Python Programming for Data Science

Week 39, Friday

- Regular expressions
- Regular expressions in Python

Recap: modules: a popquiz

- How do you create a Python module?
- What is the difference between:
  `import ...`
  and
  `from ... import ...`?
- What does the `as` keyword do?
- What is a *package*?

Regular expressions

Scenario: you receive some data...

```
# Measurements started
Sep 9, 9:05, T=22deg
SEP 9, 10:15, T=25deg
# Taking a coffee break
Sep 9, 11:15, T=-10deg
# Weekend
Sept 12, 09:00AM, T=32deg
Oct12 13:00, T=32degr
```

The data file names contain a temperature measurement and when it was recorded.

Scenario: you receive some data...

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# Measurements started
Sep 9, 9:05, T=22deg
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# Weekend
Sept 12, 09:00AM, T=32deg
Oct12 13:00, T=32degr
```

The data file names contain a temperature measurement and when it was recorded.

How do we select only entries before September 10 for which the temperature was positive?

Can this be done with our current Python knowledge?

Parsing text

```
data = '''# Measurements started
Sep 9, 9:05, T=22deg
SEP 9, 10:15, T=25deg
# Taking a coffee break
Sep 9, 11:15, T=-10deg
# Weekend
Sept 12, 09:00AM, T=32deg
Oct12 13:00, T=32degr'''

data_lines = data.split('\n')

for data_line in data_lines:
    if ???:
        print(data_line)
```

How do we proceed?

Parsing text (2)

```
...
for data_line in data_lines:
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]      # extract month name
```

Parsing text (2)

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...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]      # extract month name
    if data_line[index] == " ":
      index += 1                        # Jump passed space
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]      # extract month name
    if data_line[index] == " ":
      index += 1                        # Jump passed space
    data_line = data_line[index:]       # Remove month name from data_line
    index = 0
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]  # extract month name
    if data_line[index] == " ":
      index += 1                        # Jump passed space
    data_line = data_line[index:]   # Remove month name from data_line
    index = 0
    while data_line[index].isdigit():
        index += 1                      # Move ahead on letters
    day_number = int(data_line[:index])  # extract day number
    ...
```

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]      # extract month name
    if data_line[index] == " ":
      index += 1                        # Jump passed space
    data_line = data_line[index:]       # Remove month name from data_line
    index = 0
    while data_line[index].isdigit():
        index += 1                      # Move ahead on letters
    day_number = int(data_line[:index])  # extract day number
    ...
```

Complicated. Can we do better?

Parsing text (2)

```
...
for data_line in data_lines:
    if data_line[0] == "#":
        continue                        # Skip lines starting with #
    index = 0
    while data_line[index].isalpha():
        index += 1                      # Move ahead on letters
    month_name = data_line[:index]      # extract month name
    if data_line[index] == " ":
      index += 1                        # Jump passed space
    data_line = data_line[index:]       # Remove month name from data_line
    index = 0
    while data_line[index].isdigit():
        index += 1                      # Move ahead on letters
    day_number = int(data_line[:index])  # extract day number
    ...
```

Complicated. Can we do better?

Idea: we specify a single *text pattern* that matches exactly what we are interested in.

Regular expressions

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Regular expressions can be used to specify *text patterns*.

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You can then use this pattern to *match* a string, or *search* in a string.

The good news: You've already used regular expressions: Any normal search string is automatically also a regular expression.

Regular expressions - Ingredients 1

`.`	Match any character
`a`	Match 'a' (normal text)
`ab`	Match 'a' followed by 'b' (normal text)
`[abc]`	Character class. Match **one** character: **either** 'a' **or** 'b' **or** 'c'
`[^abc]`	Character class. Match **one** character: **anything except** 'a' **or** 'b' **or** 'c'
`[a-z]`	Character class. Match **one** character: **anything between** 'a' **and** 'z'
`^` and `$`	Matches beginning and end of line
`\A` and `\Z`	Matches beginning and end of entire string

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	
`[a-zA-Z]`	
`.ellow`	
`.[ei]llow`	
`[ab0-9]`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	'0' '2'
`[a-zA-Z]`	
`.ellow`	
`.[ei]llow`	
`[ab0-9]`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	'0' '2'
`[a-zA-Z]`	'H' 'f'
`.ellow`	
`.[ei]llow`	
`[ab0-9]`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	'0' '2'
`[a-zA-Z]`	'H' 'f'
`.ellow`	'yellow' 'mellow'
`.[ei]llow`	
`[ab0-9]`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	'0' '2'
`[a-zA-Z]`	'H' 'f'
`.ellow`	'yellow' 'mellow'
`.[ei]llow`	'pillow' 'yellow'

`[ab0-9]`

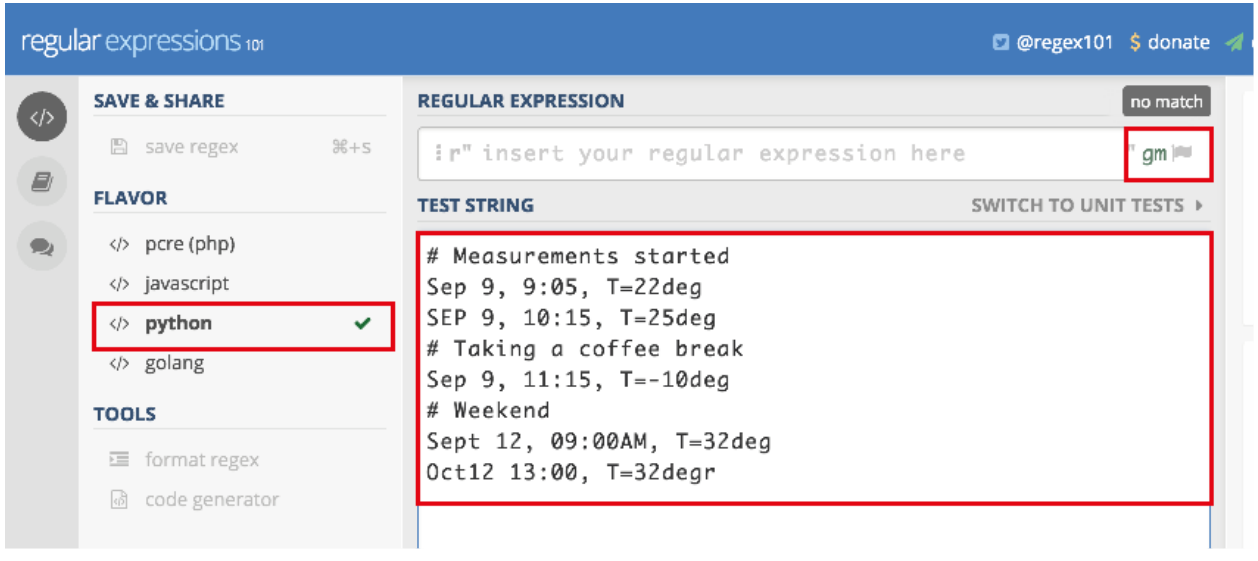
Regular expressions - Examples

pattern	examples of matching strings
`[0-9]`	'0' '2'
`[a-zA-Z]`	'H' 'f'
`.ellow`	'yellow' 'mellow'
`.[ei]llow`	'pillow' 'yellow'
`[ab0-9]`	'a' 'b' '4'

regular expressions - exercise 1

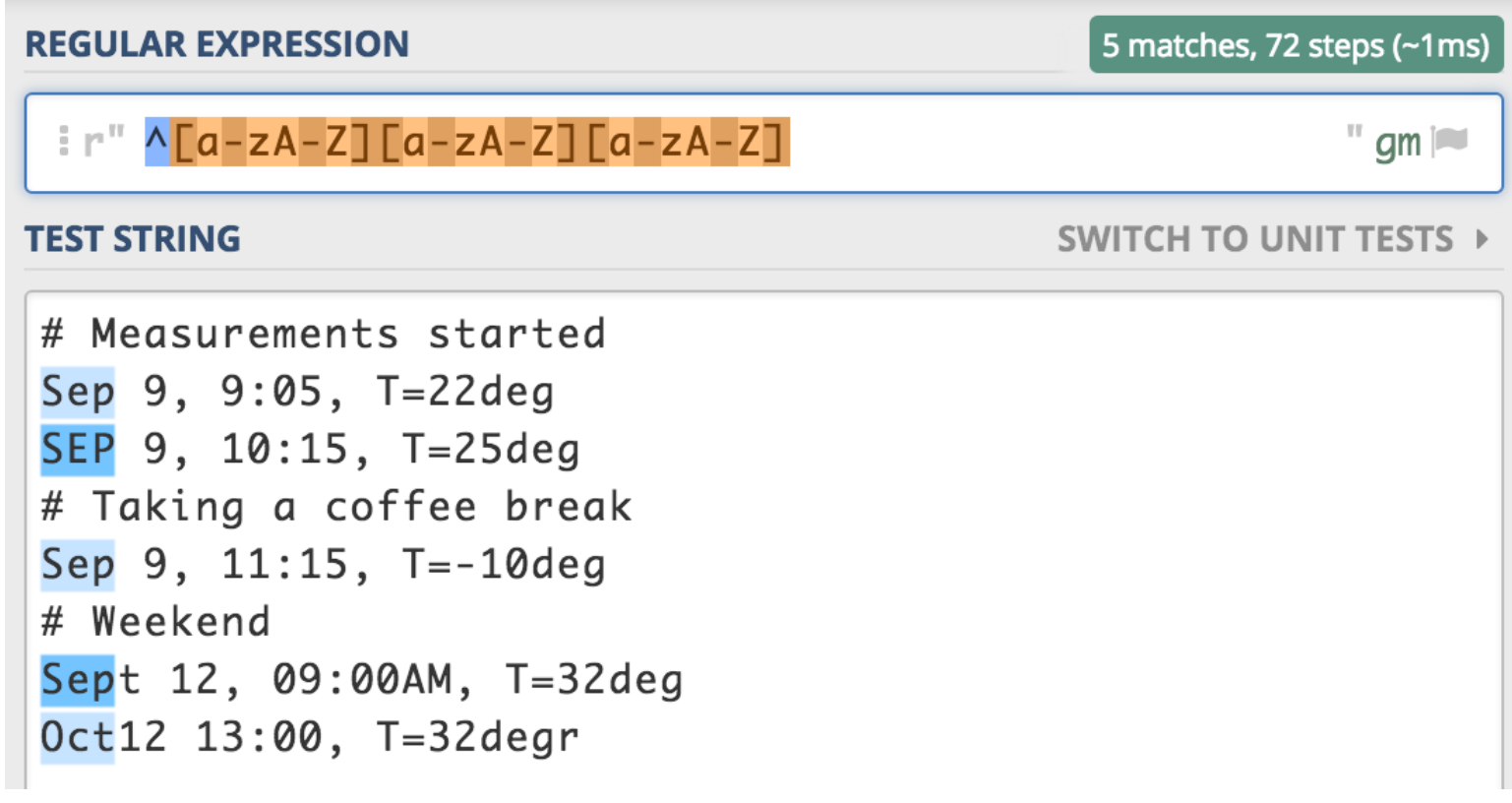
There is an free regular expression tester online: regex101.com

Click on Python in the left menu, make sure the option field states "gm", and copy the data lines into the TEST STRING field:

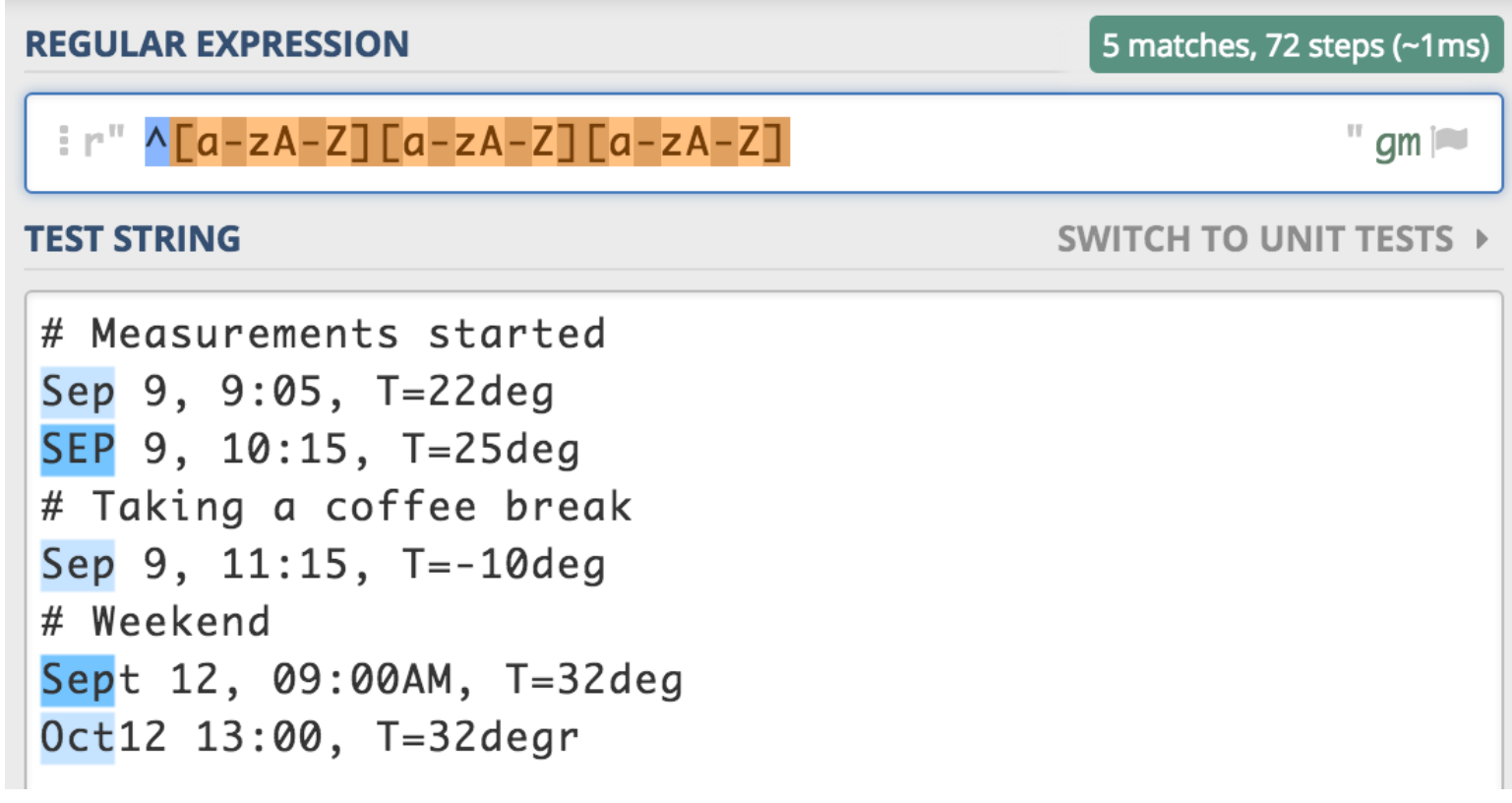


Type in a regular expression. Can you match only the data entries? (Try to write an expression that matches the entire entries - we'll see why later)

regular expressions - exercise 1 - solution



regular expressions - exercise 1 - solution



Conclusion: We cannot really solve the exercise with the ingredients we've seen so far...

More expression power: Ingredients 2

Quantifiers: How often should the preceding character or group be repeated?

*	zero or more times
+	one or more times
?	zero or one time
{*n*}	*n* times
{*n*,}	at least *n* times
{,*n*}	at most *n* times
{*n*,*m*}	between *n* and *m* times

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]+`	
`[0-9]*`	
`.?el[lb]ow`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]+`	'01' '10035'
`[0-9]*`	
`.?el[lb]ow`	

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]+`	'01' '10035'
`[0-9]*`	'01' '10035' ''

`.?el[lb]ow`

Regular expressions - Examples

pattern	examples of matching strings
`[0-9]+`	'01' '10035'
`[0-9]*`	'01' '10035' ''
`.?el[lb]ow`	'yellow' 'mellow' 'elbow'

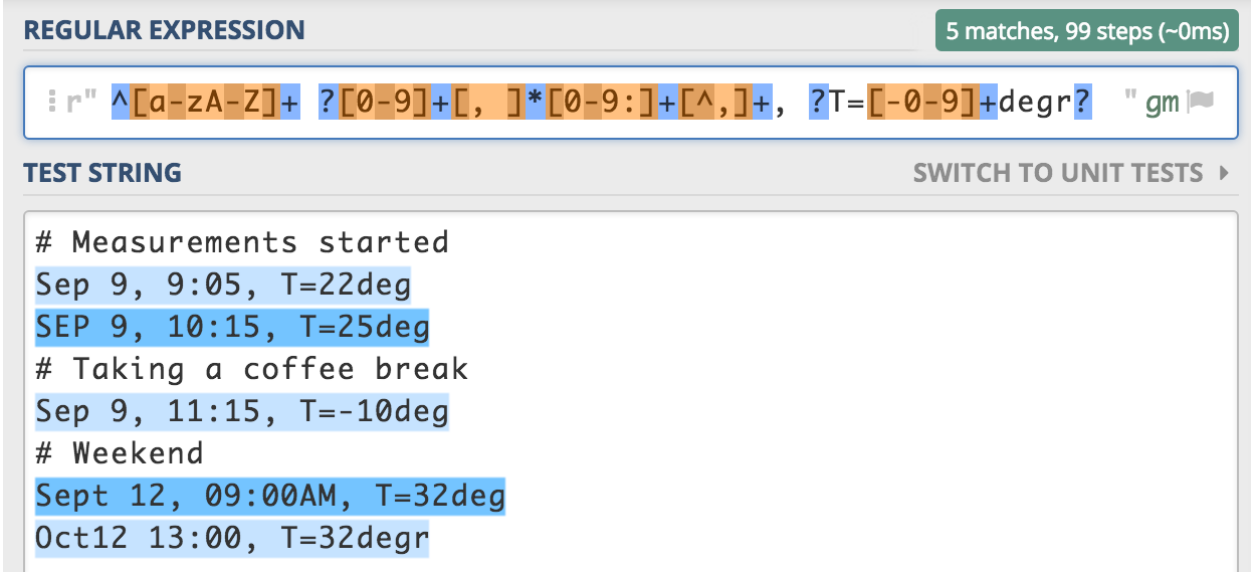
Regular expressions - Exercise 2

Using regex101.com, can we match all our data file names now?

Regular expressions - Exercise 2 - solution

Success!

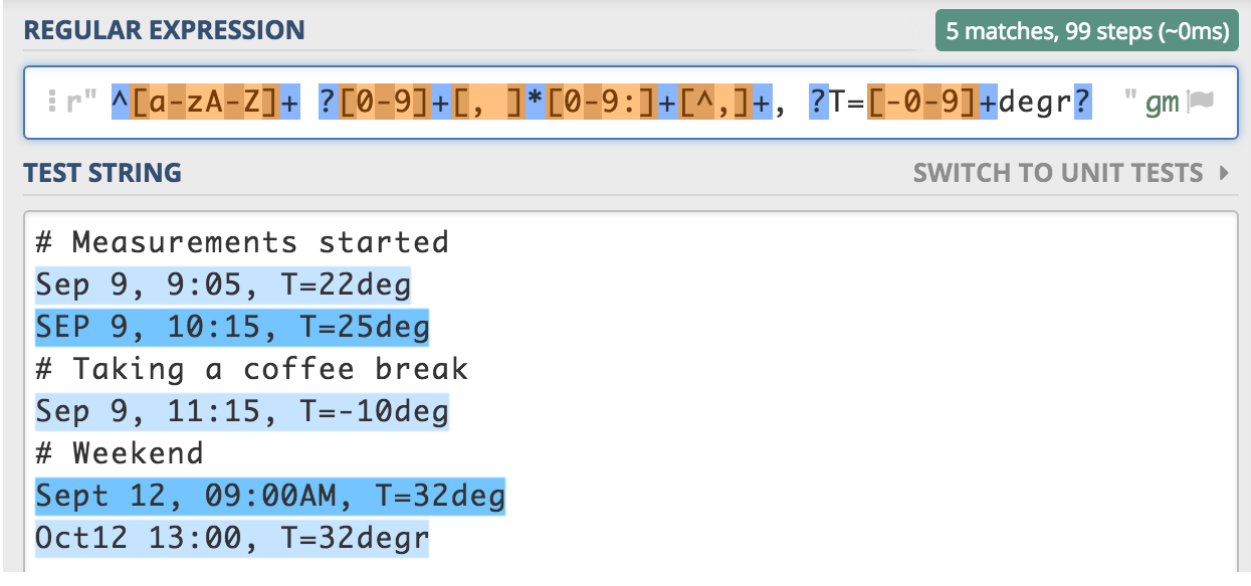
```
^[a-zA-Z]+ ?[0-9]+[, ]*[0-9:]+[^,]+, ?T=[-0-9]+degr?
```



Regular expressions - Exercise 2 - solution

Success!

```
^[a-zA-Z]+ ?[0-9]+[, ]*[0-9:]+[^,]+, ?T=[-0-9]+degr?
```

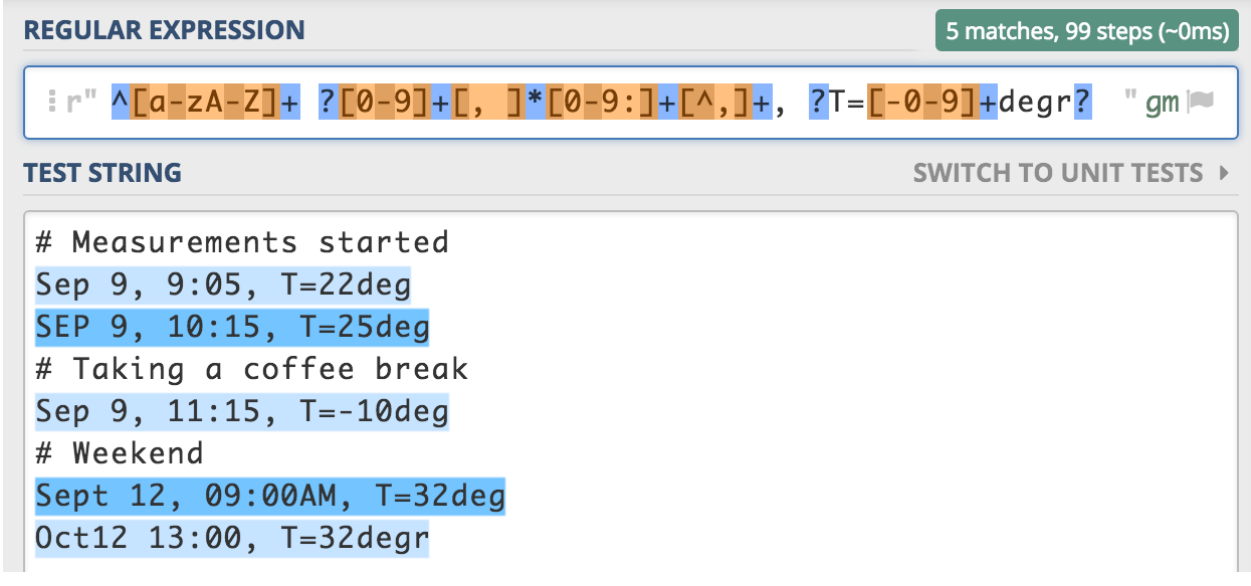


but...

Regular expressions - Exercise 2 - solution

Success!

```
^[a-zA-Z]+ ?[0-9]+[, ]*[0-9:]+[^,]+, ?T=[-0-9]+degr?
```



but... we wanted only the entries before September 10 that had positive temperature. Can we extract this information?

A few details: Ingredients 3

(*expr*)	*Group* an expression
(*expr1*|*expr2*)	Match either *expr1* or *expr2*
`\.`	Matches a literal '`.`' (escaping)
`\?`	Matches a literal '?' (escaping)
`^` and `$`	Matches beginning and end of line
`\A` and `\Z`	Matches beginning and end of entire string

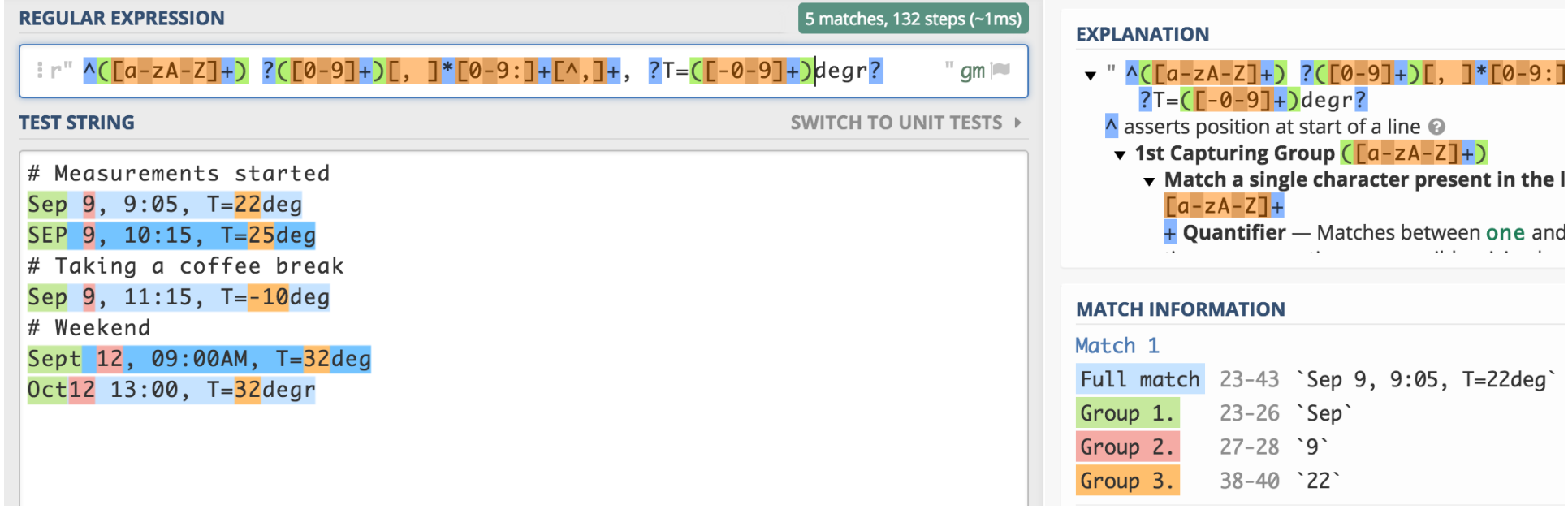
As we will see later, *groups* are accessible for extraction in Python.

Regular expressions - Exercise 3

See if you can add groups in your regular expression, so that we can extract both the temperature value and the month and day values.

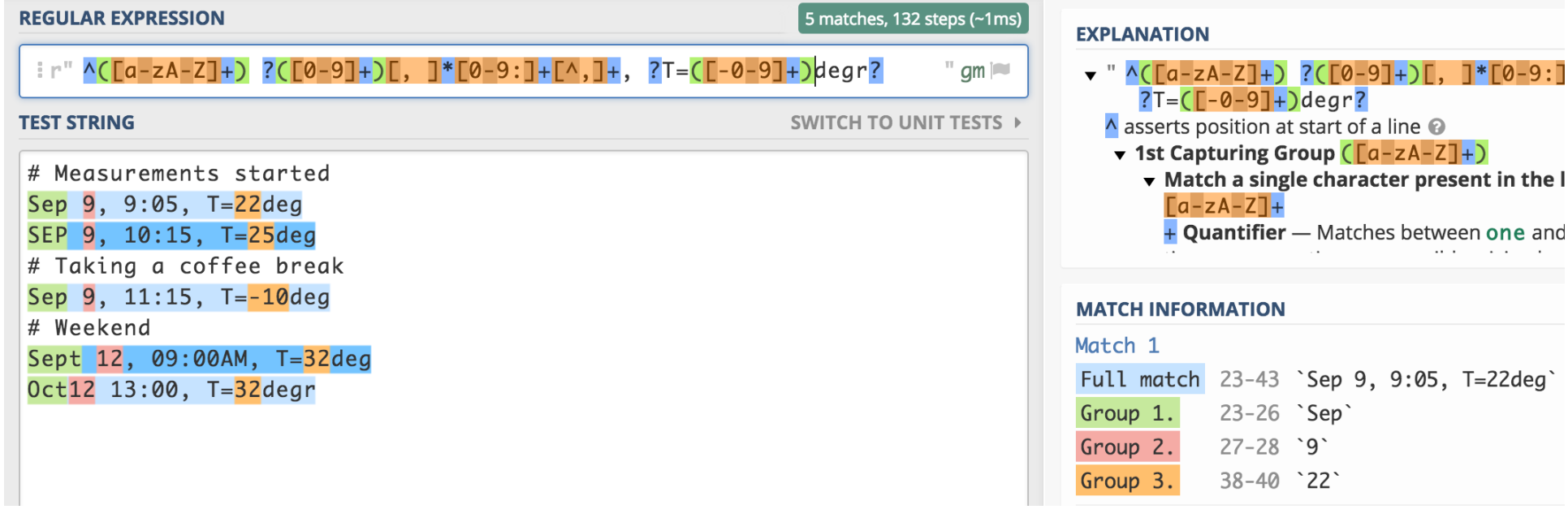
Regular expressions - Exercise 3 - solution

```
^([a-zA-Z]+) ?([0-9]+)[, ]*[0-9:]+[^,]+, ?T=([-0-9]+)degr?
```



Regular expressions - Exercise 3 - solution

```
^([a-zA-Z]+) ?([0-9]+)[, ]*[0-9:]+[^,]+, ?T=([-0-9]+)degr?
```



Hurray!

Regular expressions in Python

The `re` module

To use regular expressions in Python, you have to import the re module.

```
import re
```

Creating a pattern object

You can create a regular expression object using the compile function:

re_pattern.py

```
import re
pattern = re.compile('[a-zA-Z]+')
print(pattern)
```

output

```
<_sre.SRE_Pattern object at 0xb74db7a0>
```

match, search, and findall

Most important methods in a regular expression object:

`match()`	Check whether the pattern matches from the start of the string. Returns match object.

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Most important methods in a regular expression object:

`match()`	Check whether the pattern matches from the start of the string. Returns match object.
`search()`	Search for substrings where pattern matches. Returns match object.
`findall()`	Search for substrings where pattern matches. Returns list of strings.

re_pattern2.py

```
pattern = re.compile('[0-9]+')
print(pattern.match('13'))
print(pattern.match('hello'))
```

output

```
<_sre.SRE_Match object; span=(0, 2), match='13'> # pattern matched
None                                             # pattern not matched
```

Regular expressions - Exercise 4

Start with the code on the next slide

1. Construct (this time in Python) a regular expression that matches the data entries
2. Inside the loop, apply the regular expression, and only print out the line if it matches the regular expression

Regular expressions - Exercise 4 - code

```
data = '''# Measurements started
Sep 9, 9:05, T=22deg
SEP 9, 10:15, T=25deg
# Taking a coffee break
Sep 9, 11:15, T=-10deg
# Weekend
Sept 12, 09:00AM, T=32deg
Oct12 13:00, T=32degr'''

data_lines = data.split('\n')

for data_line in data_lines:
    if ???:
        print(data_line)
```

Regular expressions - Exercise 4 - solution

```
# Import regular expression module
import re

data = '''...'''   # data removed here to fit on slide

# Create regular expression
pattern = re.compile("^([a-zA-Z]+) ?([0-9]+)[, ]*[0-9:]+[^,]+, ?T=([-0-9]+)degr?")

for data_line in data.split('\n'):

    # Make attempt to match
    match = pattern.match(data_line)

    # If successful, print line
    if match:
        print(data_line)
```

Regular expressions - Exercise 4 - solution

```
# Import regular expression module
import re

data = '''...'''   # data removed here to fit on slide

# Create regular expression
pattern = re.compile("^([a-zA-Z]+) ?([0-9]+)[, ]*[0-9:]+[^,]+, ?T=([-0-9]+)degr?")

for data_line in data.split('\n'):

    # Make attempt to match
    match = pattern.match(data_line)

    # If successful, print line
    if match:
        print(data_line)
```

But how do we access our groups?

The match object

The match object has methods that can extract information from the string that was matched:

Some of the most common ones:

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`groups()`	Return a tuple with all groups
`start()`	Return start index of group
`end()`	Return end index of group

The `group`, `start`, and `end` methods all default to group index `0`, which corresponds to the entire matching string.

The match object - example

match_entries.py

```
import re

data_lines = ['# Measurements started',
              'Sep 9, 9:05, T=22deg']

pattern = re.compile('^[a-zA-Z]+ ?([0-9]+)')

match = pattern.search(data_lines[1])
if match:
    print(match.groups()) # all specified groups
    print(match.group())  # Group 0 -> entire matching str
    print(match.group(1)) # Group 1 -> first set of ()
```

output

```
('9',)
Sep 9
9
```

Regular expressions - Exercise 5

Start with the previous exercise

1. Inside the loop, extract the temperature value, and only print entries with positive temperatures.

Regular expressions - Exercise 5 - solution

match_entries2.py

```
...

# Same regular expression as before

for data_line in data.split('\n'):

    # Make attempt to match
    match = pattern.match(data_line)

    if match:
        # Extract temperature
        temperature = int(match.group(3))

        if temperature > 0:
            print(data_line)
```

output

```
Sep 9, 9:05, T=22deg
Sep 9, 10:15, T=25deg
Sept 12, 09:00AM, T=32deg
Oct12 13:00, T=32degr
```

Regular expression details

Special characters (character classes)

For convenience, many often-used character classes have shortcuts

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`\d`	digit character	`[0-9]`
`\D`	non-digit character	`[^0-9]`
`\w`	alphanumerical character	`[a-zA-Z0-9_]`

Special characters (character classes)

For convenience, many often-used character classes have shortcuts

`\d`	digit character	`[0-9]`
`\D`	non-digit character	`[^0-9]`
`\w`	alphanumerical character	`[a-zA-Z0-9_]`
`\W`	non-alphanumerical character	`[^a-zA-Z0-9_]`

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`\d`	digit character	`[0-9]`
`\D`	non-digit character	`[^0-9]`
`\w`	alphanumerical character	`[a-zA-Z0-9_]`
`\W`	non-alphanumerical character	`[^a-zA-Z0-9_]`
`\s`	white-space character	`[\t\n\r\f\v]`

Special characters (character classes)

For convenience, many often-used character classes have shortcuts

`\d`	digit character	`[0-9]`
`\D`	non-digit character	`[^0-9]`
`\w`	alphanumerical character	`[a-zA-Z0-9_]`
`\W`	non-alphanumerical character	`[^a-zA-Z0-9_]`
`\s`	white-space character	`[\t\n\r\f\v]`
`\S`	non-white-space character	`[^\t\n\r\f\v]`

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Per default, repetitions are *greedy* - they will match as much as possible.

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Sometimes, this is not what you want.

```
text = "Barack Obama"
pattern = re.compile("([A-Za-z]+).*([A-Za-z]+)")

print(pattern.match(text).groups())    # what does this give us?
```

The regular expression `<.*>` will match as much as possible instead of just the spaces between the words.

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Solutions:

- Improve the regular expression (`\s*` or `[^A-Za-z]*`)

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print(pattern.match(text).groups())    # what does this give us?
```

The regular expression `<.*>` will match as much as possible instead of just the spaces between the words.

Solutions:

- Improve the regular expression (`\s*` or `[^A-Za-z]*`)
- Use non-greedy repetition operators

Non-greedy repetition

The non-greedy repetition operators match as little as possible

`*?`	Match zero or more times (non-greedy)
`+?`	Match one or more times (non-greedy)
`??`	Match zero or one time (non-greedy)
`{`*n*`}?`	Match *n* times (non-greedy)
`{`*n*`,}?`	Match at least *n* times (non-greedy)
`{,`*n*`}?`	Match at most *n* times (non-greedy)
`{`*n*`,`*m*`}?`	Match between *n* and *m* times (non-greedy)

Non-greedy repetition - example

re_non_greedy.py

```
text = "Barack Obama"
pattern1 = re.compile("([A-Za-z]+).*([A-Za-z]+)")    # greedy
pattern2 = re.compile("([A-Za-z]+).*?([A-Za-z]+)")   # non-greedy
print(pattern1.match(text).groups())
print(pattern2.match(text).groups())
```

output

```
('Barack', 'a')
('Barack', 'Obama')
```

Boundaries

^ and $	match beginning and end of line
\A and \Z	match beginning and end of entire string
\b	Matches at boundary of word
\B	Matches anywhere except at boundary of word

Note that none of the above actually corresponds to a character in the string we are matching against.

re_boundaries.py

```
pattern = re.compile("\d+\\b")     # lots of backslashes (see next slide)
print(pattern.match("22 "))
print(pattern.match("22a "))
```

output

```
<_sre.SRE_Match object at 0x10ae8c440>
None
```

The backslash mess

Both Python strings and Regular expressions use the `\` character for characters with special meaning. This can be rather confusing.

The backslash mess

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```
pattern = re.compile("\d+\\b")    # \b doesn't work
```

This is annoying. Instead, use *raw strings* to write your regular expressions:

```
pattern = re.compile(r"\d+\b")    # Note the r""
```

Compile flags

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It is possible to alter the behavior by specifying *compile flags*

```
re.compile(pattern,flags)
```

`re.DOTALL`	make `.` also match newlines
`re.IGNORECASE`	Case insensitive matching
`re.MULTILINE`	Multiline matching
`re.VERBOSE`	Allow verbose regular expressions

Compile flags - example

re_compile_flags.py

```
import re
text = 'linux\npython'
pattern1 = re.compile(".*")
pattern2 = re.compile(".*", re.DOTALL)
print(pattern1.findall(text))
print(pattern2.findall(text))
```

output

```
['linux', '', 'python', '']
['linux\npython', '']
```

Sub and split

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Substitution. Replace any substring in *string* that matches *pattern* with the string *replacement*.

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Substitution. Replace any substring in *string* that matches *pattern* with the string *replacement*.

```
pattern.sub(replacement, string)
```

Split. Split up string using matches as delimiters.

```
pattern.split(string)
```

Sub and split - example

split

re_split.py

```
my_string = 'one|two@three$four'
pattern = re.compile('[|@$]')
print(pattern.split(my_string))
```

output

```
['one', 'two', 'three', 'four']
```

sub

re_sub.py

```
my_string = 'one|two@three$four'
pattern = re.compile('[|@$]')
print(pattern.sub(" - ", my_string))
```

output

```
one - two - three - four
```

Backreferencing

Inside a regular expression, you can refer to groups matched in a previous part of an expression, using using \1 \2, etc

This also works in the *replacement* string of sub:

re_sub_backref.py

```
import re
my_string = 'Hello bla bla bla hello.'
pattern = re.compile('([Hh])ello')
print(pattern.sub(r"\1ey", my_string))      # \1 refers to first group
```

output

```
Hey bla bla bla hey.                  # Note, the case of h is preserved
```

Regular expressions - Exercise 6

1. Within Python, open the `/usr/share/dict/british-english` file (or download from https://wouterboomsma.github.io/ppds2021/data/british-english)
2. Iterate over the lines, and use a regular expression to print only those words that start and end with the same letter
3. Bonus exercise (unix): can you do the same with grep?

Regular expressions - Exercise 6 - solutions

1. Within Python, open the `/usr/share/dict/british-english` file

```
dict_filename = "/usr/share/dict/british-english"

# Open file
dict_file = open(dict_filename)
```

2. Iterate over the lines, and use a regular expression to print only those words that start and end with the same letter

```
# Define regular expression
pattern = re.compile(r"^(.).*\1$")

for line in dict_file.readlines():
    if pattern.match(line):   # No match => None => interpreted as False
        print(line)
```

3. Bonus exercise (unix): can you do the same with grep?

```
$ grep -E "^(.).*\1$" /usr/share/dict/british-english
```

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3. Bonus exercise (unix): can you do the same with grep?

```
$ grep -E "^(.).*\1$" /usr/share/dict/british-english
```

Note that you sometimes need to use the "-E" (extended regexp) flag with grep to support all regexp functionality