute one statement or block { } for a true condition and a different statement or block { } for a false condition?

```
int num1 = 9, num2 = 7;
if (num1 < num2) {
    System.out.println(num1 + " is < " + num2);
}
else {
    System.out.println(num1 + " is >= " + num2);
}
System.out.println("Done!");
```

- What is the output? [IfElseExample.java](#)
- What if num1 and num2 both hold value 10?

Interactive Programs Using Standard Input

- Programs generally need user input
- The `Scanner` class provides methods for reading input values of various types
- A `Scanner` object can be set up to read input from various sources (including keyboard input)
- Keyboard input is represented by the `System.in` object



Numerical Input Example

- The following line creates a Scanner object that reads from the keyboard:

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

- The `new` operator creates the `Scanner` object
- Once created, the `Scanner` object can be used to get user input. For example, `nextInt` retrieves an integer value:

```
int numberItems = scan.nextInt();
```

- See [Difference.java](#) (also Run in Canvas  )

Part 2

- More on primitive types
- Character sets
- Operator precedence
- Increment and Decrement: prefix and postfix form
- Data conversion
- Reading user input

Numeric Primitive Data

- Why have multiple types for integer and floating point values? They are different sizes in memory, which dictate the range of possible values

<u>Type</u>	<u>Storage</u>	<u>Min Value</u>	<u>Max Value</u>
byte	8 bits	-128	127
short	16 bits	-32,768	32,767
int	32 bits	-2,147,483,648	2,147,483,647
long	64 bits	$< -9 \times 10^{18}$	$> 9 \times 10^{18}$
float	32 bits	$\pm 3.4 \times 10^{38}$ with 7 significant digits	
double	64 bits	$\pm 1.7 \times 10^{308}$ with 15 significant digits	

Numeric Primitive Data

- Suppose you want to declare a variable to hold an integer value
- You could use a byte value...

`byte` scheduledCourses;

- Takes up only a small space (8 bits)
- However, it can only be between -127 and 127

- Or an int value

`int` storeInventory;

- Now you can go all the way to 2,147,483,647!
- However, reserves much more space (32 bits)

Numeric Primitive Data

- **Think of it as picking out a suitcase.** How much space do you have? How much do you want to be able to carry?



byte



short



int



long

- Your computer/phone/etc has plenty of space, so use **int** and **double** values “just in case”

[TypesExample.java](#) (set breakpoint; Debug ; single step  ; open viewers by dragging variables from Debug tab)

jGRASP Viewers for byte

The screenshot displays the jGRASP IDE interface with a Java program named `TypesExample.java` running. The program defines a `public class TypesExample` with a `main` method containing several variable declarations and assignments. The `Variables` pane on the left shows the state of these variables during execution.

```
public class TypesExample
{
    public static void main
    {
        byte b = 15;
        short s = 15;
        int i = 15;
        long j = 15;

        float x = 999;
        double y = 999;

        char c = 'A';

        boolean bn = true;
    }
}
```

The `Variables` pane lists the following variables:

- static : `TypesExample`
- Arguments
 - args --> (obj 428 : java.lang.String[])
- Locals
 - b = 15 : byte
 - s = 15 : short
 - i = 15 : int
 - j = 15 : long
 - x = 999.0 : float
 - y = 999.0 : double
 - c = 'A' : 65 : char
 - bn = true : boolean

Four `Viewer` windows are open, each displaying the value of the `b` variable (type `byte`) in different formats:

- Detail View:** Shows the variable `b` with the value `= 15 : byte`.
- Numeric View:** Shows the decimal value 15, along with its hexadecimal (0xF), octal (017), and binary (0000 1111) representations.
- Basic View:** Shows the value 15 in a yellow box.
- Presentation String View:** Shows the value 15 in a yellow box.

The status bar at the bottom indicates the program is running: `Status: running user program in canvas`. The bottom right corner shows `Line:23 Col:2 Code:0 Top:7` and the window title `OVS [BLK]`.

jGRASP Numeric Viewers for Primitive Types (except boolean) in a Canvas Window

byte b

Decimal: 15
Hex: 0xF
Octal: 017
Binary: 0000 1111

short s

Decimal: 15
Hex: 0xF
Octal: 017
Binary: 0000 0000 0000 1111

int i

Decimal: 15
Hex: 0xF
Octal: 017
Binary: 0000 0000 0000 0000 0000 0000 0000 1111

long j

Decimal: 15
Hex: 0xF
Octal: 017
Binary: 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 1111

float x

value = 15.0

Sign	Exponent	Mantissa
0	1000 0010	111 0000 0000 0000 0000 0000
0	0x82	0x700000
0	130	7340032

sign = +
exponent = 130 - bias of 127 = 3
mantissa = assumed $1 + 7340032 / 2^{23}$
= (approximately) 1.875
value = (sign) mantissa * 2^{exponent}
= $+1.875 * 2^3$
= 15.0

double y

value = 15.0


Sign	Exponent	Mantissa
0	100 0000 0010	1110 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
0	0x402	0xe0000000000000
0	1026	3940649673949184




sign = +
exponent = 1026 - bias of 1023 = 3
mantissa = assumed $1 + 3940649673949184 / 2^{52}$
= (approximately) 1.875
value = (sign) mantissa * 2^{exponent}
= $+1.875 * 2^3$
= 15.0

char c

Character: A
Source format: 'A'
Decimal: 65
Hex: 0x41
Octal: 0101
Binary: 0000 0000 0100 0001

boolean bn

 = true : boolean

Open [TypesExample.java](#)
Run in Canvas  then
Play  or single step 

Character Sets

- A *character set* is an ordered list of characters, and character represents a unique number
 - A `char` variable in Java can store any character from the *Unicode character set*
 - The Unicode character set uses sixteen bits per character, allowing for 65,536 unique characters
 - It is an international character set, containing symbols and characters from many world languages
- *Experiment with String expressions in the interactions pane in jGRASP*

Character Sets

- The *ASCII character set* is older and smaller than Unicode, but is still quite popular
- The ASCII characters are a subset of the Unicode character set, including:

uppercase letters

A, B, C, ...

lowercase letters

a, b, c, ...

punctuation

period, semi-colon, ...

digits

0, 1, 2, ...

special symbols

&, |, \, ...

control characters

carriage return, tab, ...

Operator Precedence Q4 Q5

- Operators can be combined into complex expressions

```
result = total + count / max - offset;
```

- Operators have a precedence which determines the order in which they are evaluated
- Multiplication, division, and remainder are evaluated before addition, subtraction, and string concatenation
- Arithmetic operators with the same precedence are evaluated from left to right, but parentheses can be used to force the evaluation order

Operator Precedence

- What is the order of evaluation in the following expressions?

$$a + b + c + d + e$$

1 2 3 4

$$a + b * c - d / e$$

3 1 4 2

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

2 1 4 3

$$a / (b * (c + (d - e)))$$

4 3 2 1

Assignment Revisited

- The assignment operator has a lower precedence than the arithmetic operators

First the expression on the right hand side of the = operator is evaluated

```
answer = sum / 4 + MAX * lowest;
```

 4 1 3 2



Then the result is stored in the variable on the left hand side

Q6

Increment and Decrement

Q7

- The increment and decrement operators can be applied in *postfix form*:

`count++` uses old value in the expression,
then increments

- or *prefix form*:

`++count` increments then uses new value in
the expression

- When used as part of a larger expression, the two forms can have different effects
 - Use the increment and decrement operators with care

[IncrementOperatorExample](#)

Assignment Operators

- There are many assignment operators in Java, including the following:

<u>Operator</u>	<u>Example</u>	<u>Equivalent To</u>
+=	x += y	x = x + y
-=	x -= y	x = x - y
*=	x *= y	x = x * y
/=	x /= y	x = x / y
%=	x %= y	x = x % y

Assignment Operators

- The right hand side of an assignment operator can be a complex expression
- The entire right-hand expression is evaluated first, then the result is combined with the original variable
- Therefore

```
result /= (total-MIN) % num;
```

is equivalent to

```
result = result / ((total-MIN) % num);
```


Data Conversion

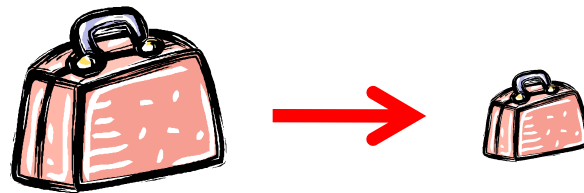
- Sometimes it is necessary to convert data from one type to another
- For example, we may want to treat an integer as a floating point value
- Conversions must be handled carefully to avoid losing information

Data Conversion

- *Narrowing conversions* go from a large data type to a smaller one or from a floating point type to an integer type which has less detail
 - If the an int value was 700 (larger than the max byte value of 127), information would be lost when converted to an byte
 - If your grade of 89.8 (a double) was converted to an int type, the new value would be 89 (a 'B'!) ☹
- *Widening conversions* go from a smaller to larger data type or from an integer type to a floating point type which has more detail
 - If a 'byte' with value 95 was converted to an 'int' type, the new value would still be 95 (your new grade could now go to 2,147,483,647!) ☺

Data Conversion

- Think about the suitcase example...
 - Narrowing conversion : you may lose data going from a larger data type to a smaller data type



Not ok if the
larger one was
full!

- In Java, data conversions can occur in three ways:
 - assignment conversion
 - promotion
 - casting

Assignment Conversion

- *Assignment conversion*: a value of one type is assigned to a variable of another; example:
 - Variable `money` is a **double** type. Variable `dollars` is an **int** type.
 - The assignment below converts the value in `dollars` to a **double** as it assigns it to `money`

```
money = dollars;
```

- The type and value of `dollars` did not change
- Allows only widening conversions

Data Conversion

Q9 Q10

- *Promotion* happens when operators in expressions convert their operands
- For example:

`sum` is a **double** (as is `result`)

`count` is an **int**

The value of `count` is converted to a floating point value to perform the following calculation:

```
result = sum / count;
```

Casting

- *Casting* allows narrowing conversions and widening conversions, so be careful!
- It is also easy to detect in code
- To cast, the type (in parentheses) is placed in front of the value being converted
- For example, if `total` and `count` are integers, the value of `total` could be converted to a **double** with a cast to avoid integer division:

```
result = (double) total / count;
```

Constants

- A *constant* is similar to a variable, but it is placed at the class level (e.g., above the main method), written in all CAPS with underscores, and its initial value cannot be changed
- The `static` modifier allows it to be shared among all methods in the class; the `final` modifier prevents the initial value from changing

```
static final int MIN_HEIGHT = 69;
```

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

Constants

- Constants are useful for three important reasons...
 1. Constants improve code readability
 - For example, MAX_LOAD means more than the literal 250 (a.k.a., a magic number)
 2. Second, they facilitate program maintenance
 - If a constant is used in multiple places, its value need only be updated in one place
 3. Third, they prevent a value from changing, avoiding inadvertent errors by other programmers
- Constants will be revisited in Chapter 4



Reading Input

- The `Scanner` class is part of the `java.util` class library, and must be imported into a program to be used:

```
import java.util.Scanner;
```

- See [ReadLineExample](#)
- The `nextLine` method reads all of the input until the end of the line is found
- Object creation and class libraries are discussed further in Chapter 3

Input Tokens

- Unless specified otherwise, *white space* is used to separate the elements (called *tokens*) of the input
- White space includes space characters, tabs, new line characters
- The `next` method of the `Scanner` class reads the next input token and returns it as a string
- Methods such as `nextInt` and `nextDouble` read data of particular types
- See [DinnerForGroup](#) (Run in Canvas  ; )

Scanning a String

Q12

- A Scanner object can be created to scan any String, breaking it into tokens
- Suppose we want to separate a phrase into words and print each word on a separate line

```
Scanner scan = new Scanner("this is a test");  
System.out.println(scan.next());  
System.out.println(scan.next());
```

. . .

[StringScan.java](#) (Run in Canvas  ; single step )