Spring 2016 Data Structures - Test 1 Name: Mark F.

Question 1. (4 points) Consider the following Python code.

```
i = n
while i > 1:
    for j in range(n * n):
        print( i, j)
    i = i // 2
```

4

$O(n^2 \log_2 n)$

What is the big-oh notation $O(\,)$ for this code segment in terms of n?

Question 2. (4 points) Consider the following Python code.

```
for i in range(n):

    for j in range(n):
        print(j)

    for k in range(n):
        print(k)
```

4

$O(n^2)$

What is the big-oh notation $O(\,)$ for this code segment in terms of n?

Question 3. (4 points) Consider the following Python code.

```
def main(n):
    for i in range(n):
      doSomething(n) -O(n²)

def doSomething(n):
    for k in range(n): - O(
      doMore(n) - O(n)

def doMore(n):
    for j in range(n):
        print(j)

main(n)
```

4

$O(n^3)$

What is the big-oh notation $O(\,)$ for this code segment in terms of n?

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Question 4. (8 points) Suppose a $O(n^3)$ algorithm takes 10 second when n = 100. How long would the algorithm run when n = 1,000?

$T(n) = c n^3$ $\quad T(100) = c\,100^3 = 10 sec$ $\quad T(1000) = c\,1000^3$

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$c = \frac{10 sec}{100^3} = 10^{-5} sec$ $\quad = \frac{1000^3}{10^5} = \frac{10^9}{10^5} = 10^4 sec$

$\boxed{10,000 sec}$

Question 5. (10 points) Why should any method/function having a "precondition" raise an exception if the precondition is violated?

To inform the programmer that an error in using the function has occurred. It aids in debugging of the program since error detected immediately

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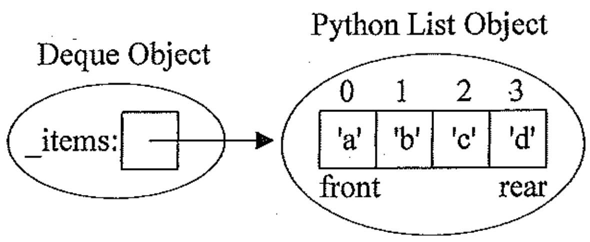
Question 6. A Deque (pronounced "Deck") is a linear data structure which behaves like a double-ended queue, i.e., it allows adding or removing items from either the front or the rear of the Deque. One possible implementation of a Deque would be to use a built-in Python list to store the Deque items such that

- the **front** item is **always stored at index 0,**
- the rear item is always at index len(self._items) -1 or -1



a) (6 points) Complete the big-oh O ( ), for each Deque operation, assuming the above implementation. Let n be the number of items in the Deque.

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isEmpty	addRear	removeRear	addFront	removeFront	size
O(1)	O(1)	O(1)	O(n)	O(n)	O(1)

b) (9 points) Complete the method for the `removeFront` operation, including the precondition check to raise an exception if it is violated.

```
def removeFront(self):
    """Removes and returns the Front item of the Deque
       Precondition:  the Deque is not empty.
       Postcondition: Front item is removed from the Deque and returned"""
        if len(self._items) == 0:
            raise ValueError("Cannot removeFront from empty Deque")
        return self._items.pop(0)
```

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c) (5 points) An alternate Deque implementation would swap the location of the front and rear items as in:

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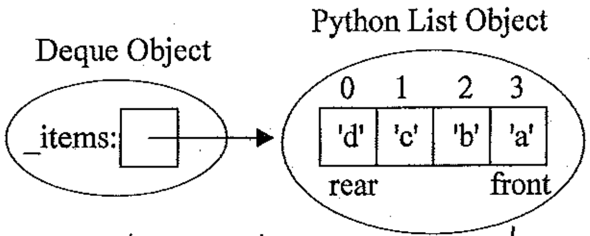

Why is this alternate implementation probably not very helpful with respect to the Deque's performance?

addRear + removeRear become O(n) and addFront and removeFront become O(1), so it just swaps the O(n)'s around.

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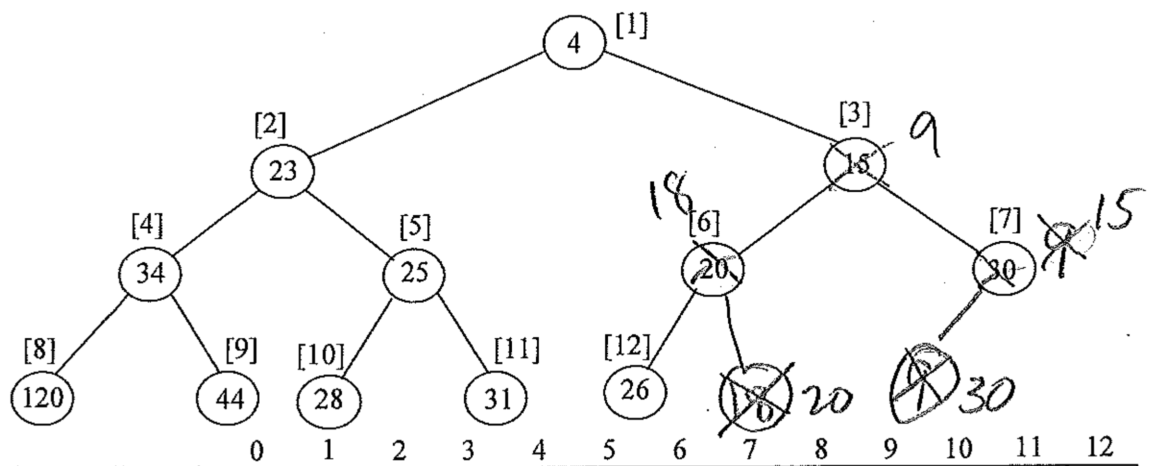
Question 7. Consider the binary heap approach to implement a priority queue. A Python list is used to store a *complete binary tree* (a full tree with any additional leaves as far left as possible) with the items being arranges by *heap-order property*, i.e., each node is ≤ either of its children. An example of a *min* heap "viewed" as a complete binary tree would be:



	0	1	2	3	4	5	6	7	8	9	10	11	12
Python List actually used to store heap items	not used	4	23	15	34	25	20	30	120	44	28	31	26

a) (3 points) For the above heap, the list indexes are indicated in [ ]'s. For a node at index *i*, what is the index of:

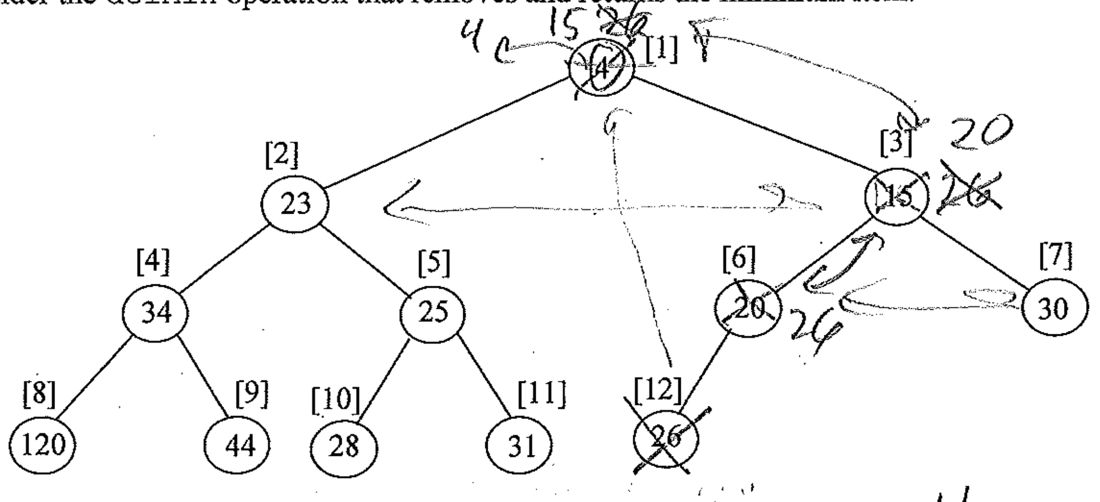
- its left child if it exists: $2*i$
- its right child if it exists: $2*i+1$
- its parent if it exists: $i//2$

b) (7 points) What would the above heap look like after inserting 18 and then 9 (show the changes on above tree)

c) (6 points) What is the big-oh notation for the `insert` operation? **(EXPLAIN YOUR ANSWER)**

$O(\log_2 n)$ The inserted it starts at index "n" where n is the # of items in the heap. ~~It's~~ Its index in the worst case is halved ($i//2$) until it reaches 1.

Now consider the `delMin` operation that removes and returns the minimum item.



d) (2 point) What item would `delMin` remove and return from the above heap? 4

e) (7 points) What would the above heap look like after `delMin`? (show the changes on above tree)

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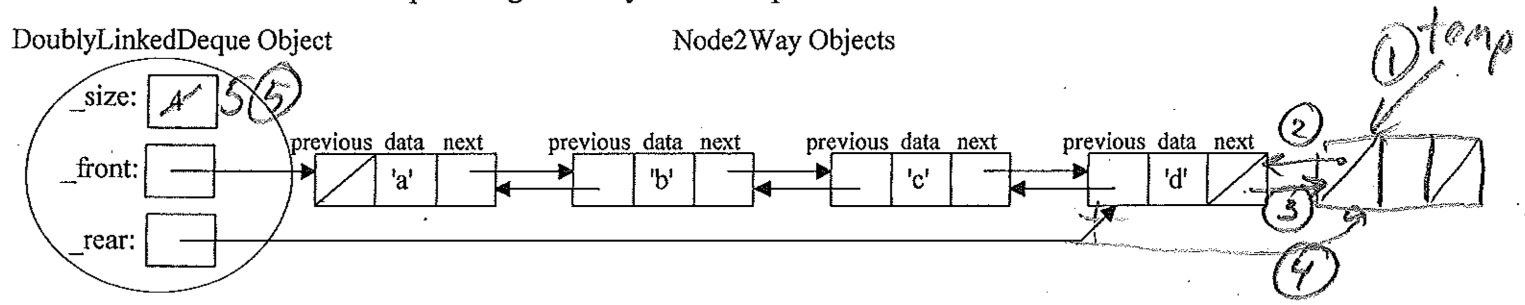
Question 8. The `Node2Way` class (which inherits the `node.py` class) can be used to dynamically create storage for each new item added to a Deque using a doubly-linked implementation as in:



a) (6 points) Determine the big-oh, O ( ), for each Deque operation assuming the above doubly-linked implementation. Let n be the number of items in the Deque.

6

addFront	removeFront	addRear	removeRear	size	`__str__`
$O(1)$	$O(1)$	$O(1)$	$O(1)$	$O(1)$	$O(n^2)$

b) (14 points) Complete the `addRear` method.

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```
class DoublyLinkedDeque(object):
    """ Doubly-Linked list based Deque implementation."""

    def __init__(self):
        self._size = 0
        self._front = None
        self._rear = None

    def addRear(self, newItem):
        """ Adds the newItem to the rear of the Deque.
            Precondition:  none """
        temp = Node2Way(newItem)
        if self._size ==0:
            self._front = temp
        else:
            temp.setPrevious(self._rear)
            self._rear.setNext(temp)
        self._rear = temp
        self._size += 1
```

(special case adding 1st item)

```
class Node:
    def __init__(self,initdata):
        self.data = initdata
        self.next = None

    def getData(self):
        return self.data

    def getNext(self):
        return self.next

    def setData(self,newdata):
        self.data = newdata

    def setNext(self,newnext):
        self.next = newnext
```

```
class Node2Way(Node):
    def __init__(self,initdata):
        Node.__init__(self,initdata)
        self.previous = None

    def getPrevious(self):
        return self.previous

    def setPrevious(self,newprevious):
        self.previous = newprevious
```

picture +2
# of steps +2
normal case code +7
Special case(s) +3

c) (5 points) Would using singly-linked nodes (i.e., `Node` objects instead of `Node2Way`) slow down any of the Deque operations? Justify your answer

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Yes, the removeRear would become O(n) because we need to reset the self._rear pointer by starting at the first node and traversing down the chain of nodes

.5