CS 162FZ: Introduction to Computer Science II

Lecture 04

Regular Expressions

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What is a regular expression?

- A regular expression is a special sequence of characters that helps you match or find other strings or sets of strings, using a specialized syntax held in a pattern.

- They can be used to search, edit, or manipulate text and data.

Regular Expressions: RegEx

- **Reg**ular **Ex**pressions are routinely used for validating input and retrieving information
- They ensure some level of validity when users are required to input (including web forms):
  - *peoples name, postal address, birth dates, Zip code, phone numbers, , credit card numbers*
  - *user ID names, passwords (& levels of security), email addresses, WWW address, file names*
  - *product codes, valid dates, cash amounts, MU Moodle course codes ...*

RegEx can find or specify:

- We can find/specify any of the following:
- The word "*car*" when it appears as an isolated word
- The sequence of characters "*car*" appearing consecutively in any context, such as in "***ca**r*", "***car**toon*", or "*bi**car**bonate*"
- The characters "*car*" occurring in that order with other characters between them, such as in "*I**c**el**a**nde**r***" or "***c**h**a**ndle**r***"

RegEx can find or specify:

- The word "*car*" when preceded by the word "*blue*" or "*red*"
- The word "*car*" when *not* preceded by the word "*motor*"
- A Euro sign immediately followed by one or more digits, and then optionally a period and exactly two more digits (for example, *“€100"* or *“€245.99")*.

Regular Expressions (RegEx)

- A concise means of matching strings
- Written in a formal language that is **VERY** widely used
  - Java, C, C++, .Net, Python, Perl, Ruby, Tcl, Unix (grep), and many text editors…
  - See Java's `Pattern class.`
    - `matches()`, but also applies to `replace()` and `split()`

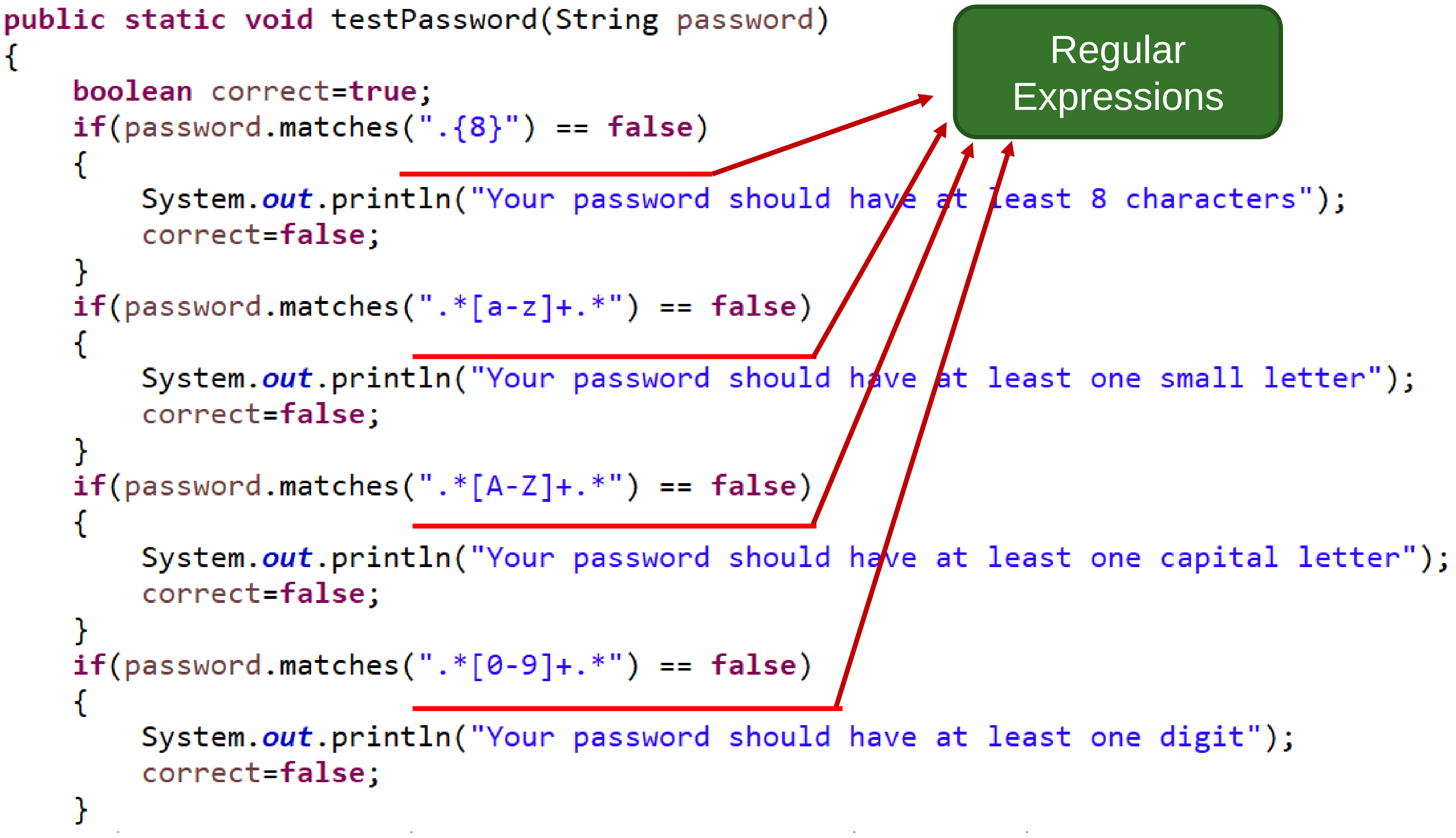
Password Example

- Write a Java method called testPassword that accepts a single string variable called password.
- Your method should examine this password and print suggestions to the user about how to improve the quality of that password.
- Use regular expressions to examine the password.

Good Passwords

- A good password has 8 characters or more
- A good password contains at least one lower case letter
- A good password contains at least one capital letter
- A good password contains at least one digit

Code Segment of Password Example

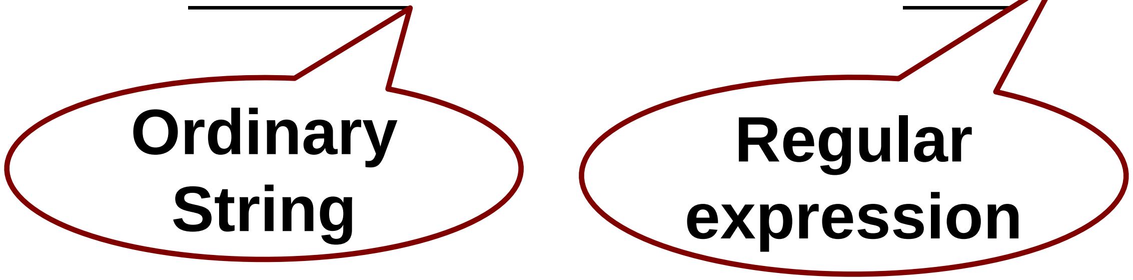


```
public static void testPassword(String password)
{
    boolean correct=true;
    if(password.matches(".{8}") == false)
    {
        System.out.println("Your password should have at least 8 characters");
        correct=false;
    }
    if(password.matches(".*[a-z]+.*") == false)
    {
        System.out.println("Your password should have at least one small letter");
        correct=false;
    }
    if(password.matches(".*[A-Z]+.*") == false)
    {
        System.out.println("Your password should have at least one capital letter");
        correct=false;
    }
    if(password.matches(".*[0-9]+.*") == false)
    {
        System.out.println("Your password should have at least one digit");
        correct=false;
    }
```

Regular Expressions

String.matches(String regex)

- Regular expressions are used by both the
  - String class using matches() method, and the
  - Pattern & Matcher classes
-
```
boolean bool =
“abbbb”.matches(“ab*”)
```


Ordinary String

Regular expression

- The general format for the matches method is

“Problem-string” .matches(“RegEx”)

Example .matches

- “abc”.matches(“abc”)
- “Abc”.matches(“Abc”)
- “Abc”.matches(“abc”) //false
- “aabbaba”.matches(“[ab]*”)
- “aabbaba”.matches(“a[ab]*”)
- “bbaba”.matches(“a[ab]*”)//false

RegEx as a String Template

- We can think of the regular expression grammar as a ***template*** against which to match strings
- Typically, we either
  - find something that matches a template from a large volume of data
  - Ensure that a specific datum matches a template
    - Searching the internet, text of books, textual records …
  - Looking for valid phone numbers, student ID, names, variables ...

Regular Expression Grammar

- **Sequence** (*and*) is the 1st character followed by 2nd character…
  - abc // exact match
  - Abc // case sensitive
- **Alternatives** (*or*) are enclosed in **[]**
  - ca[bdn] // cab, cad, can

    //NOT car, cat...
  - Diarm[au]id //alternative spellings
  - [Dd]ean //possible captials

More RegEx

- **Not [^]**
  - ca[^brt] can and cad, but **not** ca**r**, ca**t** or ca**b**

Note ^ can be used to match the beginning of a line.

- **Ranges**
  - [a-z] any lower case letter
  - [A-Z] any capital letter
  - [0-9] any digit
  - [a-z&&[^xyz]] a-z but **Not** x, y or z

Quantifiers

- * **zero or more** times (Kleene *)
  - ab* — a ab abb abbbb
  - [ab]* — aa aabbababba aabbaba abba bbba
- + **One or more** times
  - ab+ — ab abb abbbb
  - [0-9]+ — any sequence of >1 digits
  - [A-Z]+ — any sequence of >1 capitals
- ? **Zero or once** **(An Optional character)**
  - Colou?r — Colour Color
  - rea?d — red read, but **not** reed

Counted Items

- Counted number of items
  - x{3}   // xxx only
- At least number of items
  - x{3,}   /// xxx xxxx xxxxxxxx *etc* *3 or more*
- Between 2 and 4 instances of
  - x{2,4}   xx, xxx and xxxx only
  - .[a-z]{2,4}   Top level of email address (.ie .com .info)

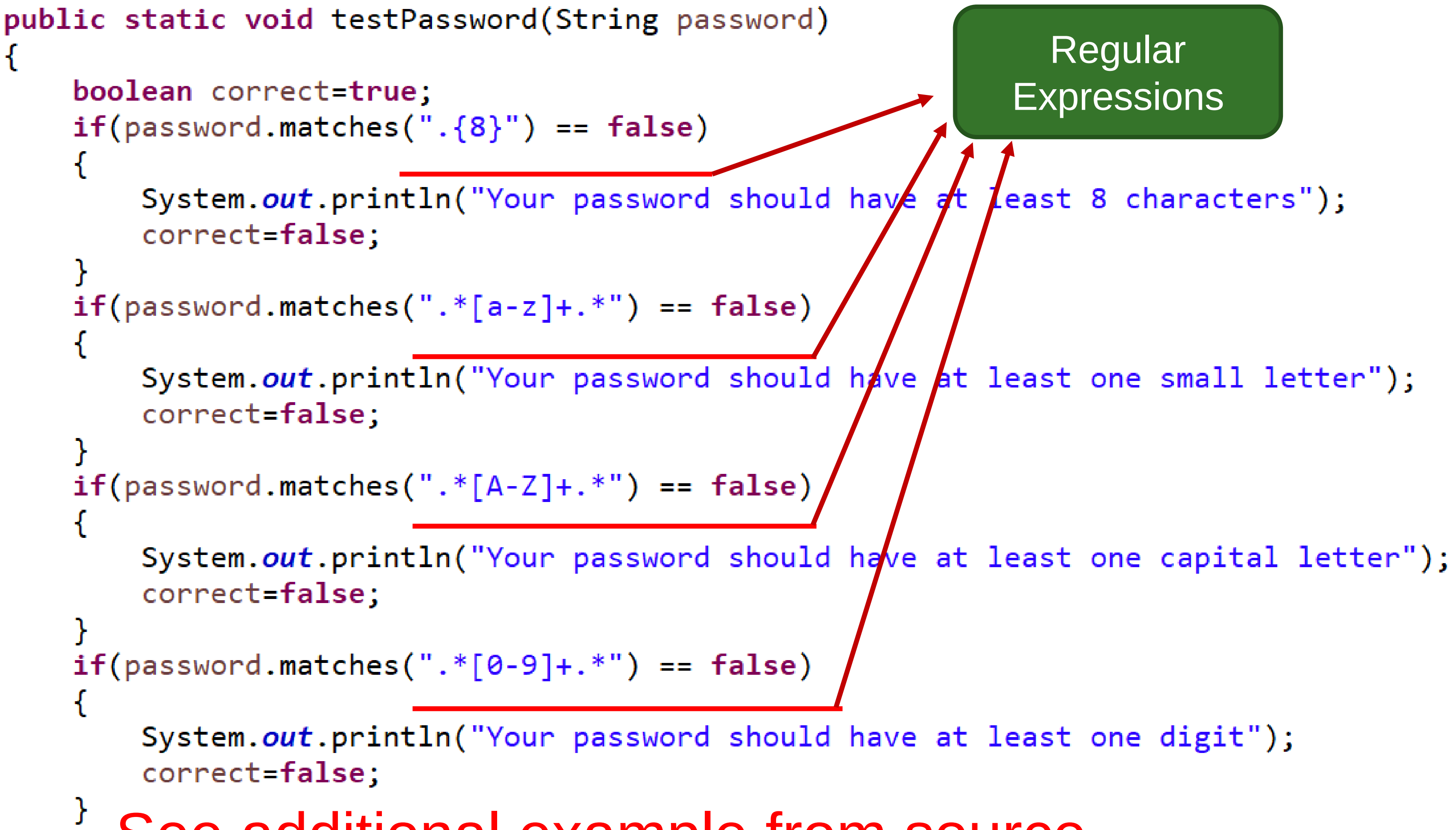
Wild Character = “ . “

- The dot **.** is the wild character which allows for **<u>any</u>** character in a string except the new line character

For example:

re.d // matches *read reed rezd*

Password Example Revisit



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        correct=false;
    }
    if(password.matches(".*[a-z]+.*") == false)
    {
        System.out.println("Your password should have at least one small letter");
        correct=false;
    }
    if(password.matches(".*[A-Z]+.*") == false)
    {
        System.out.println("Your password should have at least one capital letter");
        correct=false;
    }
    if(password.matches(".*[0-9]+.*") == false)
    {
        System.out.println("Your password should have at least one digit");
        correct=false;
    }
```

Regular Expressions

See additional example from source code:`RegularExpressions1`

Special Characters

- Special characters are occasionally used within “complicated” strings
- How do we get a String that contains the ” character?
- We use backslash so that the following character is not treated in the usual way
    - “the quote \” mark “ matches *the quote “ mark*
- So how do we get a backslash in a string?
    - “one \\ character” **Matches** *one backslash \ character*
    - “two backslash \\\\ characters”**Matches** *two backslash \\ characters*

Special Characters & Strings

- Write down the Java code that creates the following Strings

What Java sees	**What i must type**
“ab”c”	“ab\”c”
“ab””c”	“ab\”\”c”
“ab\c”	“ab\\c”
“ab\\c”	“ab\\\\c”

Special Characters in RegEx

- Remember the **.** will match any character
- Note: the backslash **** character is a special character. It means, **do Not** treat the following character in the normal way

\.	The full stop character
\b	word boundary
\s	white space (space or tab)
\\	the backslash \ character
\t	the Tab character
\d	the digits
\w	the word characters

a "word" is a nonempty sequence of alphanumeric characters and underscores

RegEx Problems

- Specify a valid variable name
  - “abc12".matches("[a-z]+[a-z1-9]*")
- Specify a forename followed by surname (lowercase)
  - “tom jones”.matches(“[a-z]*\\s[a-z]*”)
- Can you specify
  - A valid email address?
  - Are there any limitations to your answer?
  - A dollar amount?

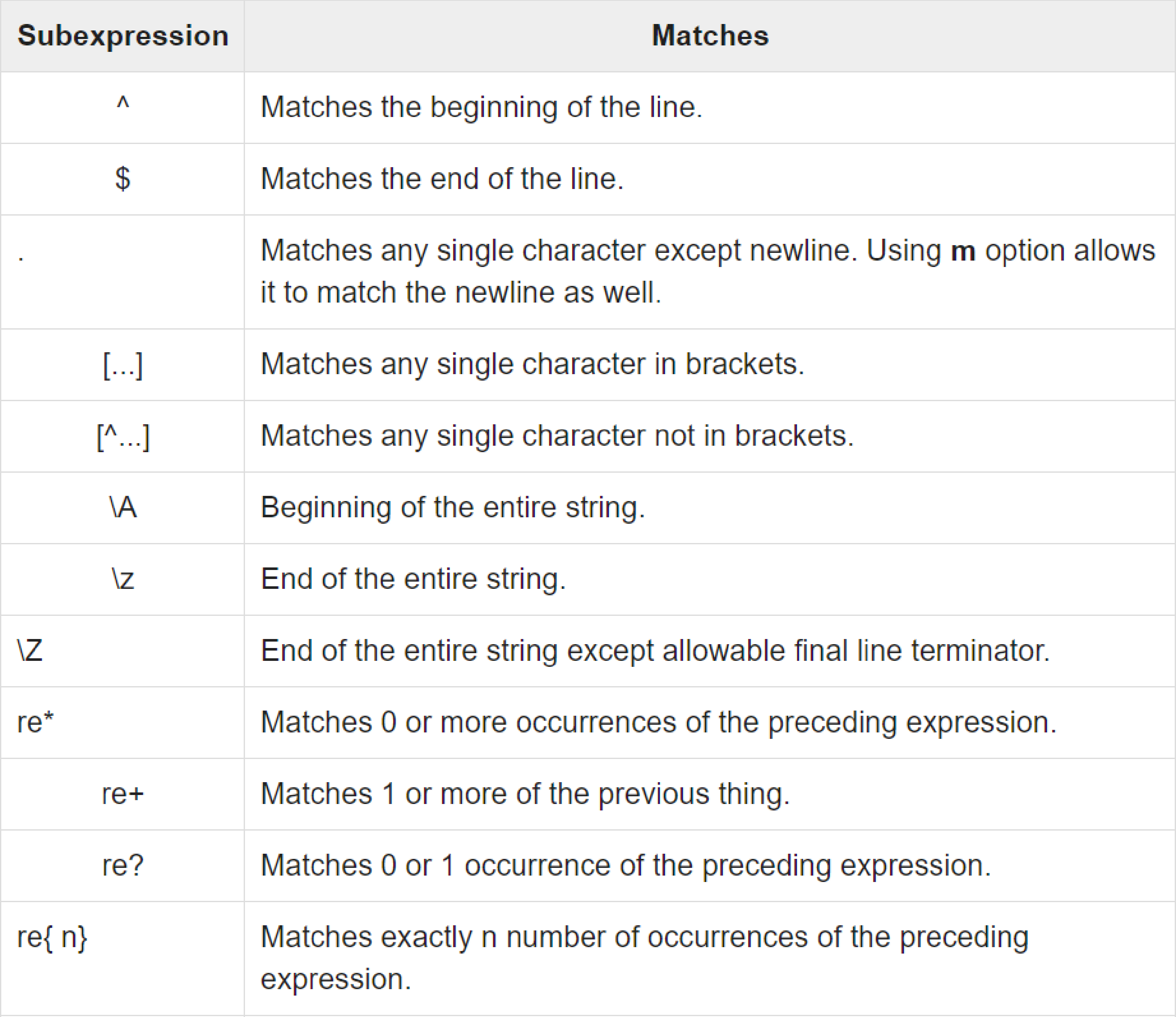
See source code:`RegularExpressions2`

Answer: [a-z]+\.[a-z]+@mu\.ie

Specify a RegEx for the

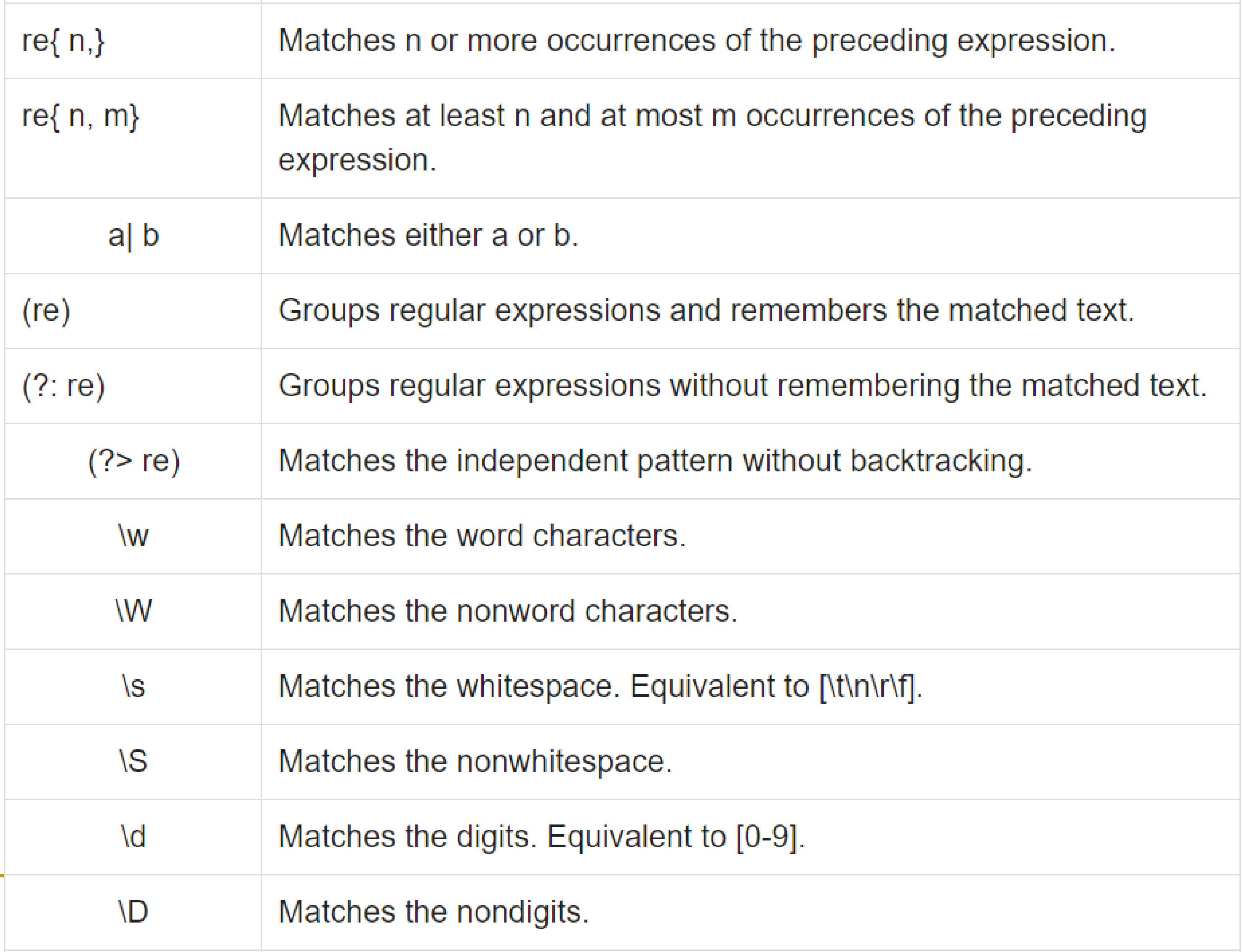
- NUIM course codes
  - *CS161, CS162 etc*
- A full Euro amount
  - *€50, €995, €65000*
- Roman numerals (between I and VII)
  - I, II, III, IV, V, VI, VII,
- Any Roman numeral
  - Using the characters IVXCLM

Regular Expression Syntax



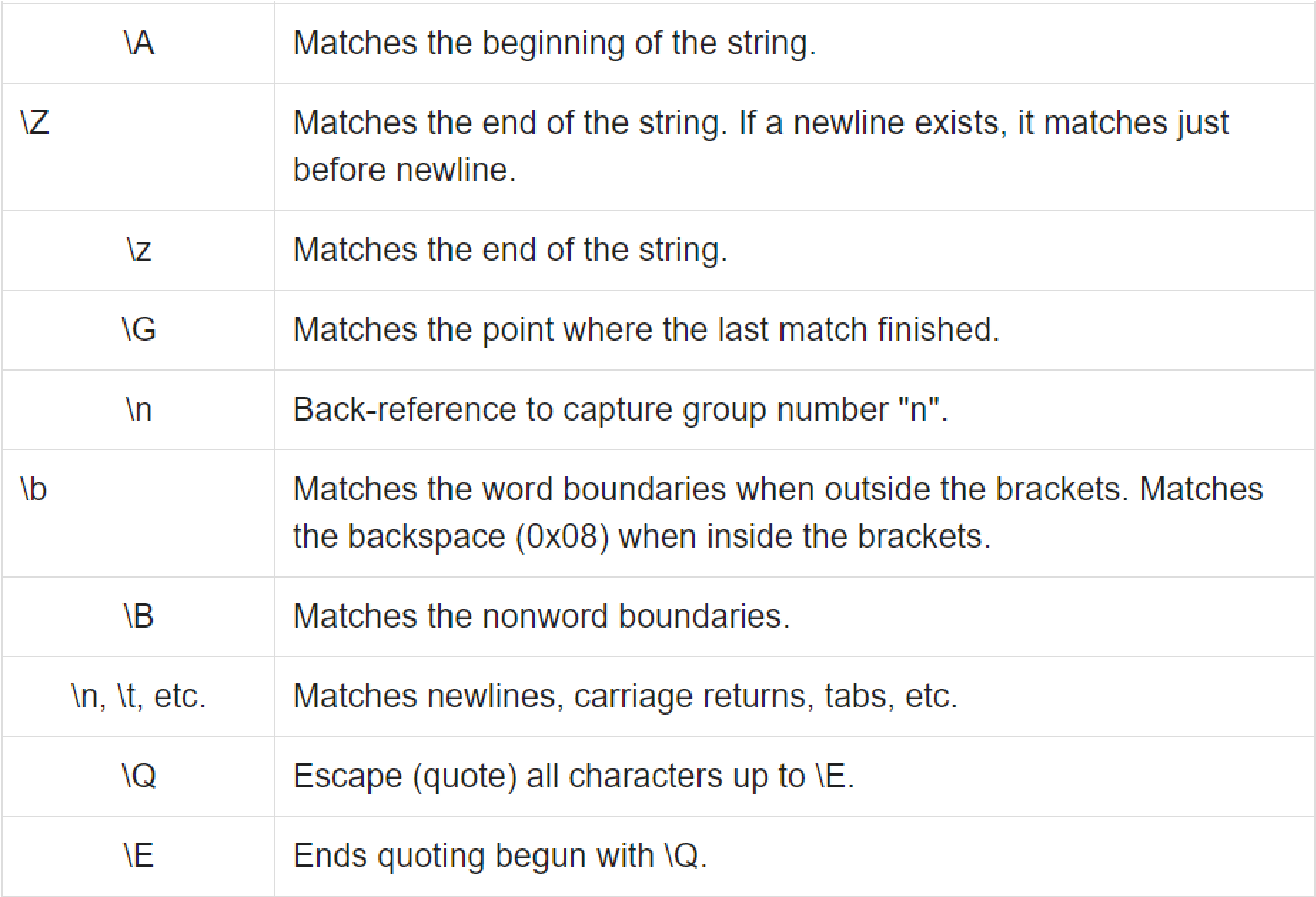
Subexpression	Matches
^	Matches the beginning of the line.
$	Matches the end of the line.
.	Matches any single character except newline. Using **m** option allows it to match the newline as well.
[...]	Matches any single character in brackets.
[^...]	Matches any single character not in brackets.
\A	Beginning of the entire string.
\z	End of the entire string.
\Z	End of the entire string except allowable final line terminator.
re*	Matches 0 or more occurrences of the preceding expression.
re+	Matches 1 or more of the previous thing.
re?	Matches 0 or 1 occurrence of the preceding expression.
re{ n}	Matches exactly n number of occurrences of the preceding expression.

Regular Expression Syntax



re{ n,}	Matches n or more occurrences of the preceding expression.
re{ n, m}	Matches at least n and at most m occurrences of the preceding expression.
a| b	Matches either a or b.
(re)	Groups regular expressions and remembers the matched text.
(?: re)	Groups regular expressions without remembering the matched text.
(?> re)	Matches the independent pattern without backtracking.
\w	Matches the word characters.
\W	Matches the nonword characters.
\s	Matches the whitespace. Equivalent to [\t\n\r\f].
\S	Matches the nonwhitespace.
\d	Matches the digits. Equivalent to [0-9].
\D	Matches the nondigits.

Regular Expression Syntax



\A	Matches the beginning of the string.
\Z	Matches the end of the string. If a newline exists, it matches just before newline.
\z	Matches the end of the string.
\G	Matches the point where the last match finished.
\n	Back-reference to capture group number "n".
\b	Matches the word boundaries when outside the brackets. Matches the backspace (0x08) when inside the brackets.
\B	Matches the nonword boundaries.
\n, \t, etc.	Matches newlines, carriage returns, tabs, etc.
\Q	Escape (quote) all characters up to \E.
\E	Ends quoting begun with \Q.

java.util.regex package

Pattern Class − A Pattern object is a compiled representation of a regular expression. The Pattern class provides no public constructors. To create a pattern, you must first invoke one of its public static compile() methods, which will then return a Pattern object. These methods accept a regular expression as the first argument.

java.util.regex package

Matcher Class − A Matcher object is the engine that interprets the pattern and performs match operations against an input string. Like the Pattern class, Matcher defines no public constructors. You obtain a Matcher object by invoking the matcher() method on a Pattern object.

java.util.regex package

PatternSyntaxException −

A PatternSyntaxException object is an unchecked exception that indicates a syntax error in a regular expression pattern.

Capturing Groups

- Capturing groups are a way to treat multiple characters as a single unit. They are created by placing the characters to be grouped inside a set of parentheses. For example, the regular expression (dog) creates a single group containing the letters "d", "o", and "g".
- Capturing groups are numbered by counting their opening parentheses from the left to the right. In the expression ((A)(B(C))), for example, there are four such groups −

  ((A)(B(C)))

  (A)

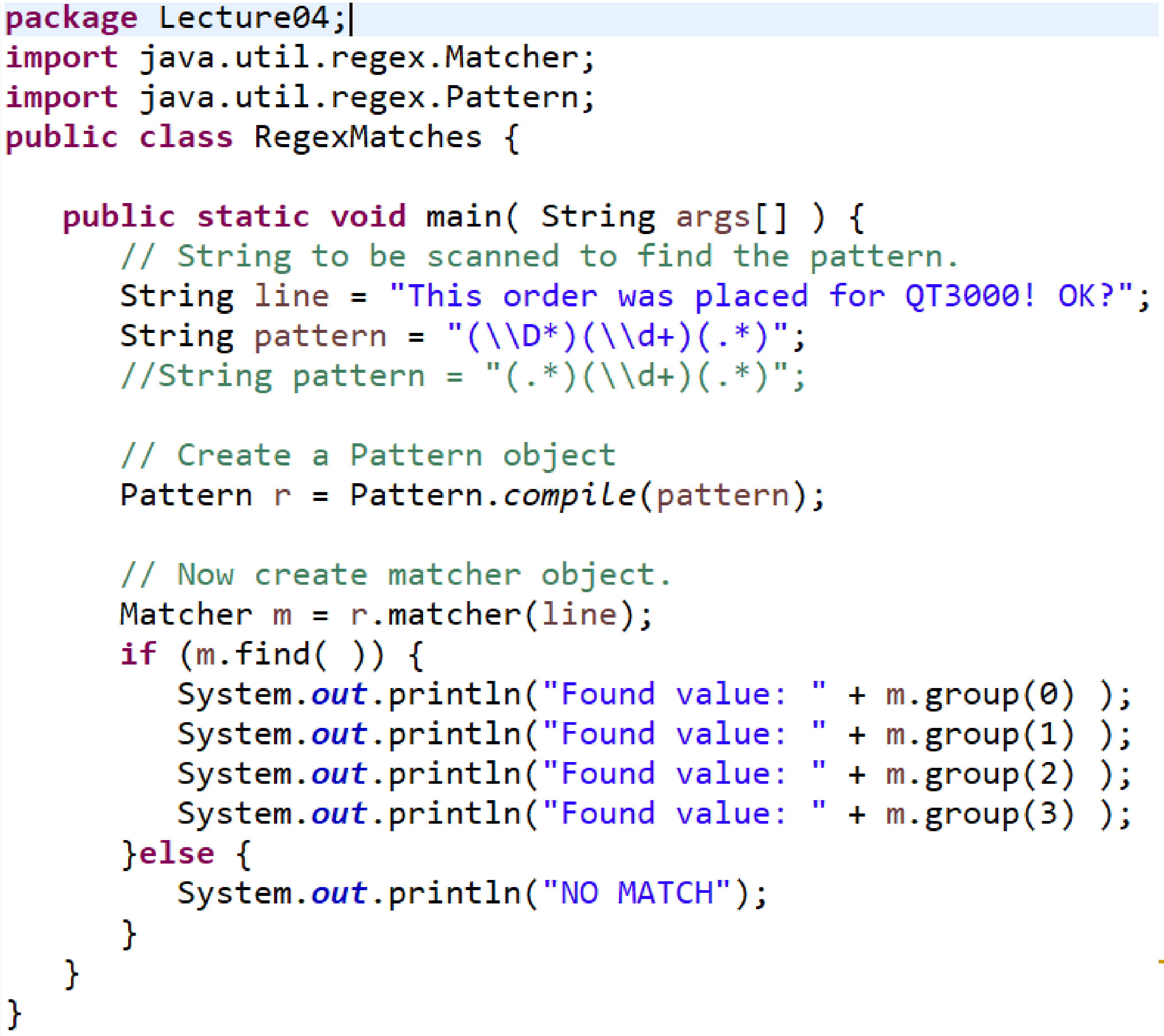
  (B(C))

  (C)

groupCount

- To find out how many groups are present in the expression, call the groupCount method on a matcher object. The groupCount method returns an **int** showing the number of capturing groups present in the matcher's pattern.
- There is also a special group, group 0, which always represents the entire expression. This group is not included in the total reported by groupCount.

groupCount - Example



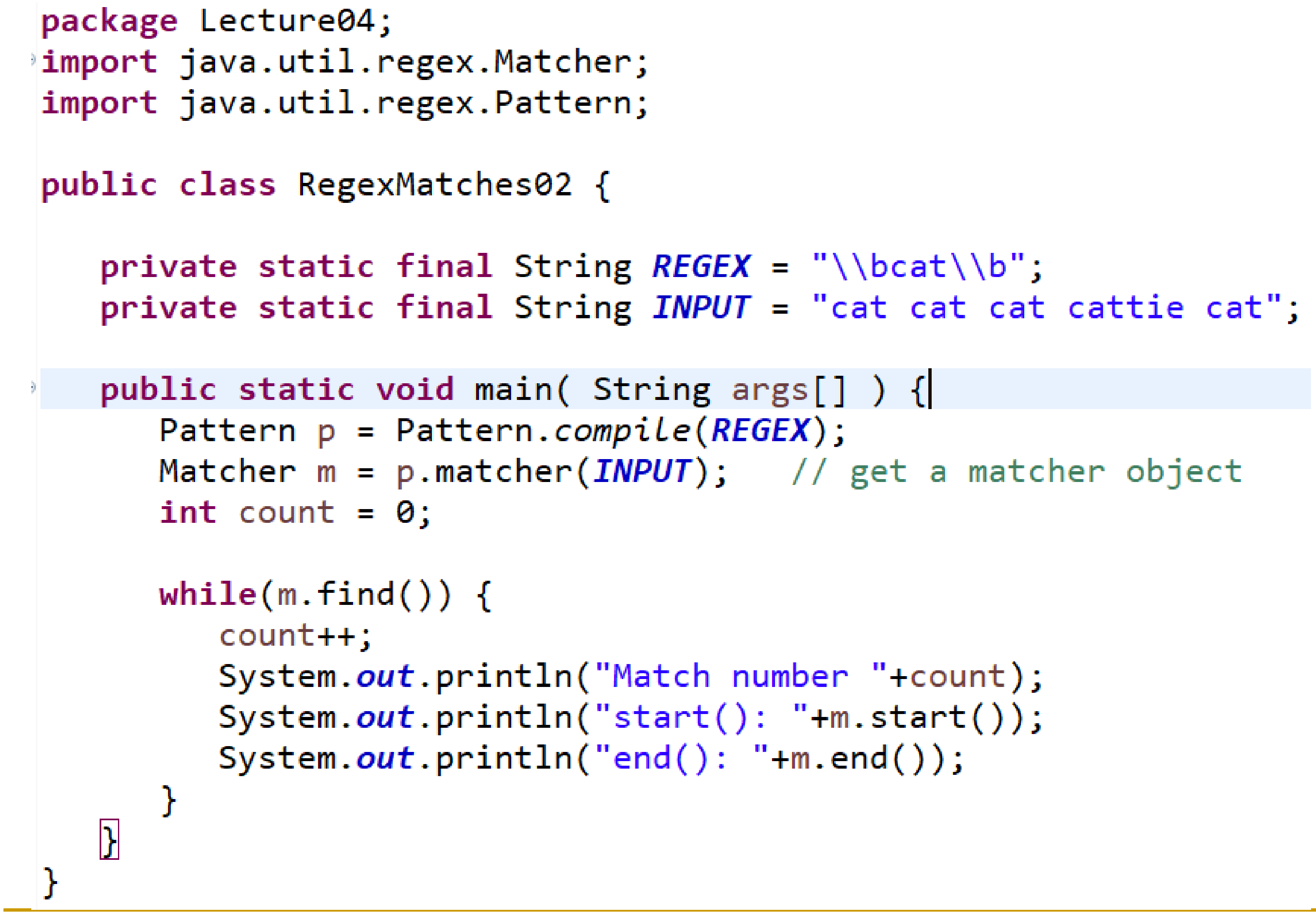
```
package Lecture04;
import java.util.regex.Matcher;
import java.util.regex.Pattern;
public class RegexMatches {

   public static void main( String args[] ) {
      // String to be scanned to find the pattern.
      String line = "This order was placed for QT3000! OK?";
      String pattern = "(\\D*)(\\d+)(.*)";
      //String pattern = "(.*)(\\d+)(.*)";

      // Create a Pattern object
      Pattern r = Pattern.compile(pattern);

      // Now create matcher object.
      Matcher m = r.matcher(line);
      if (m.find( )) {
         System.out.println("Found value: " + m.group(0) );
         System.out.println("Found value: " + m.group(1) );
         System.out.println("Found value: " + m.group(2) );
         System.out.println("Found value: " + m.group(3) );
      }else {
         System.out.println("NO MATCH");
      }
   }
}
```

The start and end Methods

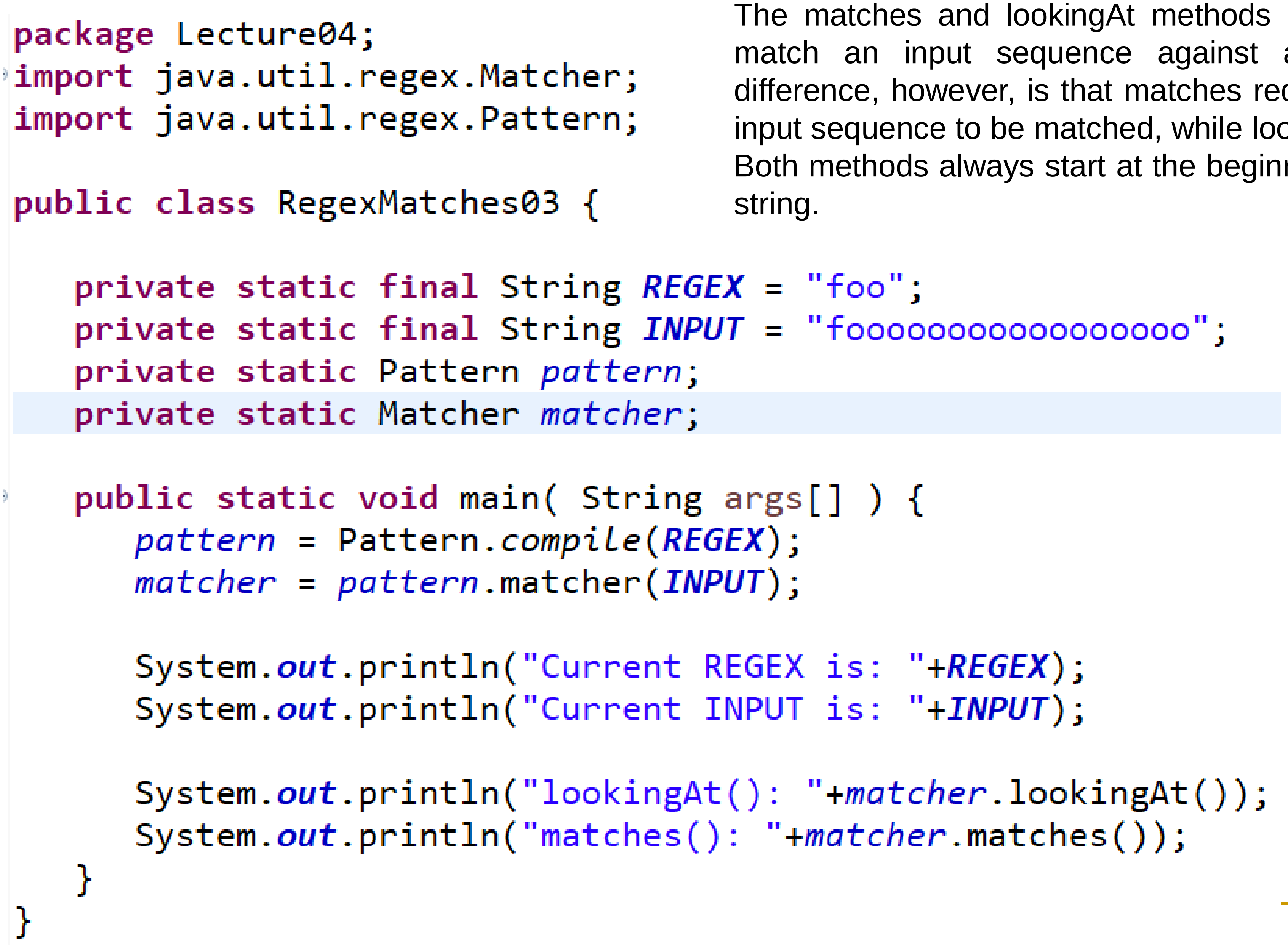


```java
package Lecture04;
import java.util.regex.Matcher;
import java.util.regex.Pattern;

public class RegexMatches02 {

    private static final String REGEX = "\\bcat\\b";
    private static final String INPUT = "cat cat cat cattie cat";

    public static void main( String args[] ) {
        Pattern p = Pattern.compile(REGEX);
        Matcher m = p.matcher(INPUT);   // get a matcher object
        int count = 0;

        while(m.find()) {
            count++;
            System.out.println("Match number "+count);
            System.out.println("start(): "+m.start());
            System.out.println("end(): "+m.end());
        }
    }
}
```

Match number 1 start(): 0 end(): 3 Match number 2 start(): 4 end(): 7 Match number 3 start(): 8 end(): 11 Match number 4 start(): 19 end(): 22

The matches and lookingAt Methods

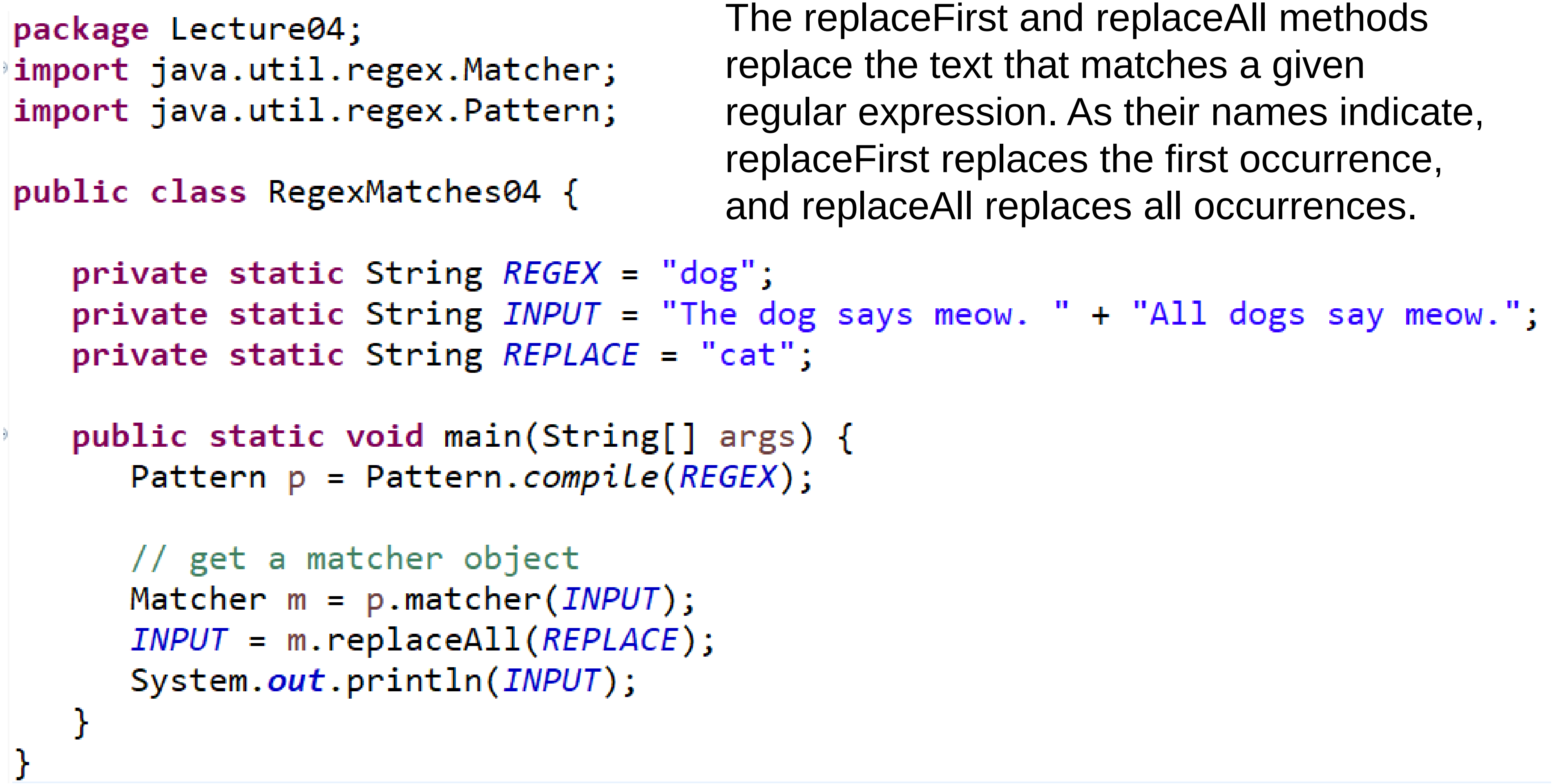
The matches and lookingAt methods both attempt to match an input sequence against a pattern. The difference, however, is that matches requires the entire input sequence to be matched, while lookingAt does not. Both methods always start at the beginning of the input string.



```
package Lecture04;
import java.util.regex.Matcher;
import java.util.regex.Pattern;

public class RegexMatches03 {

   private static final String REGEX = "foo";
   private static final String INPUT = "fooooooooooooooooo";
   private static Pattern pattern;
   private static Matcher matcher;

   public static void main( String args[] ) {
      pattern = Pattern.compile(REGEX);
      matcher = pattern.matcher(INPUT);

      System.out.println("Current REGEX is: "+REGEX);
      System.out.println("Current INPUT is: "+INPUT);

      System.out.println("lookingAt(): "+matcher.lookingAt());
      System.out.println("matches(): "+matcher.matches());
   }
}
```

replaceFirst and replaceAll Methods

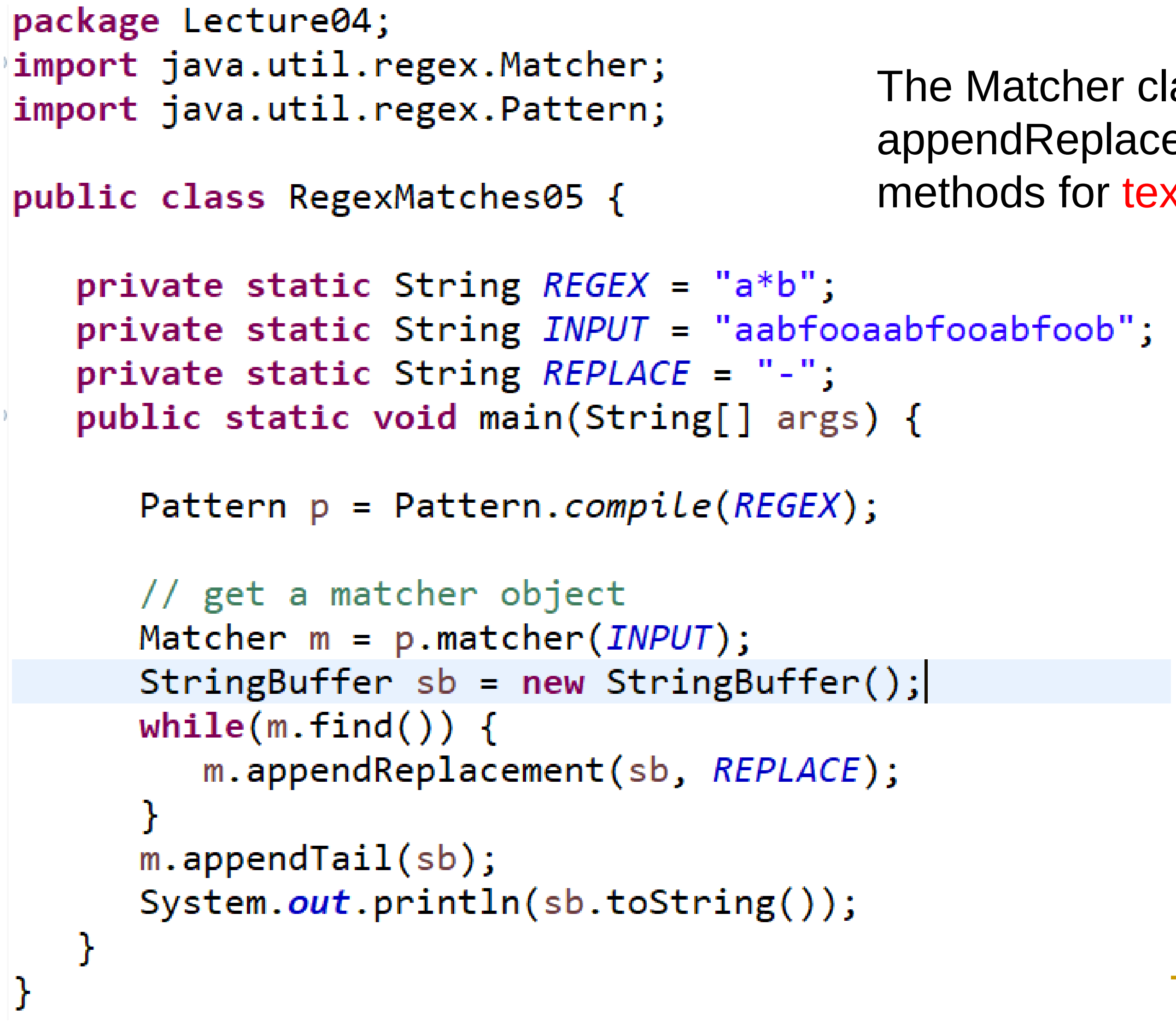
The replaceFirst and replaceAll methods replace the text that matches a given regular expression. As their names indicate, replaceFirst replaces the first occurrence, and replaceAll replaces all occurrences.



```java
package Lecture04;
import java.util.regex.Matcher;
import java.util.regex.Pattern;

public class RegexMatches04 {

   private static String REGEX = "dog";
   private static String INPUT = "The dog says meow. " + "All dogs say meow.";
   private static String REPLACE = "cat";

   public static void main(String[] args) {
      Pattern p = Pattern.compile(REGEX);

      // get a matcher object
      Matcher m = p.matcher(INPUT);
      INPUT = m.replaceAll(REPLACE);
      System.out.println(INPUT);
   }
}
```

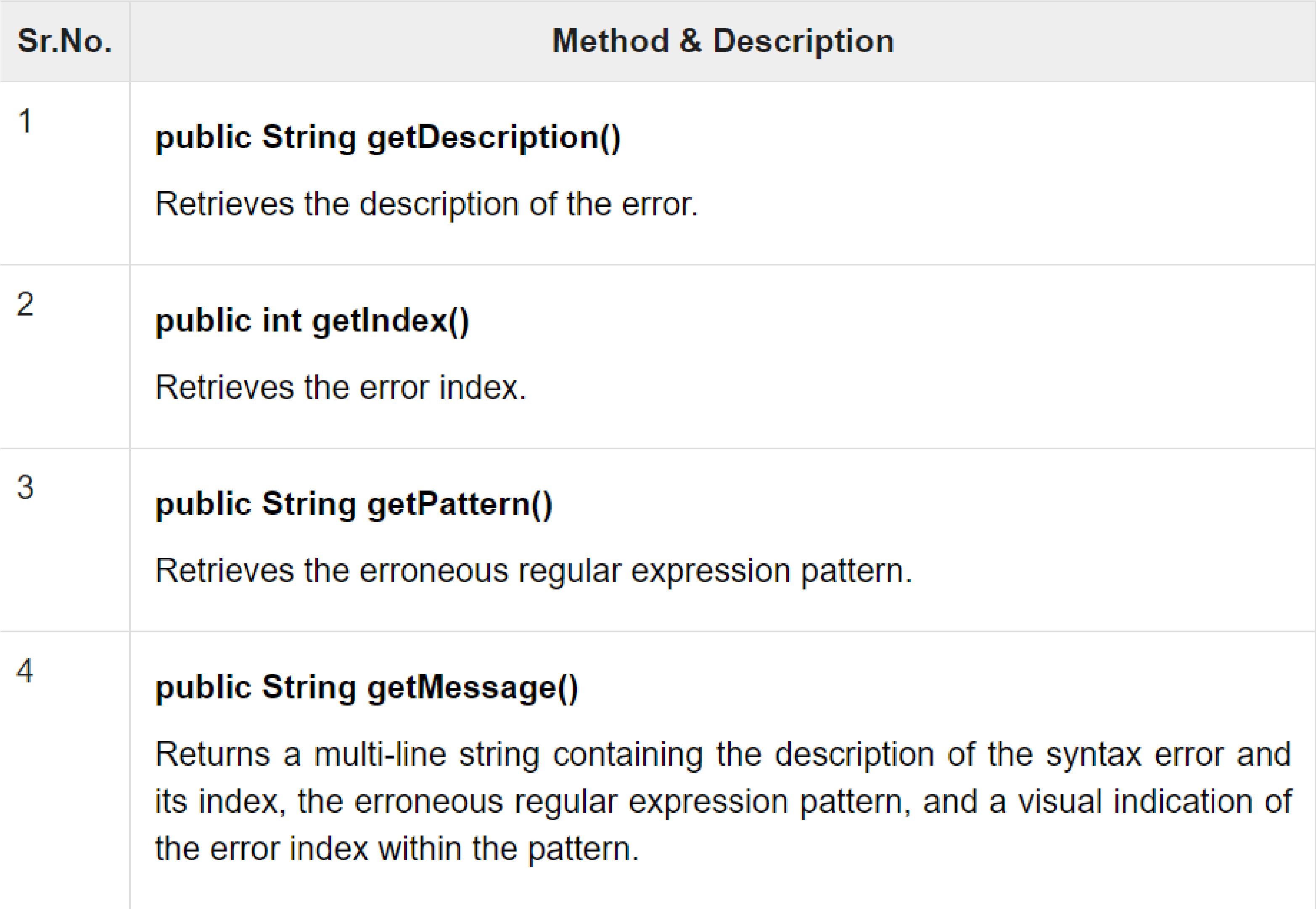
The appendReplacement and appendTail Methods

The Matcher class also provides appendReplacement and appendTail methods for text replacement.



```
package Lecture04;
import java.util.regex.Matcher;
import java.util.regex.Pattern;

public class RegexMatches05 {

   private static String REGEX = "a*b";
   private static String INPUT = "aabfooaabfooabfoob";
   private static String REPLACE = "-";
   public static void main(String[] args) {

      Pattern p = Pattern.compile(REGEX);

      // get a matcher object
      Matcher m = p.matcher(INPUT);
      StringBuffer sb = new StringBuffer();
      while(m.find()) {
         m.appendReplacement(sb, REPLACE);
      }
      m.appendTail(sb);
      System.out.println(sb.toString());
   }
}
```

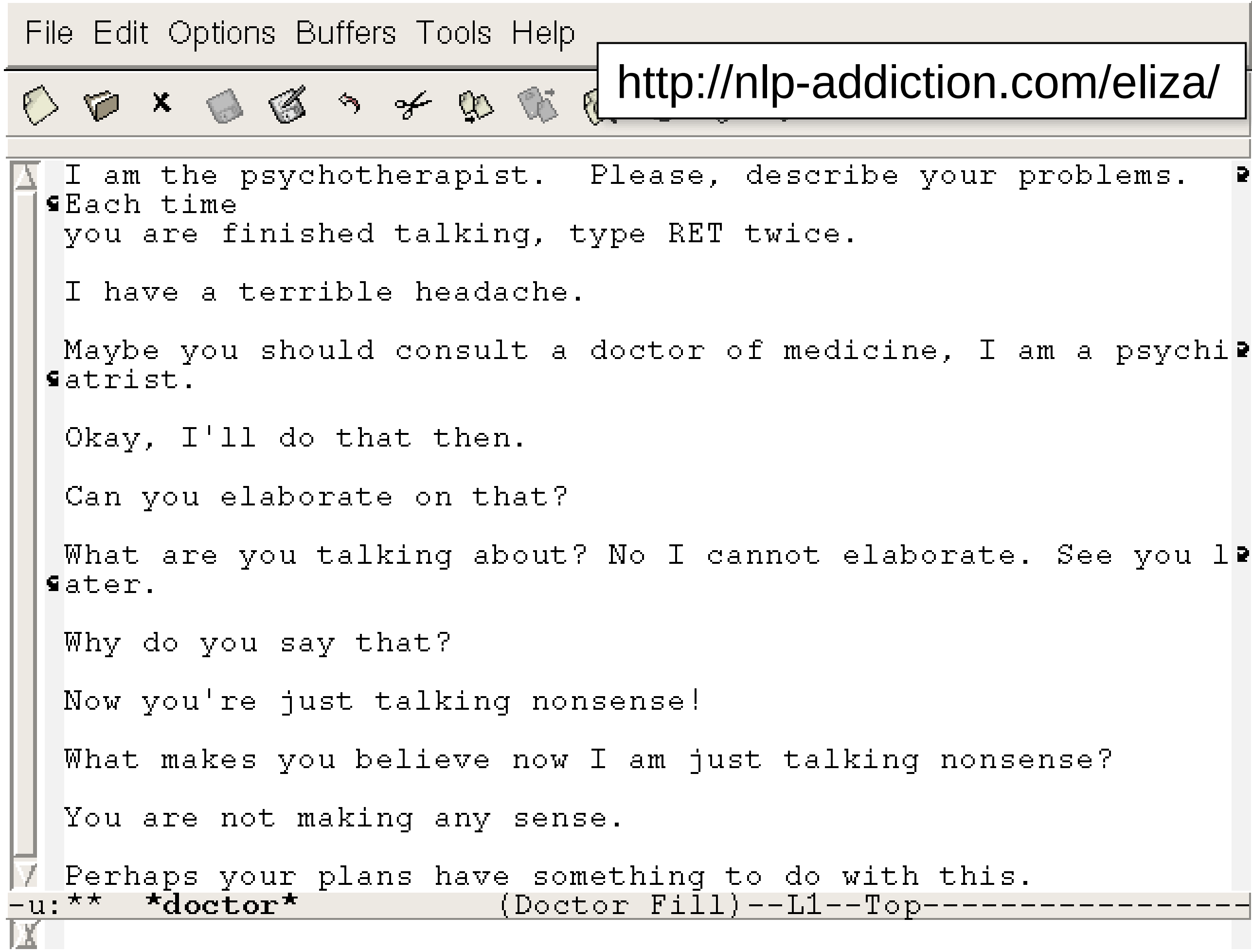
PatternSyntaxException ClassMethods



Sr.No.	Method & Description
1	**public String getDescription()** Retrieves the description of the error.
2	**public int getIndex()** Retrieves the error index.
3	**public String getPattern()** Retrieves the erroneous regular expression pattern.
4	**public String getMessage()** Returns a multi-line string containing the description of the syntax error and its index, the erroneous regular expression pattern, and a visual indication of the error index within the pattern.

Eliza - ChatBot

- A famous 1960’s computer program that acts like a Rogerian psychotherapist, based on simple pattern matching.
- Eliza uses a kind of RegEx string matching approach.



http://nlp-addiction.com/eliza/

```
I am the psychotherapist.  Please, describe your problems.  Each time
you are finished talking, type RET twice.

I have a terrible headache.

Maybe you should consult a doctor of medicine, I am a psychiatrist.

Okay, I'll do that then.

Can you elaborate on that?

What are you talking about? No I cannot elaborate. See you later.

Why do you say that?

Now you're just talking nonsense!

What makes you believe now I am just talking nonsense?

You are not making any sense.

Perhaps your plans have something to do with this.
-u:**  *doctor*          (Doctor Fill)--L1--Top-----------------
```

Chat Bot

- Eliza uses regular expressions operating on sentences (rather than individual characters)
- Find the RegEx *“I feel X”* and reply with the RegEx
  - ❑ *“Do you often feel X?”*
- *“I am X”*
  - ❑ *“Do you believe it is normal to be X”*

Conclusion

- RegEx are used throughout computer science
- We can easily specify a template for a valid string
- Special characters cause complication
  - \ for strings, \\ for RegEx themselves
- The famous Eliza ChatBot uses a similar approach

Test a Regex:
https://regex101.com/

Further reading
www.regular-expressions.info

Test a Regex in Java
https://www.regexplanet.com/advanced/java/index.html

More Regex

Generate Reg Ex to :

- Accept the words *Ireland* and *Iceland*
- Accept only the words *dart, dark, darf*
- Accept the words *ward, Ward, card, Card, lard, Lard*
- Accept any word beginning with a *c* or *d* or *l* that is *4 letters long* and has *ar* as the 2nd and 3rd letter
- Accept any sequence of *4 characters that has a digit in the first and last positions and letters everywhere else.*
- What does the following REg Ex accept? - *[vcr]at*
- *vcr, vcrat, vat, at,*