Chapter 2
Data and Expressions

Java Software Solutions
Foundations of Program Design
Seventh Edition

John Lewis
William Loftus
Data and Expressions

- Let's explore some other fundamental programming concepts

- Chapter 2 focuses on:
  - character strings
  - primitive data
  - the declaration and use of variables
  - expressions and operator precedence
  - data conversions
  - accepting input from the user
  - Java applets
  - introduction to graphics
Outline

Character Strings
Variables and Assignment
Primitive Data Types
Expressions
Data Conversion
Interactive Programs
Graphics
Applets
Drawing Shapes
Character Strings

- A *string literal* is represented by putting double quotes around the text
- A *literal* is an explicit data value used in a program – e.g., 2, "pippo", 'C'

Examples:

  "This is a string literal."
  "123 Main Street"
  "X"

- *Are these strings Java objects?*
- Every string literal is an object in Java, defined by the `String` class
The println Method

• In the *Lincoln* program from Chapter 1, we invoked the *println* method to print a character string

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

```
System.out.println("Whatever you are, be a good one.");
```
The print Method

• The `System.out` object provides another service as well

• The `print` method is similar to the `println` method, except that it does not advance to the next line

• Therefore anything printed after a `print` statement will appear on the same line

• See `Countdown.java`
public class Countdown {
    // Prints two lines of output representing a rocket countdown.
    public static void main (String[] args) {
        System.out.print ("Three... ");
        System.out.print ("Two... ");
        System.out.print ("One... ");
        System.out.print ("Zero... ");
        System.out.println ("Liftoff!"); // appears on first output line
        System.out.println ("Houston, we have a problem.");
    }
}
public class Countdown {
    public static void main (String[] args) {
        System.out.print ("Three... ");
        System.out.print ("Two... ");
        System.out.print ("One... ");
        System.out.print ("Zero... ");
        System.out.println ("Liftoff!"); // appears on first output line
        System.out.println ("Houston, we have a problem.");
    }
}
String Concatenation

• The *string concatenation operator* (+) is used to append one string to the end of another
  
  "Peanut butter " + "and jelly"

• It can also be used to append a number to a string

• A string literal cannot be broken across two lines in a program:

• The following generates a compiler error!

```
System.out.println ("We present the following facts for your extracurricular edification:");
```

• See Facts.java
public class Facts {
    // Prints various facts.
    public static void main (String[] args) {
        // Strings can be concatenated into one long string
        System.out.println ("We present the following facts for your " + "extracurricular edification:");

        System.out.println ();

        // A string can contain numeric digits
        System.out.println ("Letters in the Hawaiian alphabet: 12");
        continue
    }
}
continue

    // A numeric value can be concatenated to a string
    System.out.println("Dialing code for Antarctica: "+672);

    System.out.println("Year in which Leonardo da Vinci invented "
                      +"the parachute: "+1515);

    System.out.println("Speed of ketchup: "+40+" km per year");

}
We present the following facts for your extracurricular edification:

Letters in the Hawaiian alphabet: 12
Dialing code for Antarctica: 672
Year in which Leonardo da Vinci invented the parachute: 1515
Speed of ketchup: 40 km per year

```java
System.out.println("Speed of ketchup: " + 40 + " km per year");
```
String Concatenation

• The + operator is also used for arithmetic addition
• The function that it performs depends on the type of the information on which it operates
  • If both operands are strings, or if one is a string and the other is a number, it performs string concatenation
  • If both operands are numeric, it adds them
• The + operator is evaluated left to right, but parentheses can be used to force the order
• See Addition.java
public class Addition {
    public static void main (String[] args) {
        System.out.println ("24 and 45 concatenated: " + 24 + 45);
        System.out.println ("24 and 45 added: " + (24 + 45));
    }
}
public class Addition
{
    // Concatenates and adds two numbers and prints the results.
    public static void main (String[] args)
    {
        System.out.println("24 and 45 concatenated: " + 24 + 45);
        System.out.println("24 and 45 added: " + (24 + 45));
    }
}
Quick Check

What output is produced by the following?

```java
System.out.println("X: "+25);
System.out.println("Y: "+(15+50));
System.out.println("Z: "+300+50);
```
Quick Check

What output is produced by the following?

System.out.println("X: " + 25);
System.out.println("Y: " + (15 + 50));
System.out.println("Z: " + 300 + 50);

X: 25
Y: 65
Z: 30050
Quiz

• A string literal, for instance, "John" is an object.
• Hence, is it possible to invoke a method of the object "john"?

"John".concat(" is lazy!");
Quiz

• A string literal, for instance, "John" is an object
• Hence, is it possible to invoke a method of "john" object?

"John".concat(" is lazy!");

• YES, so for instance:
  System.out.println("John".concat(" is lazy!")));

  Will print:
  > John is lazy!
Escape Sequences

• What if we wanted to print the quote character?

• The following line would confuse the compiler because it would interpret the second quote as the end of the string

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

• An escape sequence is a series of characters that 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:

<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>

- **See** `Roses.java`
public class Roses {
    // Prints a poem (of sorts) on multiple lines.
    public static void main (String[] args) {
        System.out.println ("Roses are red,\n        Violets are blue,\n        Sugar is sweet,\n        But I have "commitment issues","\n        "So I'd rather just be friends\n        At this point in our relationship.");
    }
}
public class Roses {
    
    // Prints a poem (of sorts) on multiple lines.
    public static void main (String[] args) {
        System.out.println("Roses are red,
            Violets are blue,
            Sugar is sweet,
            But I have "commitment issues",
            So I'd rather just be friends
            At this point in our relationship.");
    }
}
Quick Check

Write a single `println` statement that produces the following output:

"Thank you all for coming to my home tonight," he said mysteriously.
Quick Check

Write a single `println` statement that produces the following output:

"Thank you all for coming to my home tonight," he said mysteriously.

```java
System.out.println ("\"Thank you all for " + "coming to my home\n\tonight,\" he said " + "mysteriously.\")
```
Outline

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Variables

- A *variable* is a name for a location in memory that holds a value

- A *variable declaration* specifies the variable's name and the type of information that it will hold

```plaintext
int total;
int count, temp, result;
```

Multiple variables can be created in one declaration
Variable Initialization

• A variable can be given an initial value in the declaration

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

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

• See PianoKeys.java
public class PianoKeys {
    public static void main (String[] args) {
        int keys = 88;
        System.out.println ("A piano has " + keys + " keys.");
    }
}
public class PianoKeys
{
  // Prints the number of keys on a piano.
  public static void main (String[] args)
  {
    int keys = 88;
    System.out.println("A piano has "+ keys + " keys.");
  }
}
Assignment

• An assignment statement changes the value of a variable — it assigns a value to a variable

• The assignment operator is the '=' sign

    \[
    \text{total} = 55;
    \]

• The value that was in total is overwritten

• You can only assign a value to a variable that is consistent with the variable's declared type

• See Geometry.java
/**
 * Demonstrates the use of an assignment statement to change the
 * value stored in a variable.
 */

class Geometry {
    public static void main (String[] args) {
        int sides = 7;  // declaration with initialization
        System.out.println("A heptagon has " + sides + " sides.");

        sides = 10;  // assignment statement
        System.out.println("A decagon has " + sides + " sides.");

        sides = 12;
        System.out.println("A dodecagon has " + sides + " sides.");
    }
}
public class Geometry {
    public static void main (String[] args) {
        int sides = 7; // declaration with initialization
        System.out.println ("A heptagon has " + sides + " sides.");

        sides = 10; // assignment statement
        System.out.println ("A decagon has " + sides + " sides.");

        sides = 12;
        System.out.println ("A dodecagon has " + sides + " sides.");
    }
}
Constants

- A constant is an identifier that is similar to a variable except that it holds the same value during its entire existence.

- As the name implies, 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.

  ```java
  final int MIN_HEIGHT = 69;
  ```
Constants

• Constants are useful for three important reasons

• First, they give meaning to otherwise unclear literal values
  – Example: `MAX_LOAD` means more than the literal 250

• Second, they facilitate program maintenance
  – If a constant is used in multiple places, its value need only be set in one place

• Third, they formally establish that a value should not change, avoiding inadvertent errors by other programmers
Primitive Data

• There are eight primitive data types in Java

• Four of them represent integers:
  – byte, short, int, long

• Two of them represent floating point numbers:
  – float, double

• One of them represents characters:
  – char

• And one of them represents boolean values:
  – boolean
Numeric Primitive Data

- The difference between the numeric primitive types is their size and the values they can store:

<table>
<thead>
<tr>
<th>Type</th>
<th>Storage</th>
<th>Min Value</th>
<th>Max Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>8 bits</td>
<td>-128</td>
<td>127</td>
</tr>
<tr>
<td>short</td>
<td>16 bits</td>
<td>-32,768</td>
<td>32,767</td>
</tr>
<tr>
<td>int</td>
<td>32 bits</td>
<td>-2,147,483,648</td>
<td>2,147,483,647</td>
</tr>
<tr>
<td>long</td>
<td>64 bits</td>
<td>&lt; -9 x 10^{18}</td>
<td>&gt; 9 x 10^{18}</td>
</tr>
<tr>
<td>float</td>
<td>32 bits</td>
<td>+/- 3.4 x 10^{38} with 7 significant digits</td>
<td></td>
</tr>
<tr>
<td>double</td>
<td>64 bits</td>
<td>+/- 1.7 x 10^{308} with 15 significant digits</td>
<td></td>
</tr>
</tbody>
</table>
Characters

- A `char` variable stores a single character.
- Character literals are delimited by single quotes:
  - 'a'  'X'  '7'  '$'  ','  '
'
- Example declarations:

  ```java
  char topGrade = 'A';
  char terminator = ';', separator = ' ';  
  ```

- Note the difference between a primitive character variable, which holds only one character, and a `String` object, which can hold multiple characters.
Character Sets

• A character set is an ordered list of characters, with each character corresponding to 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
Characters

• 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, ...
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
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Expressions

• An expression is a combination of one or more operators and operands that produces a result.

• Arithmetic expressions compute numeric results and make use of the arithmetic operators:

  - Addition: +
  - Subtraction: -
  - Multiplication: *
  - Division: /
  - Remainder: %

• If either or both operands are floating point values, then the result is a floating point value.
Division and Remainder

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

\[
14 \div 3 \quad \text{equals} \quad 4 \\
8 \div 12 \quad \text{equals} \quad 0
\]

• The remainder operator (%) returns the remainder after dividing the first operand by the second

\[
14 \% 3 \quad \text{equals} \quad 2 \\
8 \% 12 \quad \text{equals} \quad 8
\]
Quick Check

What are the results of the following expressions?

- \( \frac{12}{2} \)
- \( \frac{12.0}{2.0} \)
- \( \frac{10}{4} \)
- \( \frac{10}{4.0} \)
- \( \frac{4}{10} \)
- \( \frac{4.0}{10} \)
- \( 12 \mod 3 \)
- \( 10 \mod 3 \)
- \( 3 \mod 10 \)
Quick Check

What are the results of the following expressions?

\[
\begin{array}{ccl}
12 / 2 &=& 6 \\
12.0 / 2.0 &=& 6.0 \\
10 / 4 &=& 2 \\
10 / 4.0 &=& 2.5 \\
4 / 10 &=& 0 \\
4.0 / 10 &=& 0.4 \\
12 \% 3 &=& 0 \\
10 \% 3 &=& 1 \\
3 \% 10 &=& 3 \\
\end{array}
\]
Operator Precedence

• Operators can be **combined** into larger expressions

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

• Operators have a well-defined **precedence** which determines the order in which they are evaluated

• Multiplication, division, and remainder are evaluated **before** addition, subtraction, and string concatenation

• Parentheses have a higher precedence than the other operators

• Arithmetic operators with the **same precedence** are evaluated from **left to right**, but parentheses can be used to force the evaluation order
Quick Check

In what order are the operators evaluated in the following expressions?

\[ a + b + c + d + e \]
\[ a + b * c - d / e \]
\[ a / (b + c) - d \% e \]
\[ a / (b * (c + (d - e))) \]
Quick Check

In what order are the operators evaluated in the following expressions?

\[ a + b + c + d + e \]

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

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

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Quick Check

• How this expression is evaluated:

\[ 1 + 2 + 3 \times 4 \]
Quick Check

- How this expression is evaluated:

$$1 + 2 + 3 \times 4$$

1) $1 + 2$
2) $3 \times 4$
3) $3 + 12$
Expression Trees

- The evaluation of a particular expression can be shown using an expression tree.
- The operators lower in the tree have higher precedence for that expression.

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

\[
\text{answer} = \frac{\text{sum}}{4} + \text{MAX} \times \text{lowest};
\]

\[
\begin{array}{cccc}
4 & 1 & 3 & 2 \\
\end{array}
\]

Then the result is stored in the variable on the left hand side.
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)
Quiz

• What will be the results of the following assignment statement?
• Assume b=5, c=10

```c
int a = b * (-c + 2) / 2
```
Quiz

• What will be the results of the following assignment statement?

• Assume $b=5, \ c=10$

```c
int a = b * (-c + 2) / 2
```

-20
Quiz

• Assume that x, y, and z are all integers (int) equal to 50, 20, and 6 respectively.
• What is the result of: x / y / z

a) 0
b) 0.4166
c) 15
d) A syntax error since it is syntactically invalid
e) A run-time error because this is a division by 0
Quiz

• Assume that x, y, and z are all integers (int) equal to 50, 20, and 6 respectively.
• What is the result of: x / y / z

a) 0 ➞ division is performed left to right and 50/20 = 2, 2/6 = 0
b) 0.4166
c) 15
d) A syntax error since it is syntactically invalid
e) A run-time error because this is a division by 0
Increment and Decrement

• The increment (++) and decrement (--) operators use only one operand

• The statement

```
count++;
```

is functionally equivalent to

```
count = count + 1;
```
Increment and Decrement

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

    count++

• or prefix form:

    ++count

• When used as part of a larger expression, the two forms can have different effects

• Because of their subtleties, the increment and decrement operators should be used with care
Quick Check

• What is printed?

```java
int yy = 3;
System.out.println(++yy + yy*yy);
yy=3;
System.out.println(yy*yy + ++yy);
```
Quick Check

• What is printed?

```java
int yy = 3;
System.out.println(++yy + yy*yy);

yy=3;
System.out.println(yy*yy + ++yy);
```

20
13

The sum is not commutative in JAVA!
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
  
  \[ \text{num += count;} \]

  is equivalent to

  \[ \text{num = num + count;} \]
## Assignment Operators

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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Example</th>
<th>Equivalent To</th>
</tr>
</thead>
<tbody>
<tr>
<td>+=</td>
<td>x += y</td>
<td>x = x + y</td>
</tr>
<tr>
<td>-=</td>
<td>x -= y</td>
<td>x = x - y</td>
</tr>
<tr>
<td>*=</td>
<td>x *= y</td>
<td>x = x * y</td>
</tr>
<tr>
<td>/=</td>
<td>x /= y</td>
<td>x = x / y</td>
</tr>
<tr>
<td>%=</td>
<td>x %= y</td>
<td>x = x % y</td>
</tr>
</tbody>
</table>
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

\[
\text{result } /= (\text{total-MIN}) \% \text{ num};
\]

is equivalent to

\[
\text{result } = \text{result } / ((\text{total-MIN}) \% \text{ num});
\]
Assignment Operators

- The behavior of some assignment operators depends on the types of the operands.

- If the operands to the `+=` operator are strings, the assignment operator performs string concatenation.

- The behavior of an assignment operator (`+=`) is always consistent with the behavior of the corresponding operator (`+`).
Quiz

• What will be printed?

```java
int count, apples;
apples = (count = 3) + 1;
System.out.println("count = " + count);
System.out.println("apples= " + apples);
```
Quiz

• What will be printed?

```java
int count, apples;
apples = (count = 3) + 1;
System.out.println("count = " + count);
System.out.println("apples= " + apples);
```

count = 3
apples= 4
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Data Conversion

- Sometimes it is convenient to convert data from one type to another.

- For example, in a particular situation we may want to treat an integer (e.g. the number of students) as a floating point value (e.g. for calculating the probability of females).

- *These conversions do not change the type of a variable or the value that's stored in it – they only convert a value as part of a computation.*
## Data Conversion

### Widening Conversions

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>short, int, long, float, or double</td>
</tr>
<tr>
<td>short</td>
<td>int, long, float, or double</td>
</tr>
<tr>
<td>char</td>
<td>int, long, float, or double</td>
</tr>
<tr>
<td>int</td>
<td>long, float, or double</td>
</tr>
<tr>
<td>long</td>
<td>float or double</td>
</tr>
<tr>
<td>float</td>
<td>double</td>
</tr>
</tbody>
</table>

### Narrowing Conversions

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>char</td>
</tr>
<tr>
<td>short</td>
<td>byte or char</td>
</tr>
<tr>
<td>char</td>
<td>byte or short</td>
</tr>
<tr>
<td>int</td>
<td>byte, short, or char</td>
</tr>
<tr>
<td>long</td>
<td>byte, short, char, or int</td>
</tr>
<tr>
<td>float</td>
<td>byte, short, char, int, or long</td>
</tr>
<tr>
<td>double</td>
<td>byte, short, char, int, long, or float</td>
</tr>
</tbody>
</table>
Data Conversion

- **Widening conversions** are safest because they tend to go from a small data type to a larger one (such as a `short` to an `int`)

- **Narrowing conversions** can lose information because they tend to go from a large data type to a smaller one (such as an `int` to a `short`)

- In Java, data conversions can occur in three ways:
  - **Assignment conversion** *(only widening)*
  - **Promotion** *(only widening)*
  - **Casting** *(both widening and narrowing)*
Assignment Conversion

- *Assignment conversion* occurs when a value of one type is assigned to a variable of another type.

- Example:
  
  ```
  int dollars = 20;
  double money = dollars;
  ```

- Only widening conversions can happen via assignment (*... why?*)

- Note that the value or type of `dollars` did not change.
Promotion

• *Promotion* happens automatically when *operators* in *expressions* convert their operands

• Example:

```java
int count = 12;
double sum = 490.27;
result = sum / count;
```

• The *value of count* is converted to a floating point *(double)* value to perform the division calculation

• This is independent from the type of the variable `result`
Casting

- *Casting* is the most powerful, and dangerous, technique for conversion

- Both widening and narrowing conversions can be accomplished by explicitly casting a value

- To cast, the type is put in parentheses in front of the value being converted

  ```java
  int total = 50;
  float result = (float) total / 6;
  ```

- Without the cast, the fractional part of the answer would be lost
Quiz

- What is the value of the result variable after the execution of the following statements:

```java
long total = 5;
float result = total / 2;
```
Quiz

• What is the value of the result variable after the execution of the following statements:

```java
long total = 5;
float result = total / 2;
```

2.0
Quiz

- What value will \( z \) have if we execute the following assignment statement?
  
  ```
  int z = 50 / 10.00;
  ```

  - A) 5
  - B) 5.0
  - C) 50
  - D) 10
  - E) none of the above, a run-time error arises because \( z \) is an int and 50 / 10.00 is not
Quiz

• What value will z have if we execute the following assignment statement?
  \[ int z = 50 / 10.00; \]
  
  – A) 5
  – B) 5.0
  – C) 50
  – D) 10
  – E) none of the above, a compile-time error arises because z is an int and 50 / 10.00 is not

• Because 10.00 is a double, the division produces a double precision value which cannot be stored in the int z. Either cast to int 10.00 or the result of the division.
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Drawing Shapes
Interactive Programs

• Programs generally need input on which to operate

• The `Scanner` class provides convenient methods for reading input values of various types

• A `Scanner` object can be set up to read input from various sources, including the user typing values on the keyboard

• Keyboard input is represented by the `System.in` object
Reading Input

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

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

• The `new` operator creates the `Scanner` object

• Once created, the `Scanner` object can be used to invoke various input methods, such as:

  ```java
  answer = scan.nextLine();
  ```
Reading Input

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

- The `nextLine` method reads all of the input until the end of the line is found.

- See `Echo.java`.

- The details of object creation and class libraries are discussed further in Chapter 3.
import java.util.Scanner;

public class Echo
{
    // Reads a character string from the user and prints it.
    public static void main (String[] args)
    {
        String message;
        Scanner scan = new Scanner (System.in);

        System.out.println ("Enter a line of text:"reamble);

        message = scan.nextLine();

        System.out.println ("You entered: \"\" + message + "\"\");;
    }
}
import java.util.Scanner;

public class Echo
{
    // Reads a character string from the user and prints it.
    public static void main (String[] args)
    {
        String message;
        Scanner scan = new Scanner (System.in);

        System.out.println ("Enter a line of text:");
        message = scan.nextLine();

        System.out.println ("You entered: "+ message + "\"");
    }
}
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 *GasMileage.java*
import java.util.Scanner;

public class GasMileage
{
    // Calculates fuel efficiency based on values entered by the user.
    public static void main (String[] args)
    {
        int miles;
        double gallons, mpg;

        Scanner scan = new Scanner (System.in);

        continue
System.out.print("Enter the number of miles: ");
miles = scan.nextInt();

System.out.print("Enter the gallons of fuel used: ");
gallons = scan.nextDouble();

mpg = miles / gallons;

System.out.println("Miles Per Gallon: "+ mpg);
```java
continue
System.out.print
"Enter the number of miles: ");
miles = scan.nextInt();
System.out.print
"Enter the gallons of fuel used: ");
gallons = scan.nextDouble();
mpg = miles / gallons;
System.out.println ("Miles Per Gallon: "+ mpg);
}
```
Outline

Character Strings
Variables and Assignment
Primitive Data Types
Expressions
Data Conversion
Interactive Programs
Graphics
Applets
Drawing Shapes
Introduction to Graphics

• The last few sections of each chapter of the textbook focus on graphics and graphical user interfaces

• A picture or drawing must be digitized for storage on a computer

• A picture is made up of pixels (picture elements), and each pixel is stored separately

• The number of pixels used to represent a picture is called the picture resolution

• The number of pixels that can be displayed by a monitor is called the monitor resolution
Representing Images

• A digitized picture with a small portion magnified:
Coordinate Systems

- Each pixel can be identified using a two-dimensional coordinate system
- When referring to a pixel in a Java program, we use a coordinate system with the origin in the top-left corner
Representing Color

• A **black and white** picture could be stored using one bit per pixel (0 = white and 1 = black)

• A **colored** picture requires more information; there are several techniques for representing colors

• Every color can be represented as a mixture of the three additive primary colors **Red, Green, and Blue**

• Each color is represented by three numbers between 0 and 255 (8 bits) that collectively are called an **RGB value**

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The Color Class

- A color in a Java program is represented as an object created from the `Color` class

- The `Color` class also contains several predefined colors, including the following:

<table>
<thead>
<tr>
<th>Object</th>
<th>RGB Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color.black</td>
<td>0, 0, 0</td>
</tr>
<tr>
<td>Color.blue</td>
<td>0, 0, 255</td>
</tr>
<tr>
<td>Color.cyan</td>
<td>0, 255, 255</td>
</tr>
<tr>
<td>Color.orange</td>
<td>255, 200, 0</td>
</tr>
<tr>
<td>Color.white</td>
<td>255, 255, 255</td>
</tr>
<tr>
<td>Color.yellow</td>
<td>255, 255, 0</td>
</tr>
</tbody>
</table>
Outline

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Applets

- A Java *application* is a stand-alone program with a `main` method (like the ones we've seen so far)

- A Java *applet* is a program that is intended to be transported over the Web and executed using a web browser

- An applet also can be executed using the appletviewer tool of the Java SDK

- An applet doesn't have a `main` method

- Instead, there are several special methods that serve specific purposes
Applets

• The `paint` method is executed automatically whenever the applet’s contents are drawn

• The `paint` method accepts a parameter that is an object of the `Graphics` class

• A `Graphics` object defines a `graphics context` on which we can draw shapes and text

• The `Graphics` class has several methods for drawing shapes
Applets

• We create an applet by extending the JApplet class

• The JApplet class is part of the javax.swing package

• This makes use of inheritance, which is explored in more detail in Chapter 8

• See Einstein.java
import javax.swing.JApplet;
import java.awt.*;

public class Einstein extends JApplet {
    public void paint (Graphics page) {
        page.drawRect (50, 50, 40, 40);  // square
        page.drawRect (60, 80, 225, 30);  // rectangle
        page.drawOval (75, 65, 20, 20);  // circle
        page.drawLine (35, 60, 100, 120);  // line

        page.drawString ("Out of clutter, find simplicity.", 110, 70);
        page.drawString ("-- Albert Einstein", 130, 100);
    }
}
import javax.swing.JApplet;
import java.awt.*

public class Einstein extends JApplet {

    public void paint(Graphics page) {
        page.drawRect(50, 50, 40, 40); // square
        page.drawRect(60, 80, 225, 30); // rectangle
        page.drawOval(75, 65, 20, 20); // circle
        page.drawLine(35, 60, 100, 120); // line

        page.drawString("Out of clutter, find simplicity.", 110, 70);
        page.drawString("-- Albert Einstein", 130, 100);
    }
}

Out of clutter, find simplicity.

-- Albert Einstein
The HTML applet Tag

• An applet is embedded into an HTML file using a tag that references the bytecode file of the applet

• The bytecode version of the program is transported across the web and executed by a Java interpreter that is part of the browser

```html
<html>
  <head>
    <title>The Einstein Applet</title>
  </head>
  <body>
    <applet code="Einstein.class" width=350 height=175>
    </applet>
  </body>
</html>
```
Outline

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Drawing Shapes

• Let's explore some of the methods of the Graphics class that draw shapes in more detail.

• A shape can be filled or unfilled, depending on which method is invoked.

• The method parameters specify coordinates and sizes.

• Shapes with curves, like an oval, are usually drawn by specifying the shape’s bounding rectangle.

• An arc can be thought of as a section of an oval.
Drawing a Line

```java
page.drawLine (10, 20, 150, 45);
```

or

```java
page.drawLine (150, 45, 10, 20);
```

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Drawing a Rectangle

```
page.drawRect (50, 20, 100, 40);
```

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Drawing an Oval

```
page.drawOval (175, 20, 50, 80);
```
Drawing an Arc

- An arc is defined by an oval, a start angle, and an arc angle:

```javascript
drawArc (10, 10, 60, 30, 20, 90)
```
Drawing Shapes

• Every drawing surface has a *background color*

• Every graphics context has a current *foreground color*

• Both can be set explicitly

• See *Snowman.java*
import javax.swing.JApplet;
import java.awt.*;

public class Snowman extends JApplet {
    //---------------------------
    //  Draws a snowman.
    //---------------------------
    public void paint (Graphics page) {
        final int MID = 150;
        final int TOP = 50;

        setBackground (Color.cyan);

        page.setColor (Color.blue);
        page.fillRect (0, 175, 300, 50); // ground

        page.setColor (Color.yellow);
        page.fillOval (-40, -40, 80, 80); // sun

    }
}
continued

```java
page.setColor (Color.white);
page.fillOval (MID-20, TOP, 40, 40); // head
page.fillOval (MID-35, TOP+35, 70, 50); // upper torso
page.fillOval (MID-50, TOP+80, 100, 60); // lower torso

page.setColor (Color.black);
page.fillOval (MID-10, TOP+10, 5, 5); // left eye
page.fillOval (MID+5, TOP+10, 5, 5); // right eye

page.drawArc (MID-10, TOP+20, 20, 10, 190, 160); // smile

page.drawLine (MID-25, TOP+60, MID-50, TOP+40); // left arm
page.drawLine (MID+25, TOP+60, MID+55, TOP+60); // right arm

page.drawLine (MID-20, TOP+5, MID+20, TOP+5); // brim of hat
page.fillRect (MID-15, TOP-20, 30, 25); // top of hat
```

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continued

```java
page.setColor(Color.white);
page.fillOval(MID-20, TOP, 40, 40); // head
page.fillOval(MID-35, TOP+35, 70, 50); // upper torso
page.fillOval(MID-50, TOP+80, 100, 60); // lower torso
page.setColor(Color.black);
page.fillOval(MID-10, TOP+10, 5, 5); // left eye
page.fillOval(MID+5, TOP+10, 5, 5); // right eye
page.drawArc(MID-10, TOP+20, 20, 10, 190, 160); // smile
page.drawLine(MID-25, TOP+60, MID-50, TOP+40); // left arm
page.drawLine(MID+25, TOP+60, MID+55, TOP+60); // right arm
page.drawLine(MID-20, TOP+5, MID+20, TOP+5); // brim of hat
page.fillRect(MID-15, TOP-20, 30, 25); // top of hat
page.fillRect(MID-15, TOP-20, 30, 25); // top of hat
```

Applet Viewer: Snowman.class

Applet started.
Summary

• Chapter 2 focused on:
  – character strings
  – primitive data
  – the declaration and use of variables
  – expressions and operator precedence
  – data conversions
  – accepting input from the user
  – Java applets
  – introduction to graphics
Quiz

• What value is contained in the integer variable length after the following statements are executed?

```java
length = 5;
length *= 2;
length *= length;
length /= 100;
```
Quiz

• What value is contained in the integer variable length after the following statements are executed?

    length = 5;
    length *= 2;
    length *= length;
    length /= 100;

*The final value stored in length is 1.*
Quiz

• Write four different program statements that increment the value of an integer variable total.
Quiz

• Write four different program statements that increment the value of an integer variable `total`.

`total = total + 1;`
`total += 1;`
`total++;`
`++total;`
Quiz

• The following lines of code draw the eyes of the snowman in the Snowman applet. The eyes seem centered on the face when drawn, but the first parameters of each call are not equally offset from the midpoint. Explain.

    page.fillOval (MID-10, TOP+10, 5, 5);
    page.fillOval (MID+5, TOP+10, 5, 5);
Quiz

- The following lines of code draw the eyes of the snowman in the Snowman applet. The eyes seem centered on the face when drawn, but the first parameters of each call are not equally offset from the midpoint. Explain.

```
page.fillOval (MID-10, TOP+10, 5, 5);
page.fillOval (MID+5, TOP+10, 5, 5);
```

*The first parameter specifies the upperleft corner of the eyes, not the center of the eyes. The eyes are circles of diameter 5. Hence, the center of the first eye is $-10 + 2.5 = -7.5$ units to the left of MID, and the second eye is $5 + 2.5 = 7.5$ units to the right of MID.*