

INF1100 Lectures, Chapter 6: Files, Strings, and Dictionaries

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Reading data from a file

- A file is a sequence of characters (text)
- We can read text in the file into strings in a program
- This is a common way for a program to get input data

- **Basic recipe:**

```
infile = open('myfile.dat', 'r')
# read next line:
line = infile.readline()

# read lines one by one:
for line in infile:
    <process line>

# load all lines into a list of strings (lines):
lines = infile.readlines()
for line in lines:
    <process line>
```

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Example: reading a file with numbers (part 1)

- The file `data1.txt` has a column of numbers:

```
21.8
18.1
19
23
26
17.8
```

- Goal: compute the average value of the numbers:

```
infile = open('data1.txt', 'r')
lines = infile.readlines()
infile.close()
mean = 0
for number in lines:
    mean = mean + number
mean = mean/len(lines)
```

- Running the program gives an error message:

```
TypeError: unsupported operand type(s) for +:
'int' and 'str'
```

- Problem: number is a string!

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Example: reading a file with numbers (part 2)

- We must convert strings to numbers before computing:

```
infile = open('data1.txt', 'r')
lines = infile.readlines()
infile.close()
mean = 0
for line in lines:
    number = float(line)
    mean = mean + number
mean = mean/len(lines)
print mean
```

- A quicker and shorter variant:

```
infile = open('data1.txt', 'r')
numbers = [float(line) for line in infile.readlines()]
infile.close()
mean = sum(numbers)/len(numbers)
print mean
```

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While loop over lines in a file

Especially older Python programs employ this technique:

```
infile = open('data1.txt', 'r')
mean = 0
n = 0
while True:
    line = infile.readline()
    if not line:
        # line='' at end of file
        break
    # jump out of loop
    mean += float(line)
    n += 1
infile.close()
mean = mean/float(n)
print mean
```

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Experiment with reading techniques

```
>>> infile = open('data1.txt', 'r')
>>> fstr = infile.read() # read file into a string
>>> fstr
'21.8\n18.1\n19\n23\n26\n17.8\n'
>>> line = infile.readline() # read after end of file...
>>> line
''
>>> bool(line)
False # test if line:
# empty object is False
>>> infile.close(); infile = open('data1.txt', 'r')
>>> lines = infile.readlines()
>>> lines
['21.8\n', '18.1\n', '19\n', '23\n', '26\n', '17.8\n']
>>> infile.close(); infile = open('data1.txt', 'r')
>>> for line in infile: print line,
21.8
18.1
19
23
26
17.8
```

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Reading a mixture of text and numbers (part 1)

- The file `rainfall.dat` looks like this:

```
Average rainfall (in mm) in Rome: 1188 months between 1782 and 1970
Jan 81.2
Feb 63.2
Mar 70.3
Apr 55.7
May 53.0
...
```

- Goal: read the numbers and compute the mean
- Technique: for each line, split the line into words, convert the 2nd word to a number and add to sum

```
for line in infile:
    words = line.split() # list of words on the line
    number = float(words[1])
```

- Note `line.split()`: very useful for grabbing individual words on a line, can split wrt any string, e.g., `line.split(';')`, `line.split(':')`

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Reading a mixture of text and numbers (part 2)

The complete program:

```
def extract_data(filename):
    infile = open(filename, 'r')
    infile.readline() # skip the first line
    numbers = []
    for line in infile:
        words = line.split()
        number = float(words[1])
        numbers.append(number)
    infile.close()
    return numbers

values = extract_data('rainfall.dat')
from scitools.std import plot
month_indices = range(1, 13)
plot(month_indices, values[:-1], 'o2')
```

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What is a file?

- A file is a sequence of characters
- For simple text files, each character is one byte (=8 bits, a bit is 0 or 1), which gives $2^8 = 256$ different characters
- (Text files in, e.g., Chinese and Japanese need several bytes for each character)
- Save the text "ABCD" to file in Emacs and OpenOffice/Word and examine the file
- In Emacs, the file size is 4 bytes

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Dictionaries

- Lists and arrays are fine for collecting a bunch of objects in a single object
- List and arrays use an integer index, starting at 0, for reaching the elements
- For many applications the integer index is "unnatural" - a general text (or integer not restricted to start at 0) will ease programming
- Dictionaries meet this need
- Dictionary = list with text (or any constant object) as index
- Other languages use names like hash, HashMap and associative array for what is known as dictionary in Python

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Example on a dictionary

- Suppose we need to store the temperatures in Oslo, London and Paris
- List solution:

```
temps = [13, 15.4, 17.5]
# temps[0]: Oslo
# temps[1]: London
# temps[2]: Paris
```
- We need to remember the mapping between the index and the city name – with a dictionary we can index the list with the city name directly (e.g., `temps["Oslo"]`):

```
temps = {'Oslo': 13, 'London': 15.4, 'Paris': 17.5}
# or
temps = dict(Oslo=13, London=15.4, Paris=17.5)
# application:
print 'The temperature in London is', temps['London']
```

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Dictionary operations (part 1)

- Add a new element to a dict (dict = dictionary):

```
>>> temps['Madrid'] = 26.0
>>> print temps
{'Oslo': 13, 'London': 15.4, 'Paris': 17.5,
'Madrid': 26.0}
```
- Loop (iterate) over a dict:

```
>>> for city in temps:
...     print 'The temperature in %s is %g' % \
...         (city, temps[city])
...
The temperature in Paris is 17.5
The temperature in Oslo is 13
The temperature in London is 15.4
The temperature in Madrid is 26
```
- The index in a dictionary is called key (a dictionary holds key–value pairs)

```
for key in dictionary:
    value = dictionary[key]
    print value
```

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Dictionary operations (part 2)

- Does the dict have a particular key?

```
>>> if 'Berlin' in temps:
...     print 'Berlin:', temps['Berlin']
... else:
...     print 'No temperature data for Berlin'
...
No temperature data for Berlin
>>> 'Oslo' in temps      # standard boolean expression
True
```
- The keys and values can be reached as lists:

```
>>> temps.keys()
['Paris', 'Oslo', 'London', 'Madrid']
>>> temps.values()
[17.5, 13, 15.4, 26.0]
```
- Note: the sequence of keys is arbitrary! Never rely on it – if you need a specific order of the keys, use a sort:

```
for key in sorted(temps):
    value = temps[key]
    print value
```

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Dictionary operations (part 3)

- More operations:

```
>>> del temps['Oslo'] # remove Oslo key w/value
>>> temps
{'Paris': 17.5, 'London': 15.4, 'Madrid': 26.0}
>>> len(temps)      # no of key-value pairs in dict.
3
```
- Two variables can refer to the same dictionary:

```
>>> t1 = temps
>>> t1['Stockholm'] = 10.0 # change t1
>>> temps                # temps is also changed
{'Stockholm': 10.0, 'Paris': 17.5, 'London': 15.4,
'Madrid': 26.0}
>>> t2 = temps.copy()    # take a copy
>>> t2['Paris'] = 16
>>> t1['Paris']
17.5
```

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Examples: polynomials represented by dictionaries

- The polynomial
$$p(x) = -1 + x^2 + 3x^7$$
can be represented by a dict with power as key and coefficient as value:

```
p = {0: -1, 2: 1, 7: 3}
```
- Evaluate polynomials represented as dictionaries: $\sum_{i \in I} c_i x^i$

```
def poly1(data, x):
    sum = 0.0
    for power in data:
        sum += data[power]*x**power
    return sum
```
- Shorter:

```
def poly1(data, x):
    return sum([data[p]*x**p for p in data])
```

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Lists as dictionaries

- A list can also represent a polynomial
- The list index must correspond to the power
- $-1 + x^2 + 3x^7$ becomes

```
p = [-1, 0, 1, 0, 0, 0, 0, 3]
```
- Must store all zero coefficients, think about $1 + x^{100} \dots$
- Evaluating the polynomial at a given x value: $\sum_{i=0}^N c_i x^i$

```
def poly2(data, x):
    sum = 0
    for power in range(len(data)):
        sum += data[power]*x**power
    return sum
```

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What is best for polynomials: lists or dictionaries?

- Dictionaries need only store the nonzero terms
- Dictionaries can easily handle negative powers, e.g., $\frac{1}{2}x^{-3} + 2x^4$
`p = {-3: 0.5, 4: 2}`
- Lists need more book-keeping with negative powers:
`p = [0.5, 0, 0, 0, 0, 0, 0, 0, 4]`
`# p[i] corresponds to power i-3`
- Dictionaries are much more suited for this task

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Example: read file data into a dictionary

- Here is a data file:

```
Oslo:      21.8
London:   18.1
Berlin:   19
Paris:    23
Rome:     26
Helsinki: 17.8
```
- City names = keys, temperatures = values

```
infile = open('deg2.dat', 'r')
temps = {}
for line in infile.readlines():
    city, temp = line.split()
    city = city[:-1] # remove last char (:)
    temps[city] = float(temp)
```

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Reading file data into nested dictionaries

- Data file `table.dat` with measurements of four properties:

	A	B	C	D
1	11.7	0.035	2017	99.1
2	9.2	0.037	2019	101.2
3	12.2	no	no	105.2
4	10.1	0.031	no	102.1
5	9.1	0.033	2009	103.3
6	8.7	0.036	2015	101.9

- Create a dict `data[p][i]` (dict of dict) to hold measurement no. `i` of property `p` ("A", "B", etc.)
- Examine the first line: split it into words and initialize a dictionary with the property names as keys and empty dictionaries (`{}`) as values
- For each of the remaining lines: split line into words
- For each word after the first: if word is not "no", convert to float and store
- See the book for implementation details!

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Comparing stock prices (part 1)

- Problem: we want to compare the stock prices of Microsoft, Sun, and Google over a long period
- `finance.yahoo.com` offers such data in files with tabular form

```
Date,Open,High,Low,Close,Volume,Adj Close
2008-06-02,28.24,29.57,27.11,28.35,79237800,28.35
2008-05-01,28.50,30.53,27.95,28.32,69931800,28.32
2008-04-01,28.83,32.10,27.93,28.52,69066000,28.42
2008-03-03,27.24,29.59,26.87,28.38,74958500,28.28
2008-02-01,31.06,33.25,27.02,27.20,122053500,27.10
...
```
- Columns are separated by comma
- First column is the date, the final is the price of interest
- We can compare Microsoft and Sun from e.g. 1988 and add in Google from e.g. 2005
- For comparison we should normalize prices: Microsoft and Sun start at 1, Google at the max Sun/Microsoft price in 2005

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Comparing stock prices (part 2)

Algorithm for file reading:

- Skip first line, read line by line, split line wrt. colon, store first "word" in a list of dates, final "word" in a list of prices; collect lists in dictionaries with company names as keys; make a function so it is easy to repeat for the three data files

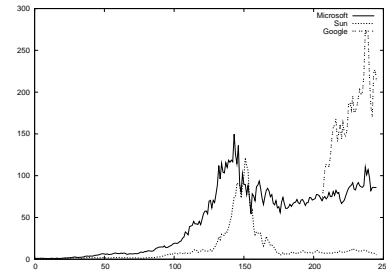
Algorithm for file plotting:

- Convert year-month-day time specifications in strings into coordinates along the x axis (use month indices for simplicity), Sun/Microsoft run 0,1,2,... while Google start at the Sun/Microsoft index corresponding to Jan 2005

See the book for all details. If you understand this example, you know and understand a lot!

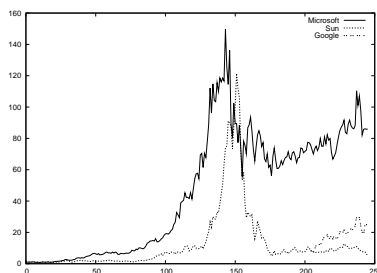
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Plot of stock prices 1988-2008



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started with Sun in 1988 and switched to Google in 2005? (simple)



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String manipulation

- Text in Python is represented as strings
- Programming with strings is therefore the key to interpret text in files and construct new text
- First we show some common string operations and then we apply them to real examples
- Our sample string used for illustration is
`>>> s = 'Berlin: 18.4 C at 4 pm'`
- Strings behave much like lists/tuples - they are a sequence of characters:

```
>>> s[0]
'B'
>>> s[1]
'e'
```

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Extracting substrings

- Substrings are just as slices of lists and arrays:

```
>>> s
'Berlin: 18.4 C at 4 pm'
>>> s[8:] # from index 8 to the end of the string
'18.4 C at 4 pm'
>>> s[8:12] # index 8, 9, 10 and 11 (not 12!)
'18.4'
>>> s[8:-1]
'18.4 C at 4 p'
>>> s[8:-8]
'18.4 C'
>>> s[8:]
'18.4 C'
```
- Find start of substring:

```
>>> s.find('Berlin') # where does 'Berlin' start?
0
>>> s.find('pm') # at index 0
20
>>> s.find('Oslo') # not found
-1
```

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Checking if a substring is contained in a string

```
>>> 'Berlin' in s:
True
>>> 'Oslo' in s:
False

>>> if 'C' in s:
...     print 'C found'
... else:
...     print 'no C'
...
C found
```

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Substituting a substring by another string

- `s.replace(s1, s2)`: replace `s1` by `s2`

```
>>> s.replace(' ', '_')
'Berlin:_18.4_C_at_4_pm'
>>> s.replace('Berlin', 'Bonn')
'Bonn: 18.4 C at 4 pm'
```
- Example: replacing the text before the first colon by 'Bonn'

```
>>> s
'Berlin: 18.4 C at 4 pm'
>>> s.replace(s[:s.find(':')], 'Bonn')
'Bonn: 18.4 C at 4 pm'
```
- 1) `s.find(':')` returns 6, 2) `s[:6]` is 'Berlin', 3) this is replaced by 'Bonn'

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Splitting a string into a list of substrings

- Split a string into a list of substrings where the separator is `sep`:
`s.split(sep)`
- No separator implies split wrt whitespace

```
>>> s
'Berlin: 18.4 C at 4 pm'
>>> s.split(' ')
['Berlin', '18.4 C at 4 pm']
>>> s.split()
['Berlin:', '18.4', 'C', 'at', '4', 'pm']
```
- Try to understand this one:

```
>>> s.split(':')[1].split()[0]
'18.4'
>>> deg = float(_) # convert last result to float
>>> deg
18.4
```

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Splitting a string into lines

- Very often, a string contains lots of text and we want to split the text into separate lines
- Lines may be separated by different control characters on different platforms. On Unix/Linux/Mac, backslash `n` is used:

```
>>> t = '1st line\n2nd line\n3rd line'
>>> print t
1st line
2nd line
3rd line
>>> t.split('\n')
['1st line', '2nd line', '3rd line']
>>> t.splitlines() # cross platform - better!
['1st line', '2nd line', '3rd line']
```

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Strings are constant (immutable) objects

- You cannot change a string in-place (as you can with lists and arrays) - all changes of a strings results in a new string

```
>>> s[18] = 5
...
TypeError: 'str' object does not support item assignment

>>> # build a new string by adding pieces of s:
>>> s[:18] + '5' + s[19:]
'Berlin: 18.4 C at 5 pm'
```

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Stripping off leading/trailing whitespace

```
>>> s = ' text with leading/trailing space \n'
>>> s.strip()
'text with leading/trailing space'
>>> s.lstrip() # left strip
'text with leading/trailing space \n'
>>> s.rstrip() # right strip
' text with leading/trailing space'
```

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Some convenient string functions

```
>>> '214'.isdigit()
True
>>> ' 214 '.isdigit()
False
>>> '2.14'.isdigit()
False

>>> s.lower()
'berlin: 18.4 c at 4 pm'
>>> s.upper()
'BERLIN: 18.4 C AT 4 PM'

>>> s.startswith('Berlin')
True
>>> s.endswith('am')
False

>>> ' '.isspace() # blanks
True
>>> '\n'.isspace() # newline
True
>>> '\t'.isspace() # TAB
True
>>> ''.isspace() # empty string
False
```

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Joining a list of substrings to a new string

- We can put strings together with a delimiter in between:

```
>>> strings = ['Newton', 'Secant', 'Bisection']
>>> ', '.join(strings)
'Newton, Secant, Bisection'
```
- These are inverse operations:

```
t = delimiter.join(stringlist)
stringlist = t.split(delimiter)
```
- Split off the first two words on a line:

```
>>> line = 'This is a line of words separated by space'
>>> words = line.split()
>>> line2 = ' '.join(words[2:])
>>> line2
'a line of words separated by space'
```

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Example: read pairs of numbers (x,y) from a file

- Sample file:

```
(1.3,0) (-1,2) (3,-1.5)
(0,1) (1,0) (1,1)
(0,-0.01) (10.5,-1) (2.5,-2.5)
```
- Method: read line by line, for each line: split line into words, for each word: split off the parenthesis and the split the rest wrt comma into two numbers

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The code for reading pairs

```
lines = open('read_pairs.dat', 'r').readlines()
pairs = [] # list of (n1, n2) pairs of numbers
for line in lines:
    words = line.split()
    for word in words:
        word = word[1:-1] # strip off parenthesis
        n1, n2 = word.split(',')
        n1 = float(n1); n2 = float(n2)
        pair = (n1, n2)
        pairs.append(pair) # add 2-tuple to last row
```

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Output of a pretty print of the pairs list

```
[(1.3, 0.0),
 (-1.0, 2.0),
 (3.0, -1.5),
 (0.0, 1.0),
 (1.0, 0.0),
 (1.0, 1.0),
 (0.0, -0.01),
 (10.5, -1.0),
 (2.5, -2.5)]
```

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Alternative solution: Python syntax in file format

- What if we write, in the file, the pairs (x,y) with comma in between the pairs?
- Adding a leading and trailing square bracket gives a Python syntax for a list of tuples (!)
- eval on that list could reproduce the list...
- The file format:

```
(1.3, 0), (-1, 2), (3, -1.5)
...
```
- We want to add a comma at the end of every line and square brackets around the whole file text, and then do an eval:

```
list = eval("[ (1.3,0), (-1, 2), (3, -1.5),
 ]")
```

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The code for reading pairs with eval

```
infile = open('read_pairs_wcomma.dat', 'r')
listtext = ''
for line in infile:
    # add line, without newline (line[:-1]),
    # with a trailing comma:
    listtext += line[:-1] + ', '
infile.close()
listtext = listtext + ']'
pairs = eval(listtext)
```

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What are web pages?

- Web pages are nothing but text files
- Commands in the text files tell the browser that this is a headline, this is boldface text, here is an image, etc.
- The commands are written in the HTML language

```
<html>
<body bgcolor="orange">
<h1>A Very Simple Web Page</h1> <!-- headline -->
Ordinary text is written as ordinary text, but when we
need headlines, lists,
<ul>
<li><em>emphasized words</em>, or
<li><b>boldfaced words</b>,
</ul>
we need to embed the text inside HTML tags. We can also
insert GIF or PNG images, taken from other Internet sites,
if desired.
<hr> <!-- horizontal line -->

</body>
</html>
```

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The web page generated by HTML code from the previous slide



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Getting data from the Internet

- A program can download a web page, as an HTML file, and extract data by interpreting the text in the file (using string operations)
- Example: climate data from the UK

```
http://www.metoffice.gov.uk/climate/uk/stationdata/
```
- Download the file:

```
import urllib
url = \
'http://www.metoffice.gov.uk/climate/uk/stationdata/oxforddata.txt'
urllib.urlretrieve(url, filename='Oxford.txt')
```
- View the file `weather.html` to see how the text looks like

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The structure of the Yahoo! weather forecast file

```
Oxford
Location: 4509E 2072N, 63 metres amsl
Estimated data is marked with a * after the value.
Missing data (more than 2 days missing in month) is marked by ---.
Sunshine data taken from an automatic ...
YYYY mm tmax tmin af rain sun
      degC degC days mm hours
1853 1 8.4 2.7 4 62.8 ---
1853 2 3.2 -1.8 19 29.3 ---
1853 3 7.7 -0.6 20 25.9 ---
1853 4 12.6 4.5 0 60.1 ---
1853 5 16.8 6.1 0 59.5 ---
...
2010 5 17.6 7.3 0 28.6 207.4
2010 6 23.0 11.1 0 34.5 230.5
2010 7 23.3* 14.1* 0* 24.4* 184.4* Provisional
2010 10 14.6 7.4 2 43.5 128.8 Provisional
```

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We want to extract the weather conditions and the temperature

- Read the file line by line
- If a line contains `Current conditions`, grab the text between the `<h3>` tags on the next line
- If a line contains `forecast-temperature`, grab the temperature between the `<h3>` tags on the next line

```
lines = infile.readlines()
for i in range(len(lines)):
    line = lines[i] # short form
    if 'Current conditions' in line:
        weather = lines[i+1][4:-6]
    if 'forecast-temperature' in line:
        temperature = float(lines[i+1][4:].split('&')[0])
        break # everything is found, jump out of loop
```

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File writing

- File writing is simple: collect the text you want to write in one or more strings and do, for each string, a

```
outfile.write(string)
```
- `outfile.write` does not add a newline, like `print`, so you may have to do that explicitly:

```
outfile.write(string + '\n')
```
- That's it! Compose the strings and write!

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Example: writing a nested list (table) to file (part 1)

- Given a table like

```
data = \
[[ 0.75, 0.29619813, -0.29619813, -0.75 ],
 [ 0.29619813, 0.11697778, -0.11697778, -0.29619813],
 [-0.29619813, -0.11697778, 0.11697778, 0.29619813],
 [-0.75, -0.29619813, 0.29619813, 0.75 ]]
```
- Write this nested list to a file

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Example: writing a nested list to file (part 2)

```
outfile = open('tmp_table.dat', 'w')
for row in data:
    for column in row:
        outfile.write('%14.8f' % column)
    outfile.write(
        '\n') # ensure linebreak
outfile.close()
```

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Summary of file reading and writing

- Reading a file:

```
infile = open(filename, 'r')
for line in infile:
    # process line

lines = infile.readlines()
for line in lines:
    # process line

for i in range(len(lines)):
    # process lines[i] and perhaps next line lines[i+1]

fstr = infile.read()
# process the whole file as a string fstr

infile.close()
```
- Writing a file:

```
outfile = open(filename, 'w') # new file or overwrite
outfile = open(filename, 'a') # append to existing file
outfile.write("Some string
...
")
```

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Dictionary functionality

<code>a = {}</code>	initialize an empty dictionary
<code>a = {'point': [2,7], 'value': 3}</code>	initialize a dictionary
<code>a = dict(point=[2,7], value=3)</code>	initialize a dictionary
<code>a['hide'] = True</code>	add new key-value pair
<code>a['point']</code>	get value corresponding to key
<code>'value' in a</code>	True if value is a key
<code>del a['point']</code>	delete a key-value pair
<code>a.keys()</code>	list of keys
<code>a.values()</code>	list of values
<code>len(a)</code>	number of key-value pairs
<code>for key in a:</code>	loop over keys in unsorted order
<code>for key in sorted(a.keys()):</code>	loop over keys in alphabetical order

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Summary of some string operations

```
s = 'Berlin: 18.4 C at 4 pm'
s[8:17]          # extract substring
s.find(':')      # index where first ':' is found
s.split(':')     # split into substrings
s.split()       # split wrt whitespace
'Berlin' in s    # test if substring is in s
s.replace('18.4', '20')
s.lower()        # lower case letters only
s.upper()        # upper case letters only
s.split()[4].isdigit()
s.strip()        # remove leading/trailing blanks
', '.join(list_of_words)
```