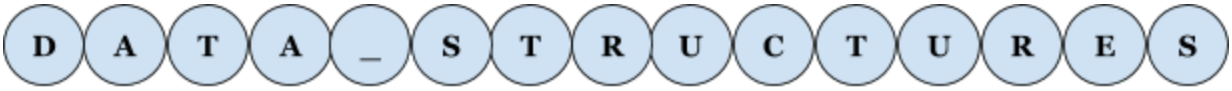
CS261 Data Structures

Assignment 2

v 1.01 (revised 6/27/2020)

Your Very Own Dynamic Array (plus Bag, Stack and Queue)



---

da = DynamicArray(list("DATA"))

self.size = 4
self.capacity = 4
self.data = ['D', 'A', 'T', 'A']

da = DynamicArray(list("STRUCTURES"))

self.size = 10
self.capacity = 16
self.data = ['S', 'T', 'R', 'U', 'C', 'T', 'U', 'R', 'E', 'S', None, None, None, None, None, None]

Contents

General Instructions

1. Programs in this assignment must be written in Python v3 and submitted to Gradescope before the due date specified in the syllabus. You may resubmit your code as many times as necessary. Gradescope allows you to choose which submission will be graded.

2. In Gradescope, your code will run through several tests. Any failed tests will provide a brief explanation of testing conditions to help you with troubleshooting. Your goal is to pass all tests.

3. We encourage you to create your own test programs and cases even though this work won't have to be submitted and won't be graded. Gradescope tests are limited in scope and may not cover all edge cases. Your submission must work on all valid inputs. We reserve the right to test your submission with more tests than Gradescope.

4. Your code must have an appropriate level of comments. At a minimum, each method should have a descriptive docstring. Additionally, put comments throughout the code to make it easy to follow and understand.

5. You will be provided with a starter "skeleton" code, on which you will build your implementation. Methods defined in skeleton code must retain their names and input / output parameters. Variables defined in skeleton code must also retain their names. We will only test your solution by making calls to methods defined in the skeleton code and by checking values of variables defined in the skeleton code. You can add more methods and variables, as needed.

   However, certains classes and methods can not be changed in any way. Please see comments in the skeleton code for guidance. In particular, content of any methods pre-written for you as part of the skeleton code must not be changed.

6. Both the skeleton code and code examples provided in this document are part of assignment requirements. They have been carefully selected to demonstrate requirements for each method. Refer to them for the detailed description of expected method behavior, input / output parameters, and handling of edge cases. Code examples may include assignment requirements not explicitly stated elsewhere.

7. For each method, you can choose to implement a recursive or iterative solution. When using a recursive solution, be aware of maximum recursion depths on large inputs. We will specify the maximum input size that your solution must handle.

Part 1 - Summary and Specific Instructions

1. Implement a Dynamic Array class by completing provided skeleton code in the file `dynamic_array.py`. Once completed, your implementation will include the following methods:

   ```
   resize()
   append()
   insert_at_index()
   get_at_index()
   remove_at_index()
   is_empty()
   length()
   slice()
   merge()
   reverse()
   sort()
   ```

2. We will test your implementation with different types of objects, not just integers. We guarantee that all such objects will have correct implementation of methods __eq__, __lt__, __gt__, __ge__, __le__ and __str__.

3. Number of objects stored in the array at any given time will be between 0 and 100,000 inclusive. Array must allow for storage of duplicate objects.

4. Variables in the DynamicArray are not marked as private. You are allowed to access and change their values directly. You are not required to write getter or setter methods for them.

5. RESTRICTIONS: You are not allowed to use ANY of the built-in methods of the Python lists (including, but not limited to append(), len(), any type of slices, IN operator, find(), indexof(), sort(), reverse()). You are also not allowed to use iterators associated with Python lists (meaning that `for my_value in my_list` type of loops are not permitted).

   You ARE allowed to use `while` loops and `for i in range()` loops.

   You are also allowed to create new lists of FIXED size, for example using constructs like `my_list = [None] * my_list_size`. Once such list is created, you can access / change value of any element, ONE AT A TIME, using its index:

   ```
   my_list_size = 20                  # store length of list in variable
   my_list = [None] * self.size       # create new list of that length
   my_list[5] = 20                    # to change value of element 6
   print(my_list[5])                  # access value of element 6
   ```

resize(self, new_capacity: int) -> None:

This method changes the capacity of the underlying storage for the array elements. It does not change values or order of any elements currently stored in the dynamic array.

It is intended to be an "internal" method of the Dynamic Array class, called by other class methods such as append(), remove_at_index(), insert_at_index() to manage the capacity of the underlying storage data structure.

Method should only accept positive integers for new_capacity. Additionally, new_capacity can not be smaller than the number of elements currently stored in the dynamic array (which is tracked by the self.size variable). If new_capacity is not a positive integer or if new_capacity < self.size, this method should not do any work and just exit.

Example #1:

```
da = DynamicArray()
print(da.size, da.capacity, da.data)
da.resize(10)
print(da.size, da.capacity, da.data)
da.resize(2)
print(da.size, da.capacity, da.data)
da.resize(0)
print(da.size, da.capacity, da.data)
```

Output:

```
0 4 [None, None, None, None]
0 10 [None, None, None, None, None, None, None, None, None, None]
0 2 [None, None]
0 2 [None, None]
```

NOTE: Example 2 below will not work properly until after append() method is implemented.

Example #2:

```
da = DynamicArray([1, 2, 3, 4, 5, 6, 7, 8])
print(da)
da.resize(20)
print(da)
da.resize(4)
print(da)
```

Output:

```
DYN_ARR Size/Cap: 8/8 [1, 2, 3, 4, 5, 6, 7, 8]
DYN_ARR Size/Cap: 8/20 [1, 2, 3, 4, 5, 6, 7, 8]
DYN_ARR Size/Cap: 8/20 [1, 2, 3, 4, 5, 6, 7, 8]
```

append(self, value: object) -> None:

This method adds a new value at the end of the dynamic array.

If internal storage associated with a dynamic array is already full, you need to DOUBLE its capacity before adding a new value.

Example #1:

```
da = DynamicArray()
print(da.size, da.capacity, da.data)
da.append(1)
print(da.size, da.capacity, da.data)
print(da)
```

Output:

```
0 4 [None, None, None, None]
1 4 [1, None, None, None]
DYN_ARR Size/Cap: 1/4 [1]
```

Example #2:

```
da = DynamicArray()
for i in range(9):
    da.append(i + 101)
    print(da)
```

Output:

```
DYN_ARR Size/Cap: 1/4 [101]
DYN_ARR Size/Cap: 2/4 [101, 102]
DYN_ARR Size/Cap: 3/4 [101, 102, 103]
DYN_ARR Size/Cap: 4/4 [101, 102, 103, 104]
DYN_ARR Size/Cap: 5/8 [101, 102, 103, 104, 105]
DYN_ARR Size/Cap: 6/8 [101, 102, 103, 104, 105, 106]
DYN_ARR Size/Cap: 7/8 [101, 102, 103, 104, 105, 106, 107]
DYN_ARR Size/Cap: 8/8 [101, 102, 103, 104, 105, 106, 107, 108]
DYN_ARR Size/Cap: 9/16 [101, 102, 103, 104, 105, 106, 107, 108, 109]
```

Example #3:

```
da = DynamicArray()
for i in range(600):
    da.append(i)
print(da.size)
print(da.capacity)
```

Output:

```
600
1024
```

insert_at_index(self, value: object, index: int) -> None:

This method adds a new value at the specified index position in the dynamic array. Index 0 refers to the beginning of the array. If the provided index is invalid, the method raises a custom "DynamicArrayException". Code for the exception is provided in the skeleton file. If the array contains N elements, valid indices for this method are [0, N] inclusive.

If internal storage associated with the dynamic array is already full, you need to DOUBLE its capacity before adding a new value.

Example #1:

```
da = DynamicArray([100])
print(da)
da.insert_at_index(0, 200)
da.insert_at_index(0, 300)
da.insert_at_index(0, 400)
print(da)
da.insert_at_index(3, 500)
print(da)
da.insert_at_index(1, 600)
print(da)
```

Output:

```
DYN_ARR Size/Cap: 1/4 [100]
DYN_ARR Size/Cap: 4/4 [400, 300, 200, 100]
DYN_ARR Size/Cap: 5/8 [400, 300, 200, 500, 100]
DYN_ARR Size/Cap: 6/8 [400, 600, 300, 200, 500, 100]
```

Example #2:

```
da = DynamicArray()
try:
    da.insert_at_index(-1, 100)
except Exception as e:
    print("Exception raised:", type(e))
da.insert_at_index(0, 200)
try:
    da.insert_at_index(2, 300)
except Exception as e:
    print("Exception raised:", type(e))
print(da)
```

Output:

```
Exception raised: <class '__main__.DynamicArrayException'>
Exception raised: <class '__main__.DynamicArrayException'>
DYN_ARR Size/Cap: 1/4 [200]
```

Example #3:

```
da = DynamicArray()
for i in range(1, 10):
    index, value = i - 4, i * 10
    try:
        da.insert_at_index(index, value)
    except Exception as e:
        print("Can not insert value", value, "at index", index)
print(da)
```

Output:

```
Can not insert value 10 at index -3
Can not insert value 20 at index -2
Can not insert value 30 at index -1
DYN_ARR Size/Cap: 6/8 [40, 50, 60, 70, 80, 90]
```

get_at_index(self, index: int) -> object:

This method returns value from the specific index in the dynamic array. Index 0 refers to the beginning of the array.

If the provided index is invalid, the method raises a custom "DynamicArrayException". Code for the exception is provided in the skeleton file. If the array contains N elements, valid indices for this method are [0, N - 1] inclusive.

Example #1:

```
da = DynamicArray([10, 20, 30, 40, 50])
print(da)
for i in range(4, -1, -1):
    print(da.get_at_index(i))
```

Output:

```
DYN_ARR Size/Cap: 5/8 [10, 20, 30, 40, 50]
50
40
30
20
10
```

Example #2:

```
da = DynamicArray([100, 200, 300, 400, 500])
print(da)
for i in range(-1, 7):
    try:
        print("Index", i, ": value", da.get_at_index(i))
    except Exception as e:
        print("Index", i, ": exception occured")
```

Output:

```
DYN_ARR Size/Cap: 5/8 [100, 200, 300, 400, 500]
Index -1 : exception occured
Index 0 : value 100
Index 1 : value 200
Index 2 : value 300
Index 3 : value 400
Index 4 : value 500
Index 5 : exception occured
Index 6 : exception occured
```

remove_at_index(self, index: int) -> None:

This method removes the element from the dynamic array given its index. Index 0 refers to the beginning of the array.

If the provided index is invalid, the method raises a custom "DynamicArrayException". Code for the exception is provided in the skeleton file. If the array contains N elements, valid indices for this method are [0, N - 1] inclusive.

When the number of elements stored in the array (before removal) is STRICTLY LESS than ¼ of it current capacity, the capacity must be reduced to TWICE the number of current elements. This check / capacity adjustment must happen BEFORE removal of the element. At no time the capacity can be reduced to less than 10 elements, regardless of the actual number of elements in the array.

Example #1:

```
da = DynamicArray([10, 20, 30, 40, 50, 60, 70, 80])
print(da)
da.remove_at_index(0)
print(da)
da.remove_at_index(6)
print(da)
da.remove_at_index(2)
print(da)
```

Output:

```
DYN_ARR Size/Cap: 8/8 [10, 20, 30, 40, 50, 60, 70, 80]
DYN_ARR Size/Cap: 7/8 [20, 30, 40, 50, 60, 70, 80]
DYN_ARR Size/Cap: 6/8 [20, 30, 40, 50, 60, 70]
DYN_ARR Size/Cap: 5/8 [20, 30, 40, 60, 70]
```

Example #2:

```
da = DynamicArray([1024])
print(da)
for i in range(17):
    da.insert_at_index(i, i)
print(da.size, da.capacity)
for i in range(16, -1, -1):
    da.remove_at_index(0)
print(da)
```

Output:

```
DYN_ARR Size/Cap: 1/4 [1024]
18 32
DYN_ARR Size/Cap: 1/10 [1024]
```

Example #3:

```
da = DynamicArray()
print(da.size, da.capacity)
[da.append(1) for i in range(100)]          # step 1 - add 100 elements
print(da.size, da.capacity)
[da.remove_at_index(0) for i in range(68)]  # step 2 - remove 69 elements
print(da.size, da.capacity)
da.remove_at_index(0)                       # step 3 - remove 1 element
print(da.size, da.capacity)
da.remove_at_index(0)                       # step 4 - remove 1 element
print(da.size, da.capacity)
[da.remove_at_index(0) for i in range(14)]  # step 5 - remove 14 elements
print(da.size, da.capacity)
da.remove_at_index(0)                       # step 6 - remove 1 element
print(da.size, da.capacity)
da.remove_at_index(0)                       # step 7 - remove 1 element
print(da.size, da.capacity)

for i in range(14):
    print("Before remove_at_index(): ", da.size, da.capacity, end="")
    da.remove_at_index(0)
    print(" After remove_at_index(): ", da.size, da.capacity)
```

Output:

```
0 4
100 128
32 128
31 128
30 62
16 62
15 62
14 30
Before remove_at_index():  14 30 After remove_at_index():  13 30
Before remove_at_index():  13 30 After remove_at_index():  12 30
Before remove_at_index():  12 30 After remove_at_index():  11 30
Before remove_at_index():  11 30 After remove_at_index():  10 30
Before remove_at_index():  10 30 After remove_at_index():  9 30
Before remove_at_index():  9 30 After remove_at_index():  8 30
Before remove_at_index():  8 30 After remove_at_index():  7 30
Before remove_at_index():  7 30 After remove_at_index():  6 14
Before remove_at_index():  6 14 After remove_at_index():  5 14
Before remove_at_index():  5 14 After remove_at_index():  4 14
Before remove_at_index():  4 14 After remove_at_index():  3 14
Before remove_at_index():  3 14 After remove_at_index():  2 10
Before remove_at_index():  2 10 After remove_at_index():  1 10
Before remove_at_index():  1 10 After remove_at_index():  0 10
```

is_empty(self) -> bool:

This method returns True if there are no elements in the array. Otherwise it returns False.

Example #1:

```
da = DynamicArray()
print(da.is_empty(), da)
da.append(100)
print(da.is_empty(), da)
da.remove_at_index(0)
print(da.is_empty(), da)
```

Output:

```
True DYN_ARR Size/Cap: 0/4 []
False DYN_ARR Size/Cap: 1/4 [100]
True DYN_ARR Size/Cap: 0/4 []
```

length(self) -> int:

This method returns the number of elements currently stored in the array.

Example #1:

```
da = DynamicArray()
print(da.length())
for i in range(10000):
    da.append(i)
print(da.length())
for i in range(9999, 5000, -1):
    da.remove_at_index(i)
print(da.length())
```

Output:

```
0
10000
5001
```

slice(self, start_index: int, size: int) -> object:

This method returns a new Dynamic Array object that contains the requested number of elements from the original array starting with the element located at the requested start index.

If the provided start index is invalid, or if there are not enough elements between start index and end of the array to make the slice of requested size, this method raises a custom "DynamicArrayException". Code for the exception is provided in the skeleton file.

Example #1:

```
  da = DynamicArray([1, 2, 3, 4, 5, 6, 7, 8, 9])
da_slice = da.slice(1, 3)
  print(da, da_slice, sep="\n")
  da_slice.remove_at_index(0)
  print(da, da_slice, sep="\n")
```

Output:

```
DYN_ARR Size/Cap: 9/16 [1, 2, 3, 4, 5, 6, 7, 8, 9]
DYN_ARR Size/Cap: 3/4 [2, 3, 4]
DYN_ARR Size/Cap: 9/16 [1, 2, 3, 4, 5, 6, 7, 8, 9]
DYN_ARR Size/Cap: 2/4 [3, 4]
```

Example #2:

```
da = DynamicArray([10, 11, 12, 13, 14, 15, 16])
print("SOUCE:", da)
slices = [(0, 7), (-1, 7), (0, 8), (2, 3), (5, 0), (5, 3)]
for i, cnt in slices:
    print("Slice", i, "/", cnt, end="")
    try:
        print(" --- OK: ", da.slice(i, cnt))
    except:
        print(" --- exception occurred.")
```

Output:

```
SOUCE: DYN_ARR Size/Cap: 7/8 [10, 11, 12, 13, 14, 15, 16]
Slice 0 / 7 --- OK:  DYN_ARR Size/Cap: 7/8 [10, 11, 12, 13, 14, 15, 16]
Slice -1 / 7 --- exception occurred.
Slice 0 / 8 --- exception occurred.
Slice 2 / 3 --- OK:  DYN_ARR Size/Cap: 3/4 [12, 13, 14]
Slice 5 / 0 --- OK:  DYN_ARR Size/Cap: 0/4 []
Slice 5 / 3 --- exception occurred.
```

merge(self, second_list: object) -> None:

This method takes another Dynamic Array object as a parameter, and appends all elements from the second array to the current one, in the same order as they are stored in the second array.

Example #1:

```
da = DynamicArray([1, 2, 3, 4, 5])
da2 = DynamicArray([10, 11, 12, 13])
print(da)
da.merge(da2)
print(da)
```

Output:

```
DYN_ARR Size/Cap: 5/8 [1, 2, 3, 4, 5]
DYN_ARR Size/Cap: 9/16 [1, 2, 3, 4, 5, 10, 11, 12, 13]
```

Example #2:

```
da = DynamicArray([1, 2, 3])
da2 = DynamicArray()
da3 = DynamicArray()
da.merge(da2)
print(da)
da2.merge(da3)
print(da2)
da3.merge(da)
print(da3)
```

Output:

```
DYN_ARR Size/Cap: 3/4 [1, 2, 3]
DYN_ARR Size/Cap: 0/4 []
DYN_ARR Size/Cap: 3/4 [1, 2, 3]
```

reverse(self) -> None:

This method reverses elements stored in the array. Reversal must be done "in place", without creating any temporary storage array.

Example #1:

```
da = DynamicArray([4, 5, 6, 7, 8, 9])
print(da)
da.reverse()
print(da)
da.reverse()
print(da)
```

Output:

```
DYN_ARR Size/Cap: 6/8 [4, 5, 6, 7, 8, 9]
DYN_ARR Size/Cap: 6/8 [9, 8, 7, 6, 5, 4]
DYN_ARR Size/Cap: 6/8 [4, 5, 6, 7, 8, 9]
```

Example #2:

```
da = DynamicArray()
da.reverse()
print(da)
da.append(100)
da.reverse()
print(da)
```

Output:

```
DYN_ARR Size/Cap: 0/4 []
DYN_ARR Size/Cap: 1/4 [100]
```

sort(self) -> None:

This method sorts the content of the current array in non-descending order. You can implement any sort method of your choice. Sorting does not have to be efficient or fast, a simple insertion sort will suffice. Duplicates in the array can be placed in any relative order in the sorted array (in other words, your sort does not have to be 'stable').

Example #1:

```
da = DynamicArray([1, 10, 2, 20, 3, 30, 4, 40, 5])
print(da)
da.sort()
print(da)
```

Output:

```
DYN_ARR Size/Cap: 9/16 [1, 10, 2, 20, 3, 30, 4, 40, 5]
DYN_ARR Size/Cap: 9/16 [1, 2, 3, 4, 5, 10, 20, 30, 40]
```

Part 2 - Summary and Specific Instructions

1. Implement a Bag ADT class by completing provided skeleton code in the file `bag_da.py`. You will use the Dynamic Array data structure that you have implemented in part 1 of this assignment as underlying data storage for your Bag ADT.

2. Once completed, your implementation will include the following methods:

   ```
   add()
   remove()
   count()
   clear()
   size()
   equal()
   ```

3. We will test your implementation with different types of objects, not just integers. We guarantee that all such objects will have correct implementation of methods __eq__, __lt__, __gt__, __ge__, __le__ and __str__.

4. Number of objects stored in the Bag at any given time will be between 0 and 100,000 inclusive. Bag must allow for storage of duplicate objects.

5. RESTRICTIONS: You are not allowed to use ANY built-in Python data structures and their methods. You must solve this portion of the assignment by importing the DynamicArray class that you wrote in part 1 and using class methods to write your solution.

   You are also not allowed to directly access any variables of the DynamicArray class (like self.size, self.capacity and self.data in part 1). All work must be done by only using class methods.

add(self, value: object) -> None:

This method adds a new element to the bag.

Example #1:

```
bag = Bag()
print(bag)
values = [10, 20, 30, 10, 20, 30]
for value in values:
    bag.add(value)
print(bag)
```

Output:

```
BAG: 0 elements. []
BAG: 6 elements. [10, 20, 30, 10, 20, 30]
```

remove(self, value: object) -> bool:

This method removes any one element from the bag that matches the provided "value" object. Method returns True if some object was actually removed from the bag. Otherwise it returns False.

Example #1:

```
bag = Bag([1, 2, 3, 1, 2, 3, 1, 2, 3])
print(bag)
print(bag.remove(7), bag)
print(bag.remove(3), bag)
print(bag.remove(3), bag)
print(bag.remove(3), bag)
print(bag.remove(3), bag)
```

Output:

```
BAG: 9 elements. [1, 2, 3, 1, 2, 3, 1, 2, 3]
False BAG: 9 elements. [1, 2, 3, 1, 2, 3, 1, 2, 3]
True BAG: 8 elements. [1, 2, 1, 2, 3, 1, 2, 3]
True BAG: 7 elements. [1, 2, 1, 2, 1, 2, 3]
True BAG: 6 elements. [1, 2, 1, 2, 1, 2]
False BAG: 6 elements. [1, 2, 1, 2, 1, 2]
```

count(self, value: object) -> int:

This method counts the number of elements in the bag that match the provided "value" object.

Example #1:

```
bag = Bag([1, 2, 3, 1, 2, 2])
print(bag, bag.count(1), bag.count(2), bag.count(3), bag.count(4))
```

Output:

```
BAG: 6 elements. [1, 2, 3, 1, 2, 2] 2 3 1 0
```

clear(self) -> None:

This method clears the content of the bag.

Example #1:

```
bag = Bag([1, 2, 3, 1, 2, 3])
print(bag)
bag.clear()
print(bag)
```

Output:

```
BAG: 6 elements. [1, 2, 3, 1, 2, 3]
BAG: 0 elements. []
```

size(self) -> int:

This method returns the number of elements currently in the bag.

Example #1:

```
bag = Bag([10, 20, 30, 40])
print(bag.size(), bag.remove(30), bag.size())
bag.clear()
print(bag.size())
```

Output:

```
4 True 3
0
```

equal(self, second_bag: object) -> bool:

This method compares the content of the bag with the content of the second bag provided by the user. Method returns True if the bags are equal (have the same number of elements and contain the same elements without regards to the order of elements). Otherwise it returns False.

Empty bag is only considered equal to another empty bag. This method should not change the contents of either bag.

Example #1:

```
bag1 = Bag([1, 2, 3, 4, 5, 6])
bag2 = Bag([6, 5, 4, 3, 2, 1])
bag3 = Bag([1, 2, 3, 4, 5])
bag_empty = Bag()

print(bag1, bag2, bag3, bag_empty, sep="\n")
print(bag1.equal(bag2), bag2.equal(bag1))
print(bag1.equal(bag3), bag3.equal(bag1))
print(bag2.equal(bag3), bag3.equal(bag2))
print(bag1.equal(bag_empty), bag_empty.equal(bag1))
print(bag_empty.equal(bag_empty))
print(bag1, bag2, bag3, bag_empty, sep="\n")
```

Output:

```
BAG: 6 elements. [1, 2, 3, 4, 5, 6]
BAG: 6 elements. [6, 5, 4, 3, 2, 1]
BAG: 5 elements. [1, 2, 3, 4, 5]
BAG: 0 elements. []
True True
False False
False False
False False
True
BAG: 6 elements. [1, 2, 3, 4, 5, 6]
BAG: 6 elements. [6, 5, 4, 3, 2, 1]
BAG: 5 elements. [1, 2, 3, 4, 5]
BAG: 0 elements. []
```

Part 3 - Summary and Specific Instructions

1. Implement a Stack ADT class by completing provided skeleton code in the file `stack_da.py`. You will use the Dynamic Array data structure that you have implemented in part 1 of this assignment as underlying data storage for your Stack ADT.

2. Once completed, your implementation will include the following methods:

```
push()
pop()
top()
is_empty()
size()
```

3. We will test your implementation with different types of objects, not just integers. We guarantee that all such objects will have correct implementation of methods __eq__, __lt__, __gt__, __ge__, __le__ and __str__.

4. Number of objects stored in the Stack at any given time will be between 0 and 100,000 inclusive. Stack must allow for storage of duplicate objects.

5. RESTRICTIONS: You are not allowed to use ANY built-in Python data structures and their methods. You must solve this portion of the assignment by importing the DynamicArray class that you wrote in part 1 and using class methods to write your solution.

   You are also not allowed to directly access any variables of the DynamicArray class (like self.size, self.capacity and self.data in part 1). All work must be done by only using class methods.

push(self, value: object) -> None:

This method adds a new element to the top of the stack.

Example #1:

```
s = Stack()
print(s)
for value in [1, 2, 3, 4, 5]:
    s.push(value)
print(s)
```

Output:

```
STACK: 0 elements. []
STACK: 5 elements. [1, 2, 3, 4, 5]
```

pop(self) -> object:

This method removes the top element from the stack and returns its value. If the stack is empty, the method raises a custom "StackException". Code for the exception is provided in the skeleton file.

Example #1:

```
s = Stack()
try:
    print(s.pop())
except Exception as e:
    print("Exception:", type(e))

for value in [1, 2, 3, 4, 5]:
    s.push(value)

for i in range(6):
    try:
        print(s.pop())
    except Exception as e:
        print("Exception:", type(e))
```

Output:

```
Exception: <class '__main__.StackException'>
5
4
3
2
1
Exception: <class '__main__.StackException'>
```

top(self) -> object:

This method returns the value of the top element of the stack without removing it. If the stack is empty, the method raises a custom "StackException". Code for the exception is provided in the skeleton file.

Example #1:

```
s = Stack()
try:
    s.top()
except Exception as e:
    print("No elements in stack", type(e))

s.push(10)
s.push(20)
print(s)

print(s.top())
print(s.top())
print(s)
```

Output:

```
No elements in stack <class '__main__.StackException'>
STACK: 2 elements. [10, 20]
20
20
STACK: 2 elements. [10, 20]
```

is_empty(self) -> bool:

This method returns True if there are no elements in the stack. Otherwise it returns False.

Example #1:

```
s = Stack()
print(s.is_empty())
s.push(10)
print(s.is_empty())
s.pop()
print(s.is_empty())
```

Output:

```
True
False
True
```

size(self) -> int:

This method returns the number of elements currently in the stack.

Example #1:

```
s = Stack()
print(s.size())
for value in [1, 2, 3, 4, 5]:
    s.push(value)
print(s.size())
```

Output:

```
0
5
```

Part 4 - Summary and Specific Instructions

1. Implement a Queue ADT class by completing provided skeleton code in the file `queue_da.py`. You will use the Dynamic Array data structure that you have implemented in part 1 of this assignment as underlying data storage for your Queue ADT.

2. Once completed, your implementation will include the following methods:

   ```
   enqueue()
   dequeue()
   is_empty()
   size()
   ```

3. We will test your implementation with different types of objects, not just integers. We guarantee that all such objects will have correct implementation of methods __eq__, __lt__, __gt__, __ge__, __le__ and __str__.

4. Number of objects stored in the Queue at any given time will be between 0 and 100,000 inclusive. Queue must allow for storage of duplicate elements.

5. RESTRICTIONS: You are not allowed to use ANY built-in Python data structures and their methods. You must solve this portion of the assignment by importing the DynamicArray class that you wrote in part 1 and using class methods to write your solution.

   You are also not allowed to directly access any variables of the DynamicArray class (like self.size, self.capacity and self.data in part 1). All work must be done by only using class methods.

enqueue(self, value: object) -> None:

This method adds a new value to the end of the queue.

Example #1:

```
q = Queue()
print(q)
for value in [1, 2, 3, 4, 5]:
    q.enqueue(value)
print(q)
```

Output:

```
QUEUE: 0 elements. []
QUEUE: 5 elements. [1, 2, 3, 4, 5]
```

dequeue(self) -> object:

This method removes and returns the value from the beginning of the queue. If the queue is empty, the method raises a custom "QueueException". Code for the exception is provided in the skeleton file.

Example #1:

```
q = Queue()
for value in [1, 2, 3, 4, 5]:
    q.enqueue(value)
print(q)
for i in range(6):
    try:
        print(q.dequeue())
    except Exception as e:
        print("No elements in queue", type(e))
```

Output:

```
QUEUE: 5 elements. [1, 2, 3, 4, 5]
1
2
3
4
5
No elements in queue <class '__main__.QueueException'>
```

is_empty(self) -> bool:

This method returns True if there are no elements in the queue. Otherwise it returns False.

Example #1:

```
q = Queue()
print(q.is_empty())
q.enqueue(10)
print(q.is_empty())
q.dequeue()
print(q.is_empty())
```

Output:

```
True
False
True
```

size(self) -> int:

This method returns the number of elements currently in the queue.

Example #1:

```
q = Queue()
print(q.size())
for value in [1, 2, 3, 4, 5, 6]:
    q.enqueue(value)
print(q.size())
```

Output:

```
0
6
```