The Project

You will begin working on the project starting next week.

- A simple computer game.
- 4 compulsory parts + 1 bonus part
- 10% of the total course mark

You will write small pieces of code that completes the game

- Similar to fill-in-the-blanks
- ***Aim***: see how little pieces you learn fits into larger project
- You will do parts of the project during the lab time or on your own time (check the schedule).

Things to download and use

- Project overview
- starter Java code (for every part)
  - description of the requirements
- Video demonstrations (for every part)

COSC 111

Computer Programming I

Chapter 4: Mathematical Functions, Characters, and Strings

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Acknowledgement: The slides mainly rely on the textbook of Y. D. Liang titled “Introduction to Java Programming, 10th Ed.”, Pearson Edu. Inc.

Formatting Console Output

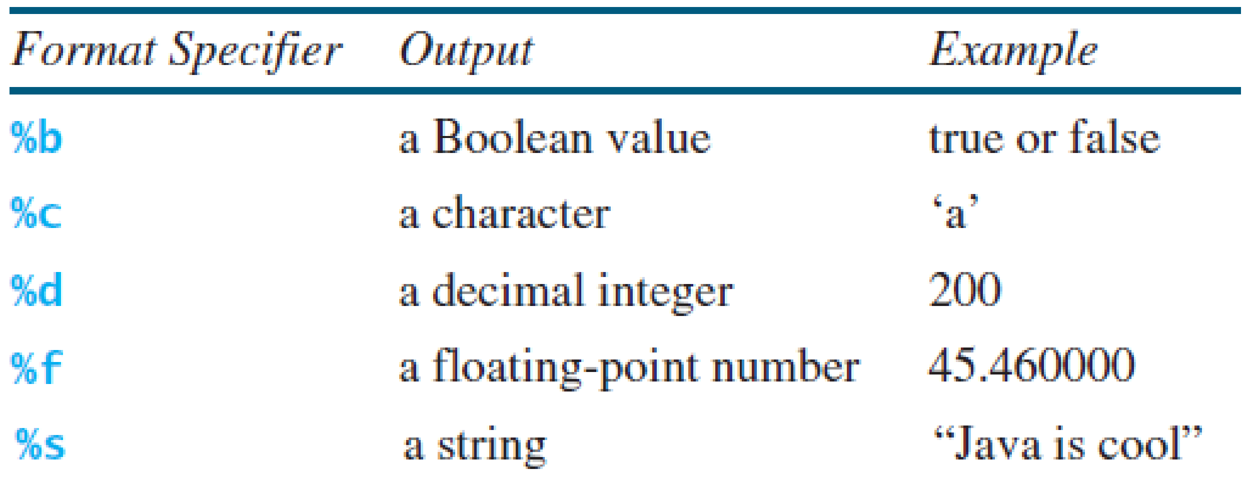
Formatting Console Output: `printf`

You can use the **System.out.printf** *method to display formatted output on the console.* The syntax to invoke this method is

```
System.out.printf(format, item1, ..., itemk)
```

where

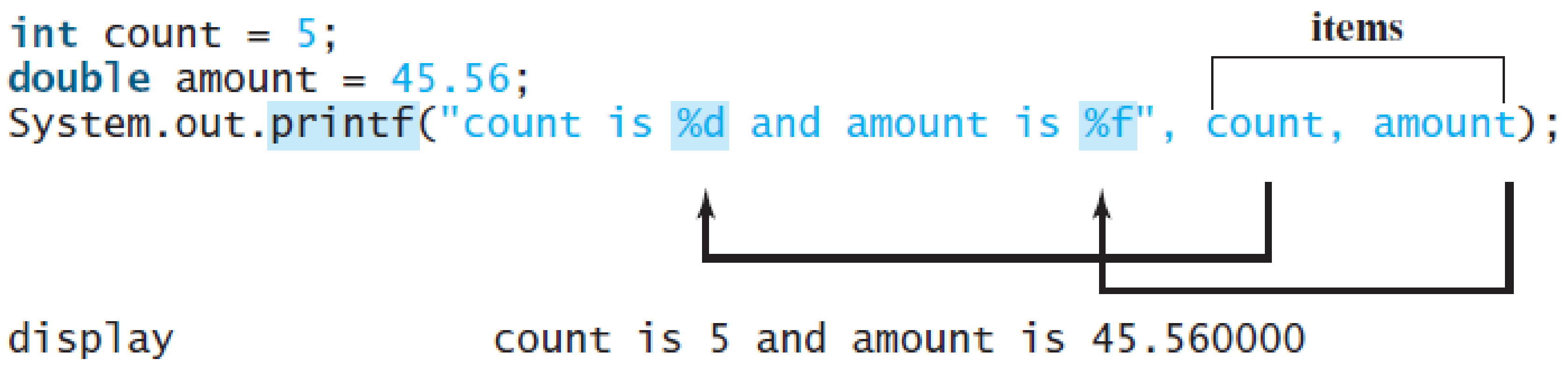
- **format** is a string that may consist of substrings and *format specifiers.*
  - A *format specifier* specifies how an item should be displayed. Each specifier begins with a percent sign.
- **item** may be a numeric value, character, boolean value, or a string.



Format Specifier	*Output*	*Example*
%b	a Boolean value	true or false
%c	a character	‘a’
%d	a decimal integer	200
%f	a floating-point number	45.460000
%s	a string	“Java is cool”

Formatting Console Output

Example:



```
int count = 5;
double amount = 45.56;
System.out.printf("count is %d and amount is %f", count, amount);
```

```
display              count is 5 and amount is 45.560000
```

Formatting Console Output

You can specify the width and precision in a format specifier, as shown in the examples:

%5c	Output the character and add four spaces **before** the character item, because the width is 5.
%6b	Output the Boolean value and add one space before the false value and two spaces before the true value.
%5d	Output the integer item with width at least 5.
%9.2f	Output the floating-point item with width at least 9 including a decimal point and two digits after the point. Thus, there are 6 digits allocated before the decimal point.
%8s	Output the string with width at least 8 characters.

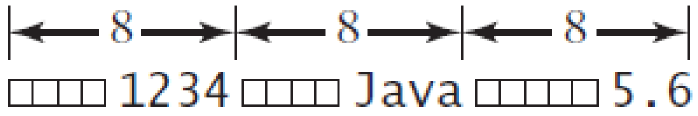
Notes:

- If an item requires more spaces than the specified width, the width is automatically increased.
- By default, the output is right justified. You can put the minus sign (-) in the format specifier to specify that the item is left justified
- The % sign denotes a format specifier. To output a literal % in the format string, use %%.

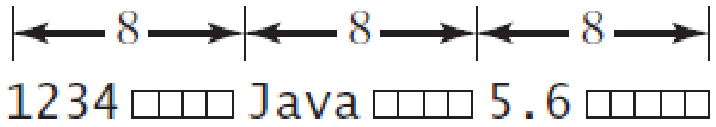
Formatting Console Output: Example1

Examples:

```
System.out.printf("%8d%8s%8.1f\n", 1234, "Java", 5.63);
```



```
System.out.printf("%-8d%-8s%-8.1f \n", 1234, "Java", 5.63);
```



Clicker Question

What is the output?

```
int x = 7;
System.out.println("value of x is %d" + x);
```

A. value of x is 7

B. value of x is %d7

C. value of 7 is 7

D. value of 7 is %d7

E. Error

Clicker Question

What is the output?

```
int x = 7;
System.out.printf("value of x is %d" + x);
```

A. value of x is 7

B. value of x is %d 7

C. value of 7 is 7

D. value of 7 is %d 7

E. Error

Clicker Question

What is the output?

```
int x = 7;
System.out.printf("value of x is %d", x);
```

A. value of x is 7

B. value of x is %d 7

C. value of 7 is 7

D. value of 7 is %d 7

E. Error

Clicker Question

What is the output?

```
int x = 7;
System.out.printf("value of x is %d" + x, x);
```

A. value of x is 77

B. value of x is %d 77

C. value of 7 is 77

D. value of 7 is %d 77

E. Error

The `Math` Class

Mathematical Functions and Constants

Java provides many useful methods in the **`Math`** class for performing common mathematical functions.

- *trigonometric methods*,
- *exponent methods*, and
- *service methods*

Two useful double constants,

- PI
- E (the base of natural logarithms).

Trigonometric Methods

```
Math.sin(r)

Math.cos(r)

Math.tan(r)

Math.acos(r)

Math.asin(r)

Math.atan(r)


Math.toRadians(d)

Math.toDegree(r)
```

Examples:

Math.toDegrees(Math.PI/2) returns 90.0

Math.toRadians(30) returns 0.5236
(i.e., π/6)

Math.sin(0) returns 0.0

Math.sin(Math.PI/6) returns 0.5

Math.sin(Math.toRadians(90)) returns 1.0

Math.cos(0) returns 1.0

Math.cos(Math.PI / 6) returns 0.866

Math.cos(Math.PI / 2) returns 0

Exponent Methods

`Math.pow(a, b)`

- returns a raised to power of b.

`Math.sqrt(a)`

- returns square root of a.

`Math.exp(a)`

- returns e raised to power of a.

`Math.log(a)`

- returns natural logarithm of a.

`Math.log10(a)`

- returns the 10-based logarithm of a.

Examples:

Math.exp(1) returns 2.71

Math.log(2.71) returns 1.0

Math.pow(2, 3) returns 8.0

Math.pow(3, 2) returns 9.0

Math.pow(3.5, 2.5) returns 22.9176

Math.sqrt(4) returns 2.0

Math.sqrt(10.5) returns 3.24

Rounding Methods

`Math.ceil(x)`

- x rounded up to its nearest integer.

`Math.floor(x)`

- x is rounded down to its nearest integer.

`Math.rint(x)`

- x is rounded to its nearest integer.
- If x is equally close to two integers, the ***even*** one is returned

`Math.round(x)`

- Return (int)Math.floor(x+0.5).

In all methods, the result is returned as a double value.

Rounding Methods Examples

<u>Examples:</u>

Math.ceil(2.1) returns 3.0

Math.ceil(2.0) returns 2.0

Math.ceil(-2.0) returns –2.0

Math.ceil(-2.1) returns -2.0

Math.floor(2.1) returns 2.0

Math.floor(2.0) returns 2.0

Math.floor(-2.0) returns –2.0

Math.floor(-2.1) returns -3.0

Math.rint(2.1) returns 2.0

Math.rint(2.0) returns 2.0

Math.rint(-2.0) returns –2.0

Math.rint(-2.1) returns -2.0

Math.rint(2.5) returns 2.0

Math.rint(-2.5) returns -2.0

Math.round(2.6f) returns 3

Math.round(2.0) returns 2

Math.round(-2.0f) returns -2

Math.round(-2.6) returns -3

min, max, and abs methods

`Math.max(a, b)`

`Math.min(a, b)`

- Return the maximum or minimum of a and b.

`Math.abs(a)`

- Returns the absolute value of a.

Examples:

Math.max(2, 3) returns 3

Math.max(2.5, 3) returns 3.0

Math.min(2.5, 3.6) returns 2.5

Math.abs(-2) returns 2

Math.abs(-2.1) returns 2.1

The random Method

`random()`

- Returns a random double value in the range [0.0, 1.0).
  - 0 <= Math.random() < 1.0

Examples:

`(int)(Math.random() * 10)` $\longrightarrow$ Returns a random integer between `0` and `9`.

`50 + (int)(Math.random() * 50)` $\longrightarrow$ Returns a random integer between `50` and `99`.

In general,

`a + Math.random() * b` $\longrightarrow$ Returns a random number between `a` and `a + b`, excluding `a + b`.

Clicker Question

What is the output? (note that Math class is imported by default)

```
double x = floor(2.3) + ceil (1.01);
System.out.println(x);
```

A. 3

B. 3.0

C. 4

D. 4.0

E. Error

Clicker Question

What is the output? (note that Math class is imported by default)

```
double x = Math.floor(-2.3) + Math.ceil (1.01);
System.out.println (x);
```

A. -2.0

B. -1.0

C. 0.0

D. 1.0

E. Error

Clicker Question

Which of the following statements generates a random integer from 0 to 25 inclusive?

A. `int x = Math.random() * 26;`

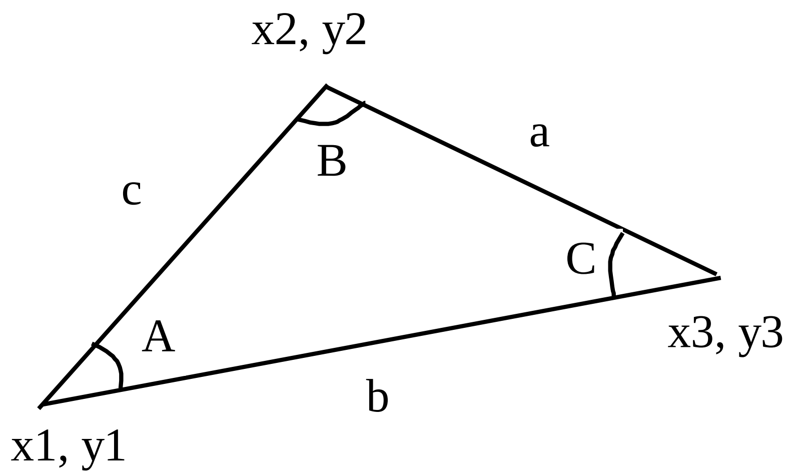
B. `int x = (int) Math.random() * 26;`

C. `int x = (int)( Math.random() * 26 );`

D. `int x = (int)( Math.random() * 25 );`

Practice

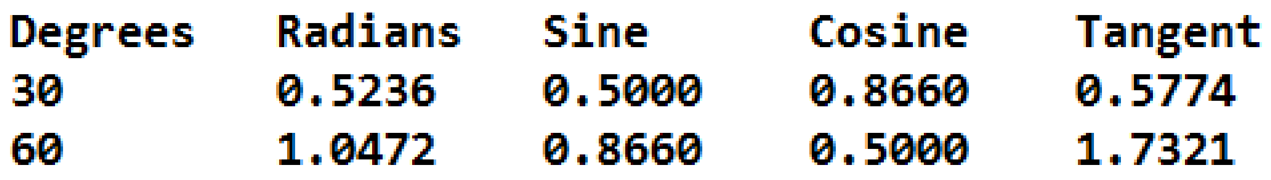
Write a program that prompts the user to enter the x- and y-coordinates of the three corner points in a triangle and then displays the triangle's angles.



A = acos((a * a - b * b - c * c) / (-2 * b * c))
B = acos((b * b - a * a - c * c) / (-2 * a * c))
C = acos((c * c - b * b - a * a) / (-2 * a * b))

Practice

Write a program that declares a variable degrees, assigns it to 30 then 60, and in both cases prints out the following **formatted** output



```
Degrees    Radians    Sine       Cosine     Tangent
30         0.5236     0.5000     0.8660     0.5774
60         1.0472     0.8660     0.5000     1.7321
```

Algorithm

- Step 1: print out the header using printf
- Step 2: Declare a variable degrees and initialize it to 30
- Step 3: print the second line. Hint: use printf and Math functions
- Step 4: assign 60 to degrees
- Step 5: print the third line. Hint: use printf and Math functions

Character Data Type and Operations

Character Data Type

The character data type, **char**, is used to represent a single character.

A character literal is enclosed in single quotation marks.

Examples:

```
char letter = 'A';
char numChar = '4';

char letter = '\u0041';
char numChar = '\u0034';
```

Unicode for character 'A' is 0041

The ++ and -- operators can be used on char variables to get the next or preceding Unicode character. For example.

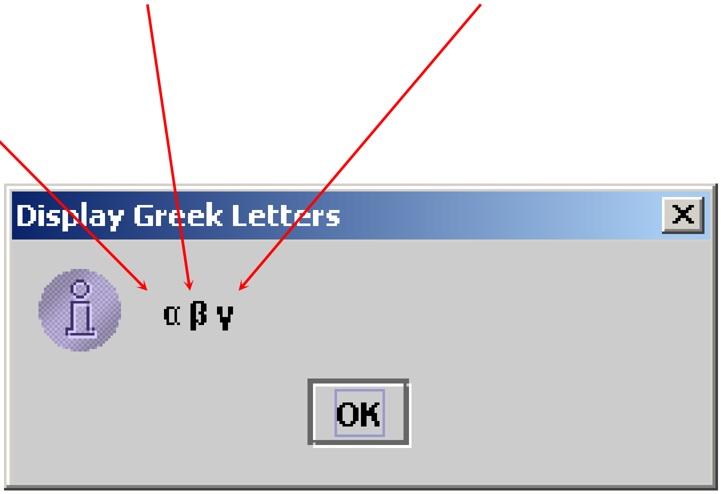
```
char ch = 'a';
System.out.println(++ch); // displays character b
```

Unicode Format

Java characters use Unicode, a 16-bit encoding scheme to support the interchange, processing, and display of written texts in the world's diverse languages.

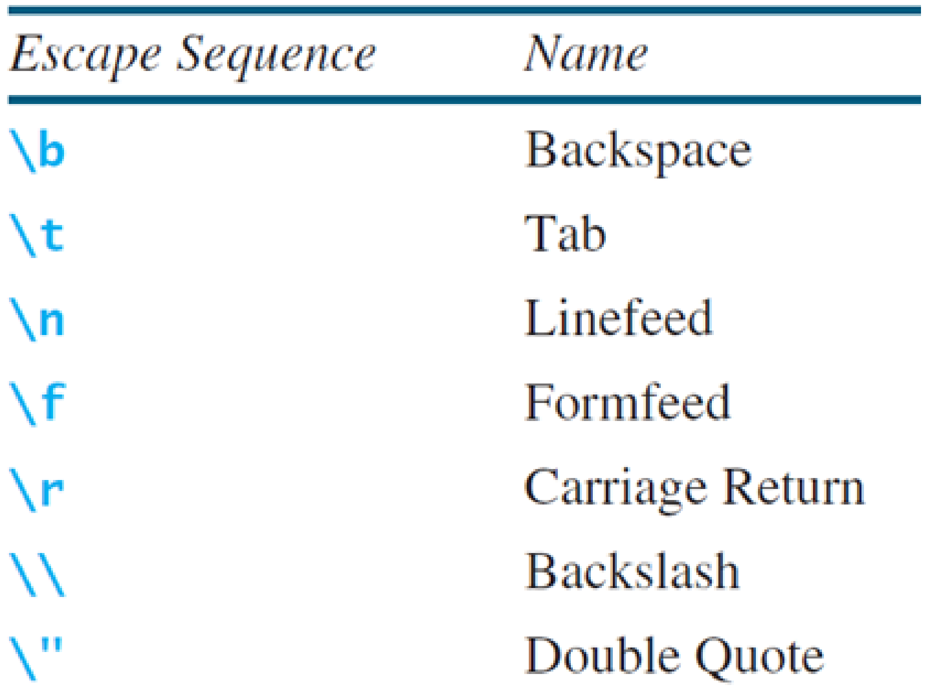
Unicode takes two bytes, preceded by \u, expressed in four hexadecimal numbers that run from '\u0000' to '\uFFFF'.

Unicode `\u03b1` `\u03b2` `\u03b3` for three Greek letters



Escape Sequences for Special Characters

A character preceded by a backslash (\) is an escape sequence and has special meaning to the compiler.



Escape Sequence	*Name*
`\b`	Backspace
`\t`	Tab
`\n`	Linefeed
`\f`	Formfeed
`\r`	Carriage Return
`\\`	Backslash
`\"`	Double Quote

<u>Example</u>: `System.out.println("Welcome to \"UBC\"");`

The output is: Welcome to "UBC"

Casting between char and Numeric Types

A char can be cast into numeric types, and vice versa.

```
int i = 'A';        // decimal value of A which is 65 is stored in I
int i = (int) 'A'; // Same as above
char c = 97;        // Same as char c = (char)97;
```

floating-point values (must be explicit)

```
char ch = (char)65.25;  // Decimal 65 is assigned to ch
```

Comparing and Testing Characters

Characters can be compared based on their Unicode values.

Examples:

'1' < '8'

- **True** because the Unicode for **'1'** (**49**) is less than the Unicode for **'8'** (**56**).

'a' < 'b'

- **True** because the Unicode for **'a'** (**97**) is less than the Unicode for **'b'** (**98**).

'a' < 'A'

- **False** because the Unicode for **'a'** (**97**) is greater than the Unicode for **'A'** (**65**).

Methods in the `Character` Class

`isDigit(ch)`

- Returns true if the specified character is a digit.

`isLetter(ch)`

- Returns true if the specified character is a letter.

`isLetterOrDigit(ch)`

- Returns true if the specified character is a letter or digit.

`isLowerCase(ch)`

- Returns true if the specified character is a lowercase letter.

`isUpperCase(ch)`

- Returns true if the specified character is an uppercase letter.

`toLowerCase(ch)`

- Returns the lowercase of the specified character.

`toUpperCase(ch)`

- Returns the uppercase of the specified character.

Methods in the `Character` Class

For example,

- Character.isDigit(**'a'**) returns false
- Character.isLetter(**'a'**) returns true
- Character.isLowerCase(**'a'**) returns true
- Character.isUpperCase(**'a'**) returns false
- Character.toLowerCase(**'T'**) returns t
- Character.toUpperCase(**'q'**) returns Q

Clicker Question

What is the output?

```
char x = 'a', y = 'c';
System.out.print(++x);
System.out.print(y++);
System.out.print(y - x);
```

A. ac2

B. bc2

C. bd2

D. ac1

E. bc1

Clicker Question

What is the output?

```
System.out.print('a' < 'b');
System.out.print('a' <= 'A');
System.out.print('a' > 'b');
System.out.print('a' != 'b');
```

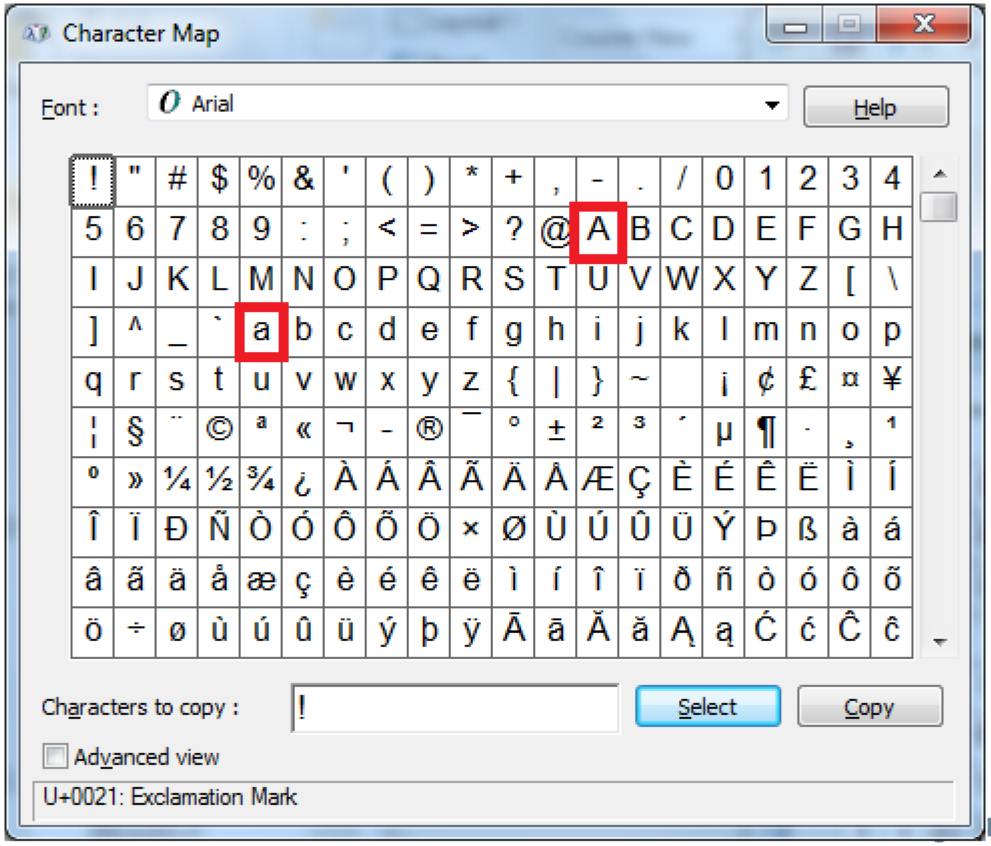
A. true true true true

B. false false false false

C. true true false true

D. true false false true

E. Error



Character Map

Font : Arial

Help

!	"	#	$	%	&	'	(	)	*	+	,	-	.	/	0	1	2	3	4
5	6	7	8	9	:	;	<	=	>	?	@	A	B	C	D	E	F	G	H
I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	[	\
]	^	_	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
q	r	s	t	u	v	w	x	y	z	{	|	}	~		¡	¢	£	¤	¥
¦	§	¨	©	ª	«	¬	-	®	¯	°	±	²	³	´	µ	¶	·	¸	¹
º	»	¼	½	¾	¿	À	Á	Â	Ã	Ä	Å	Æ	Ç	È	É	Ê	Ë	Ì	Í
Î	Ï	Ð	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß	à	á
â	ã	ä	å	æ	ç	è	é	ê	ë	ì	í	î	ï	ð	ñ	ò	ó	ô	õ
ö	÷	ø	ù	ú	û	ü	ý	þ	ÿ	Ā	ā	Ă	ă	Ą	ą	Ć	ć	Ĉ	ĉ

Characters to copy : !

Select

Copy

Advanced view

U+0021: Exclamation Mark

Clicker Question

What is the output?

```
char ch = '5';
int x = ch - '0';  //converts from '5' to 5 ☆
System.out.println(x + 2);
```

A. 52

B. 502

C. '7'

D. 7

E. Error

Clicker Question

What is the output?

```
char ch = '55';

System.out.println(x + 2);
```

A. 552

B. 557

C. "57"

D. 57

E. Error

The String Type

The String Type

To represent *a sequence of characters*, use the data type called **String**.

```
String message = "Welcome to Java";
```

The String type is **not a primitive type**.

- String is actually a predefined class in the Java library just like the System class and Scanner class. It is known as a reference type.
  - Any Java class can be used as a reference type for a variable. Reference data types will be thoroughly discussed in Chapter 9,
  - For the time being, you just need to know how to declare a String variable, how to assign a string to the variable, how to concatenate strings, and to perform simple operations for strings.

Methods for String Objects

`s1.length()`

- Returns the number of characters in the string s1.

  "Welcome".length() returns 7

`s1.charAt(index)`

- Returns the character at the specified index from string s1.

  "Welcome".charAt(0) returns ‘W’

`String s2 = s1.toUpperCase()`

- Returns a new string s2 with all letters of s1 in uppercase.

  "Welcome".toUpperCase() returns a new string, WELCOME

`String s2 = s1.toLowerCase()`

- Returns a new string with all letters in lowercase.

  "Welcome".toLowerCase() returns a new string, welcome

`s1.trim()`

- Trims whitespace characters on both sides of s1.

  " Welcome ".trim() returns a new string, Welcome

Methods for String Objects

Strings are objects in Java.

The methods in the preceding table can only be invoked from a **specific string instance**. For this reason, these methods are called instance methods.

- e.g,

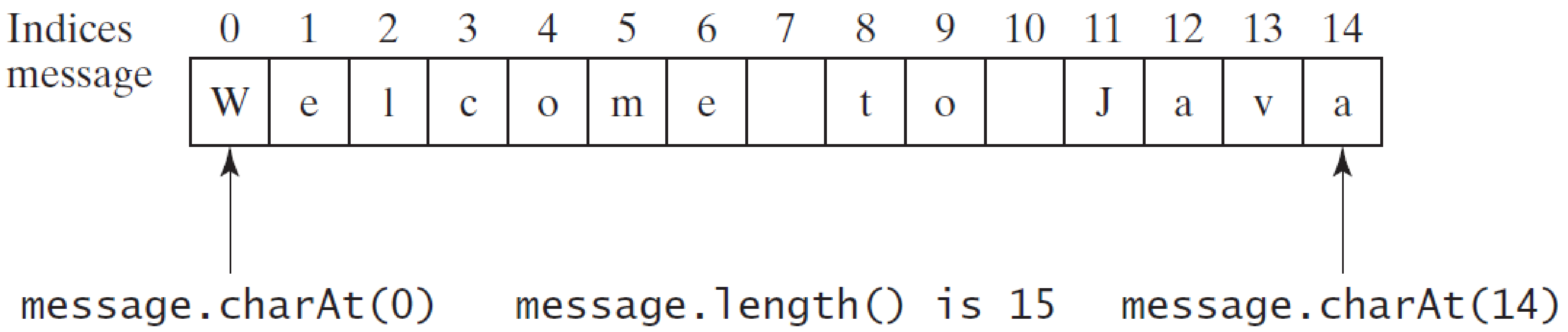
```
String s = “abc”;
int x = s.length()
```

A non-instance method is called a static method. A static method can be invoked without using an object.

- All the methods defined in the **Math class are static methods**. They are not tied to a specific object instance. They can be invoked directly using the Math class. e.g.,

```
Math.sin(Math.PI/2)
```

String: `charAt()`



```
String s= "Welcome to Java";
System.out.println("First character is "
                    + s.charAt(0));
```

Reading a String from the Console

You can use a Scanner object to read a string from the console.

You may use the methods:

- next().
  - To reads a ‘token’.
- nextLine().
  - To read a line of text (ends with *newline* character)
  - The newline character is not read.

Reading a String from the Console

Using next() method.

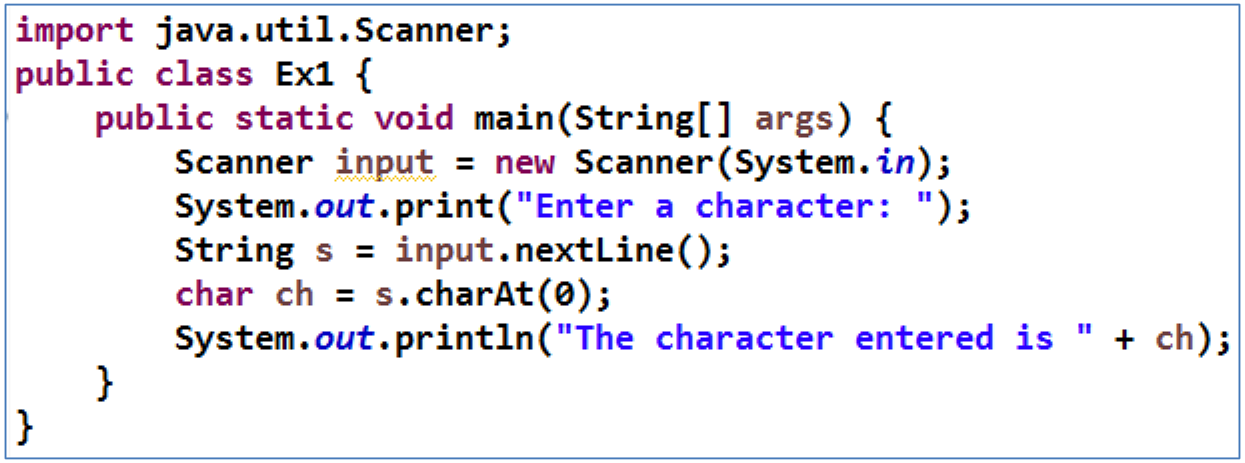
```
import java.util.Scanner;
public class Ex1 {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        System.out.print("Enter 2 words separated by spaces: ");
        String s1 = input.next();
        String s2 = input.next();
        System.out.println("s1 is " + s1);
        System.out.println("s2 is " + s2);
    }
}
```

Using nextLine() method

```
import java.util.Scanner;
public class Ex1 {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        System.out.println("Enter a line: ");
        String s = input.nextLine();
        System.out.println("The line entered is " + s);
    }
}
```

Reading a Character from the Console

use the **nextLine()** method to read text and then invoke the **charAt(0)** method on the text to return the first character.



```java
import java.util.Scanner;
public class Ex1 {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        System.out.print("Enter a character: ");
        String s = input.nextLine();
        char ch = s.charAt(0);
        System.out.println("The character entered is " + ch);
    }
}
```

More methods: Comparing Strings

`s1.equals(s2)`

- returns ***true*** if s1 is equal to s2

`s1.equalsIgnoreCase(s2)`

- same as equals but it is case insensitive.

`s1.compareTo(s2)`

- returns an ***integer*** > 0, = 0, or < 0 to indicate whether s1 is greater than, equal to, or less than s2.

`s1.compareToIgnoreCase(s2)`

- same as compareTo except that it is case insensitive

`s1.startsWith(prefix)`

- returns ***true*** if s1 starts with the specified prefix.

`s1.endsWith(suffix)`

- Returns true if s1 ends with the specified suffix.

`compareTo()`

The method returns

- **0** if **s1** is equal to **s2**
- **Negative value** if **s1** is lexicographically less than **s2**, and
- **Positive value** if **s1** is lexicographically greater than **s2**.

The value returned from the **compareTo** method depends on the **offset of the first two different characters** in **s1** and **s2** from left to right.

Example:

Assume s1 is “**abc**” and **s2** is “**abe**”

s1.compareTo(s2) returns **-2**.

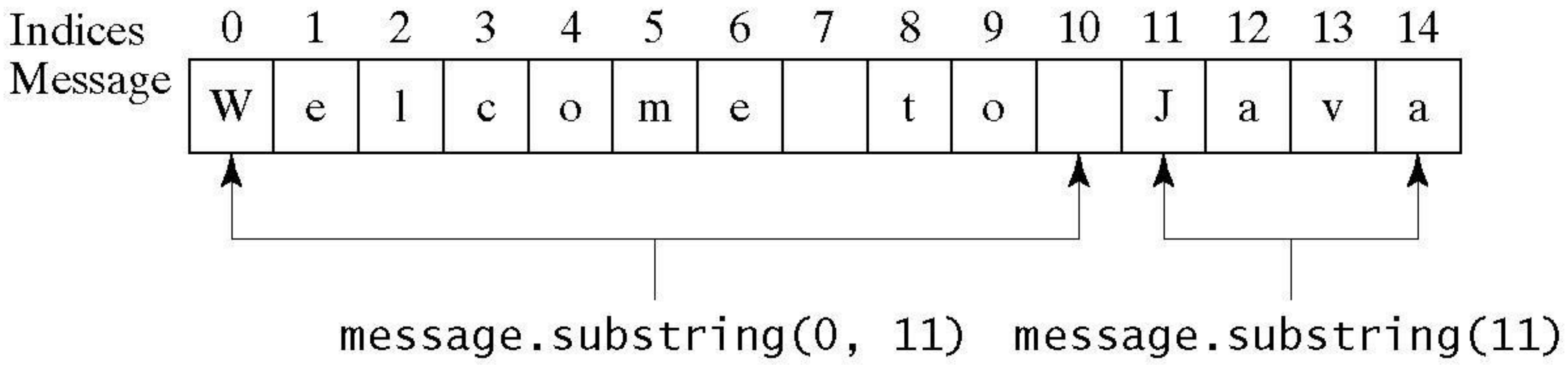
`substring()`

`substring(beginIndex)`

- Returns this string’s substring that begins with the character at the specified beginIndex and extends to the end of the string.

`substring(beginIndex, endIndex)`

- Returns this string’s substring that begins at the specified beginIndex and extends to the character at index endIndex – 1,. Note that the character at endIndex **is not part of** the substring.



`indexOf()` and `lastIndexOf()`

`s1.indexOf(s)`

- Returns index of the first occurrence of s in the s1.

`s1.indexOf(s, fromIndex)`

- Returns index of the first occurrence of s after fromIndex in s1.

`s1.lastIndexOf(s)`

- Returns index of the last occurrence of s in s1.

`s1.lastIndexOf(s, fromIndex)`

- Returns index of last occurrence of s before fromIndex in s1

All above methods

- **return -1 if no match is found.**
- **s could be a character or a string**

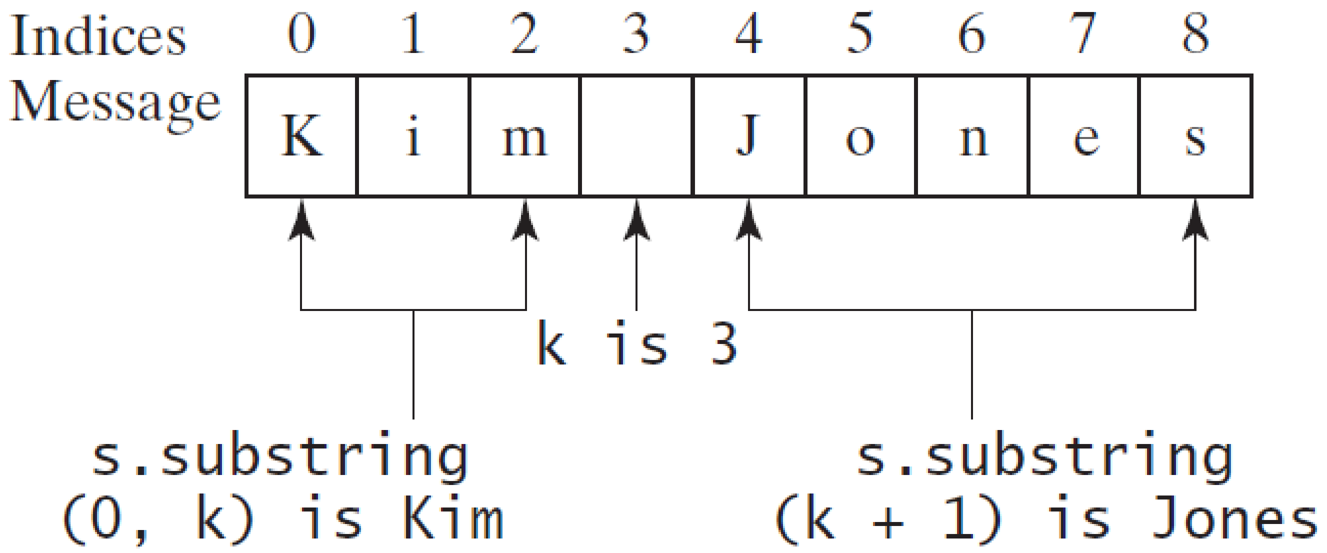
Example1: Finding a Character/Substring

`"Welcome to Java".indexOf('W')` returns `0`.
`"Welcome to Java".indexOf('o')` returns `4`.
`"Welcome to Java".indexOf('o', 5)` returns `9`.
`"Welcome to Java".indexOf("come")` returns `3`.
`"Welcome to Java".indexOf("Java", 5)` returns `11`.
`"Welcome to Java".indexOf("java", 5)` returns `-1`.

`"Welcome to Java".lastIndexOf('W')` returns `0`.
`"Welcome to Java".lastIndexOf('o')` returns `9`.
`"Welcome to Java".lastIndexOf('o', 5)` returns `4`.
`"Welcome to Java".lastIndexOf("come")` returns `3`.
`"Welcome to Java".lastIndexOf("Java", 5)` returns `-1`.
`"Welcome to Java".lastIndexOf("Java")` returns `11`.

Example2: Extracting two words from a string

```
int k = s.indexOf(' ');
String firstName = s.substring(0, k);
String lastName = s.substring(k + 1);
```



Practice

Suppose that **s1**, **s2**, and **s3** are three strings, given as follows:

```
String s1 = "Welcome to Java";
String s2 = "Programming is fun";
String s3 = "Welcome to Java";
```

What are the results of the following expressions?

(a) s1 == s2
(b) s2 == s3
(c) s1.equals(s2)
(d) s1.equals(s3)
(e) s1.compareTo(s2)
(f) s2.compareTo(s3)
(g) s2.compareTo(s2)
(h) s1.charAt(**0**)
(i) s1.indexOf(**'j'**)
(j) s1.indexOf(**"to"**)
(k) s1.lastIndexOf(**'a'**)
(l) s1.lastIndexOf(**"o"**, **15**)
(m) s1.length()
(n) s1.substring(**5**)
(o) s1.substring(**5**, **11**)
(p) s1.startsWith(**"Wel"**)
(q) s1.endsWith(**"Java"**)
(r) s1.toLowerCase()
(s) s1.toUpperCase()
(t) s1.concat(s2)
(u) s1.contains(s2)
(v) **"\t Wel \t"**.trim()

Clicker Question

What is the output?

```
String s1, s2;
Scanner in = new Scanner(System.in);

s1 = in.nextLine();  // User enters: abc
s2 = in.nextLine();  // User enters: abc

System.out.println(s1 == s2)
```

A. true

B. false

Clicker Question

What is the output?

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

String s1 = in.nextLine(); // User enters abc
String s2 = in.nextLine(); // User enters abc

System.out.println(s1.equals(s2));
System.out.println(s1 == s2);
```

A. `true    true`

B. `false   false`

C. `true    false`

D. `false   true`

Conversion between Strings and Numbers

Numeric String → Number :

```
int x = Integer.parseInt("5");                //x is now equal to 5
double y = Double.parseDouble("5.21"); //y is now equal to 5.21
```

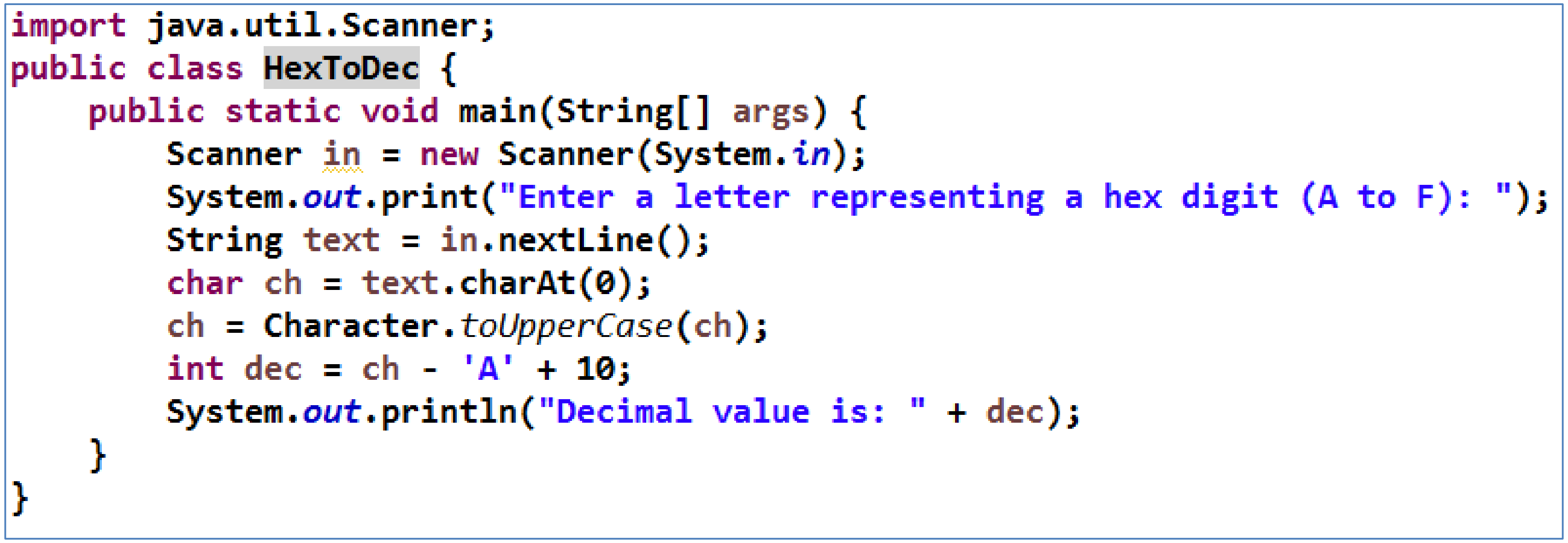
Number → string:

```
String s = 3.1 + "";                          //s is now equal to "3.1"
```

Practice

Write a program that reads from a user a single letter representing a hexadecimal digit and convert it into a decimal value. Hexadecimal digits represented by a letter are (with their values): A = 10, B=11, …, F=15.

- Hint: the ‘-’ operator can be used with characters.



```java
import java.util.Scanner;
public class HexToDec {
    public static void main(String[] args) {
        Scanner in = new Scanner(System.in);
        System.out.print("Enter a letter representing a hex digit (A to F): ");
        String text = in.nextLine();
        char ch = text.charAt(0);
        ch = Character.toUpperCase(ch);
        int dec = ch - 'A' + 10;
        System.out.println("Decimal value is: " + dec);
    }
}
```