COMP08033 Computational Thinking with Algorithms, Semester 2 2018/2019	
Document Title:	Algorithms Problem Sheet (Python)
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Algorithms Problem Sheet (Python)

Question 1

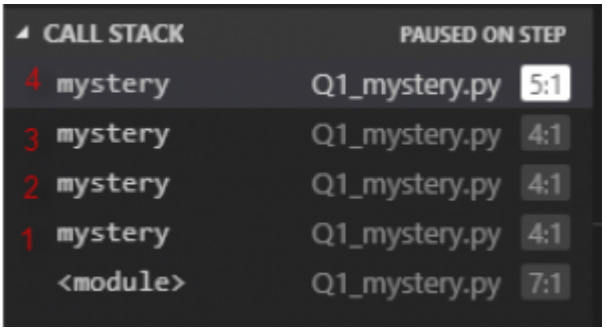
What will the output of the call mystery(1) be? Write an explanation of the reasoning behind your answer, using the aid of either a recursion trace diagram or a stack diagram. Include any code which you write for testing or explanation purposes as part of your answer.

Running the code:

```
1. def mystery(n):
2.     print(n)
3.     if n < 4:
4.         mystery(n+1)
5.     print(n)
6.
7. mystery(1)
```

outputs the following results:

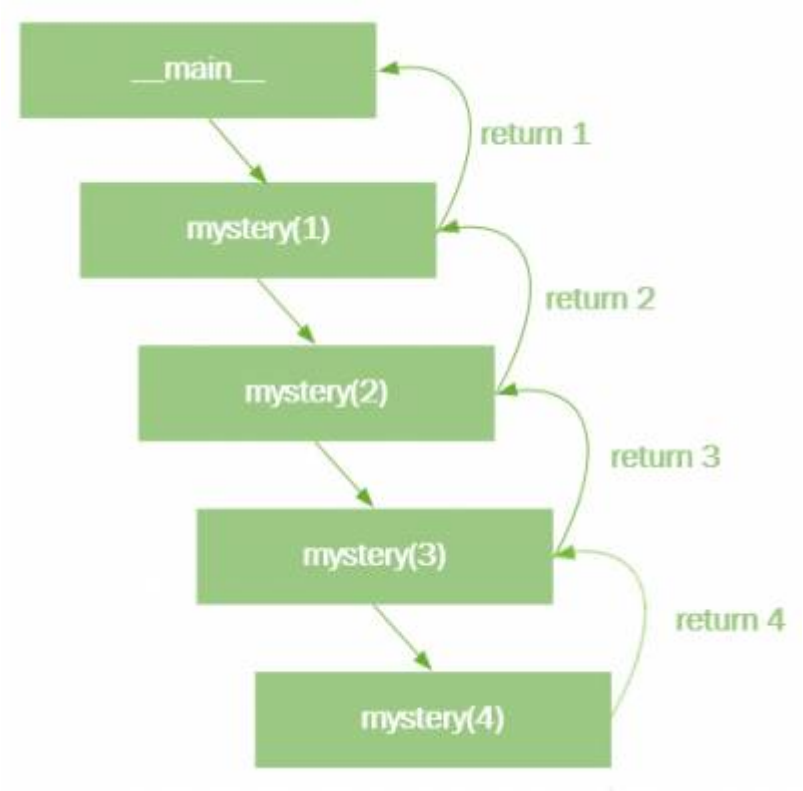
```
λ python Q1_mystery.py
1
2
3
4
4
3
2
1
```



The diagram above show the stack on the python debugger output.

At first running the code was confusing as the output did not make much sense since the variable *n* seems to decrement mysteriously once equal to four, however on closer inspection the key point to observe in the code sample “Q1_mystery.py” line 4, the function *mystery* calls itself repeatably inside the function and adds another instance of the function *mystery* on

top of the runtime call stack.



This results in four separate calls to the function *mystery*, piling up on the runtime stack, all holding the last value of *n* in the call to the function *mystery*. The call frames concludes with the print function on line five and popped from the stack in reverse order [1)] and printing the value of *n* that was initially passed into the function *mystery* until the stack is cleared and the function terminates.

Question 2

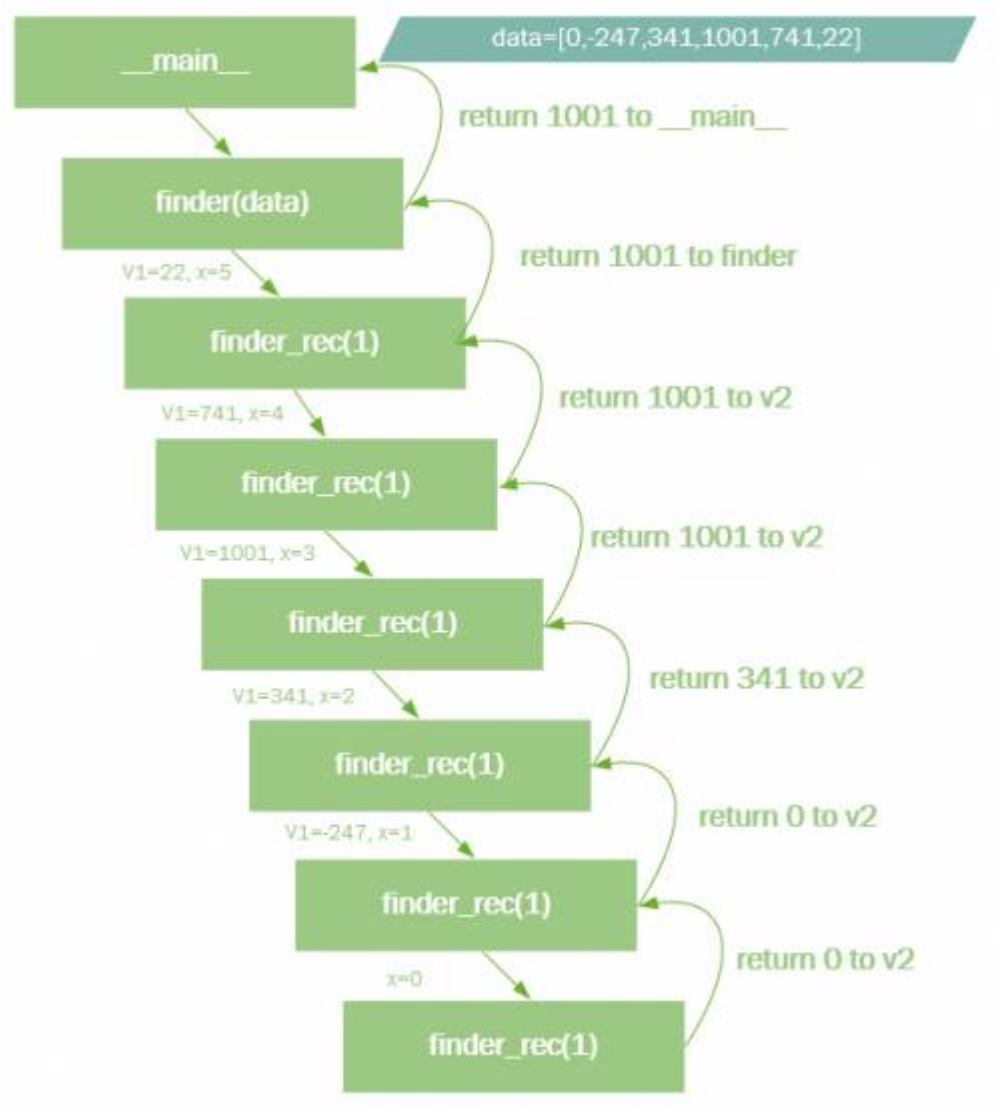
Q2 (a) What value is returned by a call to finder when the following array is used as input? (1 mark)

The Value returned is: 1001

Q2 (b) What characteristic of the input data set does the finder method determine? How does it determine this result? (3 marks)

The finder function finds the biggest number in the data array.

```
data=[0, -247, 341, 1001, 741, 22]
```



The data array above is passed into the first finder function and the passed into finder_rec using two values, the data array and the length of the array. The function funder_rec is then called recursively, calling itself until the all the values in the array is placed on the stack. The last call to finder_rec returns data[0] to V2, i.e. the value of 0, then the biggest value between -247 and zero is returned to the next stacked finder _rec that compares the returned value with the last value stored in v1 on the stack. The next cycle compares 341 and zero and again returns the biggest of the two. This repeats until the biggest number in the array is finally returned, i.e. 1001.

Q2 (c) Can you add some inline comments to the code above to explain how it works? (2 marks)

```
def finder(data):
    # call finder_rec function with data array and the length of the array
    # and return the final answer from finder_rec to the calling function
    return finder_rec(data, len(data)-1)

def finder_rec(data, x):
    # if the arra index is zero, return the value in the first position for comparison
    if x == 0:
        return data[x]
    # store the current value  from the array in v1 for comparison
    v1 = data[x]
    # store the biggest of the two variables from the last call to finder_rec in v2
    # for comparison when the call returns
    v2 = finder_rec(data, x-1)
    # compare the two values stored in v1 and v2 and return the biggest value for
    # the next comparison step, the biggest of v1 or v2 will be returned to v2 from
    # previous call to finder when popping off the stack
    if v1 > v2:
        return v1 # if v1 is bigger than v2 return v1
    else:
        return v2 # if v2 is bigger than v1 return v2

if __name__ == '__main__':
    # define the array of values to pass in to finder
    dat = [0, -247, 341, 1001, 741, 22]
    # call finder with the dataset created above and return the result to retval
    retval = finder(dat)
    # print retval to the console output
    print('The Value returned is:', retval)
```

Q2 (d) Write a method which achieves the same result as finder, but which uses an iterative approach instead of recursion. (2 marks)

```
def return_the_biggest(data):
    # assign the first item in the list to the variable "largest"
    largest=data[0]
    # now iterate through the list assigning one value at a time to testval
    for testval in numlist:
        # compare the values and assign the biggest to the variable "largest" if bigger
        if testval > largest:
            largest=testval
    #finally return the result
    return largest

if __name__ == '__main__':
    # define the list of number to process
    numlist=[0, -247, 341, 1001, 741, 22]
    retval = return_the_biggest(numlist)
    print('The biggest value in the list is:',retval)
```

The output of the code in the terminal is:

```
The biggest value in the list is: 1001
```

Question 3

Q3 (a) What is the best-case time complexity for this method, and why? (2 marks)

The best case time complexity is achieved when the first two element in the array is equal.

```
1. import time
2.
3. def contains_duplicates(elements):
4.     for i in range (0, len(elements)):
5.         for j in range(0, len(elements)):
6.             if i == j: # avoid self comparision
7.                 continue
8.             if elements[i] == elements[j]:
9.                 return True
10.     return False
11.
12. if __name__ == '__main__':
13.     testarr=[i for i in range(0,5001)]
14.     testarr[1]=0 # set the second element in the array to the value zero so it matches
    the first.
15.     start = time.time()
16.     result = contains_duplicates(testarr)
17.     end = time.time()
18.     print("duplicates found: ", result, "- Time taken:", (end-start)*1000, "ms")
```

The code executes and completes almost instantaneously when given an array of 5000 points to compare. The reason it completes so fast is that the function returns true as soon as a duplicate is found and stops comparing the rest of the array.

Q3 (b) What is the worst-case time complexity for this method, and why? (2 marks)

The worst case time scenario is achieved when there are no duplicates in the list.

```
1. import time
2.
3. def contains_duplicates(elements):
4.     for i in range (0, len(elements)):
5.         for j in range(0, len(elements)):
6.             if i == j: # avoid self comparison
7.                 continue
8.             if elements[i] == elements[j]:
9.                 return True
10.     return False
11.
12. if __name__ == '__main__':
13.     testarr=[i for i in range(0,5001)]
14.     # testarr[1]=0
15.     start = time.time()
16.     result = contains_duplicates(testarr)
17.     end = time.time()
18.     print("Duplicates found: ", result, "- Time taken:", (end-start)*1000, "ms")
```

The timing of the function is represented by the formula $O\left(n^2\right)$

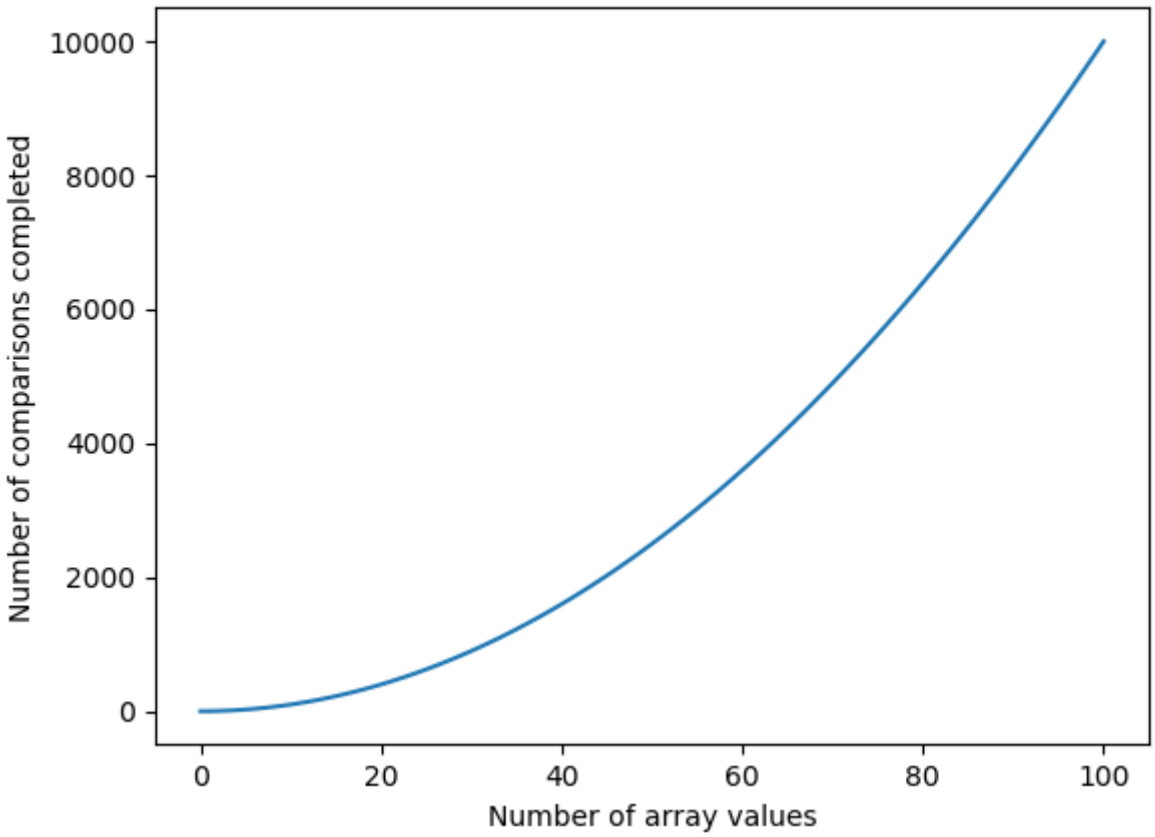
		Actual Test Case timing
Best Case	$O\left(2^2\right)=4\ cycles$	< 1 ms
Worst Case	$O\left(5000^2\right)=25,000,000\ cycles$	5713.1910 ms

So for no duplicates the entire array is stepped through in one loop and scanned against every value in the array as shown in the complexity formula, resulting in an exponential increase in time based on the number of values searched.

The python code below graphically illustrates the nature of the exponential growth of the code searching for duplicates.

```
import matplotlib.pyplot as pl

exp=[i**2 for i in range(0,101)]
pl.plot(exp)
pl.xlabel('Number of array values')
pl.ylabel('Number of comparisons completed')
pl.show()
```



Q3 (c) Modify the code above, so that instead of returning a boolean indicating whether or not a duplicate was found, it instead returns the number of comparisons the method makes between different elements until

a duplicate is found. (2 marks)

```
 1. import time
 2.
 3. def contains_duplicates(elements):
 4.     for i in range (0, len(elements)):
 5.         for j in range(0, len(elements)):
 6.             steps=(i+1)*(j+1)
 7.             if i == j: # avoid self comparison
 8.                 continue
 9.             if elements[i] == elements[j]:
10.                 #return True, steps
11.                 return steps
12.     #return False, steps
13.     return steps
14.
15. if __name__ == '__main__':
16.     testarr=[i for i in range(0,5001)]
17.     #testarr[0]=1000
18.     start = time.time()
19.     result = contains_duplicates(testarr)
20.     end = time.time()
21.     #print("Duplicates found:", result, "- Execution Time:", (end-start)*1000, "ms")
22.     print("Duplicates found in stepcount:", result, "- Execution Time:", (end-
    start)*1000, "ms")
```

The code in line 6 calculates the step value by first adding one to the zero based indexes, lines 11 and 13 then returns the step values calculated and returns the step values instead of the booleans.

Lines 10 and 12, commented out returns both, i.e. the boolean states and the counters.

Q3 (d) Construct an input instance with 5 elements for which this method would exhibit its best-case running time. (1 mark)

```
testarr=[1,1,3,4,5]
```

```
Duplicates found in stepcount: 2 - Execution Time: 0.0 ms
```

The best case scenario as illustrated in the code snippet above with five element are where the first two elements of the five elements match. The code will then complete in two cycles.

Q3 (e) Construct an input instance with 5 elements for which this method would exhibit its worst-case running time. (1 mark)

For worst case timing the array with five element will look like this:

```
testarr=[1,2,3,5,5]
```

The terminal output running the array with worst case element will result in 25 cycles.

```
Duplicates found in stepcount: 20 - Execution Time: 0.0 ms
```

Q3 (f) Which of the following input instances, [10,0,5,3,-19,5] or [0,1,0,-127,346,125] would take longer for this method to process, and why? (1 mark)

```
test1=[10,0,5,3,-19,5]
test2=[0,1,0,-127,346,125]
```

In test case one values 3 and 6 matches, so the code will complete 18 cycles to find the match.

In test case two values 1 and three matches, so only three cycles will be completed before a match is found.

```
if __name__ == '__main__':
    test1=[10,0,5,3,-19,5]
    test2=[0,1,0,-127,346,125]
    start = time.time()
    result = contains_duplicates(test2)
    end = time.time()
    print("Duplicates found in stepcount:", result, "- Execution Time:", (end-start)*1000,
"ms")
```

The terminal outputs running the code above confirms the results.

```
Duplicates found in stepcount: 18 - Execution Time: 0.0 ms
Duplicates found in stepcount: 3 - Execution Time: 0.0 ms
```

1)

https://www.cs.ucsb.edu/~pconrad/cs8/topics.beta/theStack/02/

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