

**Homework #3**  
**Due by Sunday 10/17, 11:59pm**

**Submission instructions:**

- a) You should turn in 6 files:
- 3 '.py' files: one, with all the code related, to each of the questions 2-4. Name your files: 'YourNetID\_hw3\_q2.py', 'YourNetID\_hw3\_q3.py', and 'YourNetID\_hw3\_q4.py'.
  - A '.pdf' file with all your written answers. Name your file: 'YourNetID\_hw3.pdf'
- Note: your netID follows an abc123 pattern, not N12345678.
- b) You should submit your homework via Gradescope.  
For Gradescope's autograding feature to work:
- a. Name all classes, functions and methods **exactly as they are in the assignment specifications**.
  - b. Make sure there are **no print statements** in your code. If you have tester code, please put it in a "main" function and **do not call it**.

**Question 1:**

Consider the following two implementations of a function that if given a list, `lst`, create and return a new list containing the elements of `lst` in reverse order.

```
def reverse1(lst):  
    rev_lst = []  
    i = 0  
    while(i < len(lst)):  
        rev_lst.insert(0, lst[i])  
        i += 1  
    return rev_lst
```

```
def reverse2(lst):  
    rev_lst = []  
    i = len(lst) - 1  
    while (i >= 0):  
        rev_lst.append(lst[i])  
        i -= 1  
    return rev_lst
```

If `lst` is a list of  $n$  integers,

1. What is the worst case running time of `reverse1(lst)`? Explain of your answer.
2. What is the worst case running time of `reverse2(lst)`? Explain of your answer.

### **Question 2:**

Consider the implementation we made in class for `ArrayList`, and its extensions you did in the lab.

In this question, we will add two more methods to this class: the `insert` method and the `pop` method. For this question, please submit the modified `ArrayList` class.

a) Implement the method `insert(self, index, val)` that inserts `val` before `index` (shifting the elements to make room for `val`).

For example, your implementation should follow the behavior below:

```
>>> arr_lst = ArrayList()
>>> for i in range(1, 4+1):
...     arr_lst.append(i)
>>> arr_lst.insert(2, 30)
>>> arr_lst
[1, 2, 30, 3, 4]
```

#### **Notes:**

1. Make sure to double the capacity of the array, if there is no room for an additional element.
2. Your function should raise an `IndexError` exception in any case the index (positive or negative) is out of range.

b) Implement the method `pop(self)`, that removes the last element from the list.

The `pop` method should return the element removed from the list, and put `None` in its place in the array. If `pop` was called on an empty list, an `IndexError` exception should be raised.

In order to maintain the linear memory usage of the list data structure, and its efficient amortized performance, we use the following shrinking strategy: When the number of elements in the list goes strictly below a quarter of the array's capacity, we shrink its capacity by half.

For example, your implementation should follow the behavior below:

```
>>> arr_lst = ArrayList()
>>> for i in range(1, 5+1):
...     arr_lst.append(i)
>>> arr_lst.pop()
5
>>> arr_lst.pop()
4
>>> arr_lst.pop()
3
>>> arr_lst.pop()
2
>>> arr_lst
[1]
```

**Note:** After the executing the code above, the capacity of the array in `ArrayList` will be 4.

- c) *Extra Credit (You don't need to submit):* The extending and shrinking strategies we use in our `ArrayList` implementation (doubling the capacity of the array each time there is no room to add an element, and shrinking the capacity of the array by a factor of 2 each time the number of elements is less than a quarter of the array's capacity), guarantees two important things:
- In any given time, the memory used to store the elements is linear. That is, if there are  $n$  elements in the array, then:  $n \leq (\text{capacity of the array}) \leq 4n$ .
  - Any sequence of  $n$  `append` and/or `pop` operations on an initially empty `ArrayList` object, takes  $O(n)$  time.

Proving these properties is out of the scope of this assignment, but we will show two supporting insights:

- Show that the following series of  $2n$  operations takes  $O(n)$  time:  $n$  `append` operations on an initially empty array, followed by  $n$  `pop` operations.
- Consider a variant to our shrinking strategy, in which an array of capacity  $N$ , is resized to capacity precisely that of the number of elements, any time the number of elements in the array goes strictly below  $N/2$ .  
Show that there exists a sequence of  $n$  `append` and/or `pop` operations on an initially empty `ArrayList` object, that requires  $\Omega(n^2)$  time to execute.

- d) Modify the `pop` method, so it could optionally get an index as a parameter. This index indicates the position of the element that is to be removed from the list.

Notes:

- Make sure to use the same shrinking strategy described above in section (b).
- Your function should raise an `IndexError` exception in any case the index (positive or negative) is out of range.

**Question 3:**

- a) Give a **linear implementation** of the following function:

```
def find_duplicates(lst)
```

The function is given a list `lst` of  $n$  integers. All the elements of `lst` are from the domain:  $\{1, 2, \dots, n-1\}$ . Note that this restricted domain implies that there are element/s appearing in `lst` more than once.

The function should return a list containing all the elements that appear in `lst` more than once.

For example, if `lst=[2, 4, 4, 1, 2]`, the call `find_duplicates(lst)` could return `[2, 4]`.

- b) Analyze the worst-case running time of your implementation in (a).

#### **Question 4:**

The `remove(value)` method of the `list` class, removes the **first** occurrence of `value` from the list it was called on, or raises a `ValueError` exception, if `value` is not present.

Note: Since `remove` needs to shift elements, its worst-case running time is linear.

In this question we will look into the function `remove_all(lst, value)`, that removes **all** occurrences of `value` from `lst`.

a) Consider the following implementation of `remove_all`:

```
def remove_all(lst, value):  
    end = False  
    while (end == False):  
        try:  
            lst.remove(value)  
        except ValueError:  
            end = True
```

Analyze the worst-case running time of the implementation above.

b) Give an implementation to `remove_all` that runs in worst-case linear time.

Notes:

1. Your implementation should **mutate the given list object** (in-place), without using an additional data structure.
2. Your implementation **should keep the relative order** of the elements that remain in the list

c) Analyze the worst-case running time of your implementation in (b).