Test 1 will be Thursday February 21th in class. It will be closed-book and notes, except for one 8.5" x 11" sheet of paper (you can use front and back) containing any notes that you want AND the Python Summary handout. The test will cover the following topics (and maybe more).

Chapter 1. Introduction
Python control structures: if, while, for,
Python built-in data structures: list, dictionary, string
Preconditions, postconditions, and raising exceptions to enforce the precondition
Defining classes (e.g., Die) including inheritance, overriding methods

Chapter 2. Algorithm Analysis
Machine dependent measures of performance: program running time and instruction count
Machine independent measures of performance: big-oh, orders of complexity: constant O(1), logarithmic O(log n), linear O(n), "n log n"/log linear O(n log n), quadratic $O(n^2)$, cubic $O(n^3)$, exponential $O(2^n)$
Complexity analysis of an algorithm to determine its big-oh notation
Implementation of Python lists as an array of object references with implications on operation big-oh (e.g., pop() is O(1) while pop(0) is O(n), etc.)

Chapter 3. Basic Data Structures
General concept of a stack: LIFO, top and bottom
Stack Operations: pop, push, peek, size, isEmpty, __str__
Stack Implementations: Python list to store stack items and linked list of Nodes to store stack items including big-oh of operations
Stack Applications: general idea of using a stack to do parentheses matching and palindrome checking

General concept of a queue: FIFO, front and rear
Queue Operations: enqueue, dequeue, peek, size, isEmpty, __str__
Queue Implementations: Python list to store queue items and linked list of Nodes to store stack items including big-oh of operations

General concept of a deque: double ended queue, front and rear
Deque Operations: addFront, addRear, removeFront, removeRear, size, isEmpty, __str__
Deque Implementations: Python list to store deque items, singly-linked list of Nodes to store deque items, and doubly-linked list of Nodes (e.g, Node2Way) including big-oh of operations
Deque Applications: general idea of using deque to do palindrome checking

General concept of a list: head, tail, index
Categories of List operations: index-based, content-based, cursor-based
Unordered List operations and implementation with a singly-linked list of Nodes including big-oh of operations
Ordered List operations and implementation with a singly-linked list of Nodes including big-oh of operations

Section 6.6. Priority Queue with Binary Heaps
General concept of a priority queue: remove highest priority next
Priority Queue Operations: enqueue, dequeue, peek, size, isEmpty, __str__
Priority Queue Implementations: Python list unordered, Python list ordered by priority, Binary Heap including big-oh of operations
Binary Heap implementation: insert, findMin, delMin, isEmpty, size, buildHeap including big-oh of operations, and binary-tree diagrams after insert and delMin operations

Fall 2018 Data Structures - Test 1 Name: _____

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

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

1 2 4 8 16 ... $\log_2 n$ $O(n \log_2 n)$

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

$n \log_2 n$ $n \times n$ $n^2 + n\log_2 n$ $O(n^2)$

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)

def doSomething(n):
    for j in range(n*n):
        doMore(n)

def doMore(n):
    for k in range(n*n):
        print(k)

main(n)
```

n $O(n^5)$

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

Question 4. (6 points) Suppose a $O(n^4)$ algorithm takes 10 second when n = 1000. How long would the algorithm run when n = 10,000?

$T(n) = c n^4 =$

$T(1000) = c\,1000^4 = 10\text{ sec}$

$c = \frac{10\text{ sec}}{1000^4}$

$T(10000) = c\,10000^4 = (10^4)^4 = c\,10^{16}$

$= \frac{10\text{ sec}}{1000^4}\,10000^4$

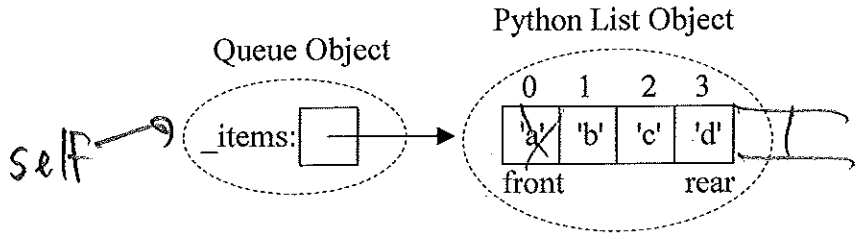
$= \frac{10\text{ sec}}{10^{12}}\,10^{16} = 10^5\text{ sec}$

Question 5. (8 points) Why should a method/function having a "precondition" raise an exception if the precondition is violated?

Raise exception immediately where error occur instead of later in code where the source of the error is harder to track down.

Question 6. A FIFO queue allows adding a new item at the rear using an enqueue operation, and removing an item from the front using a dequeue operation. One possible implementation of a queue would be to use a built-in Python list to store the queue 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 expected big-oh $O(\ )$, for each Queue operation, assuming the above implementation. Let n be the number of items in the queue.

isEmpty	enqueue(item)	dequeue	peek - returns front item without removing it	__str__	size
O(1)	O(1)	O(n)	O(1)	O(n)	O(1)

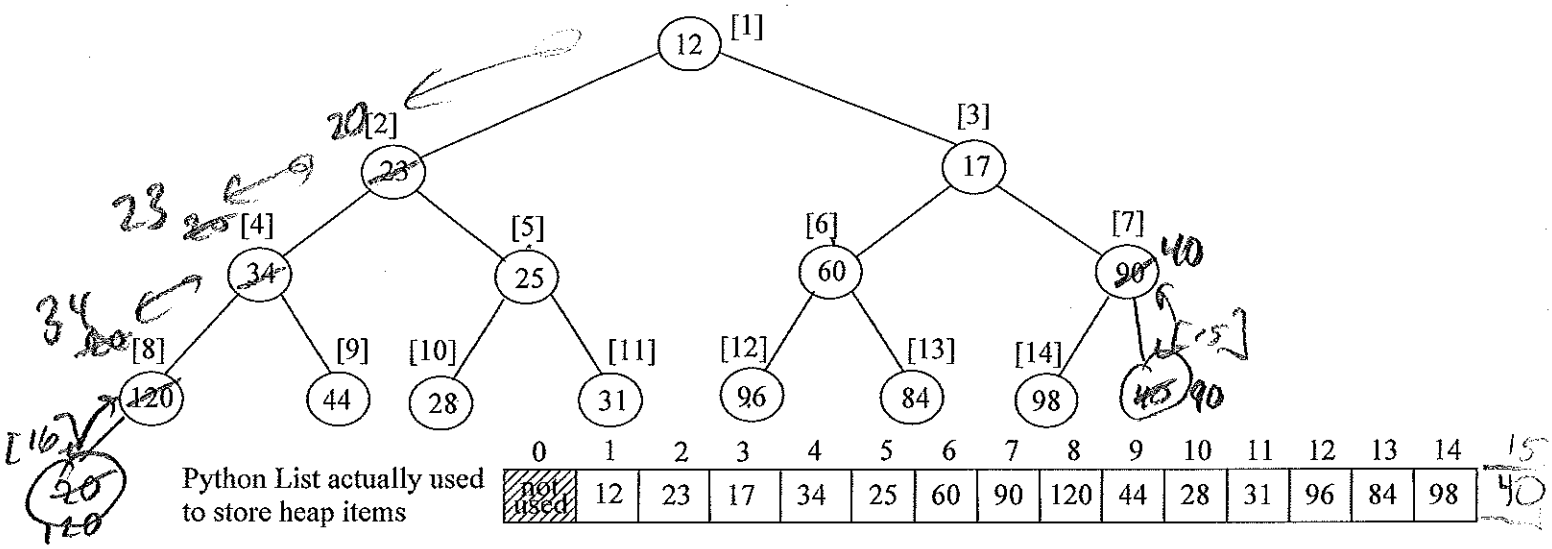
b) (8 points) Complete the method for the dequeue operation, **including the precondition check to raise an exception if it is violated.**

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

c) (8 points) Complete the method for the __str__ operation, (front) a b c d (rear)

```
def __str__(self):
    """ Returns a string representation of items from front to rear. """
    strResult = "(front) "
    for item in self._items:
        strResult += str(item) + " "
    return strResult + "(rear)"
```

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:

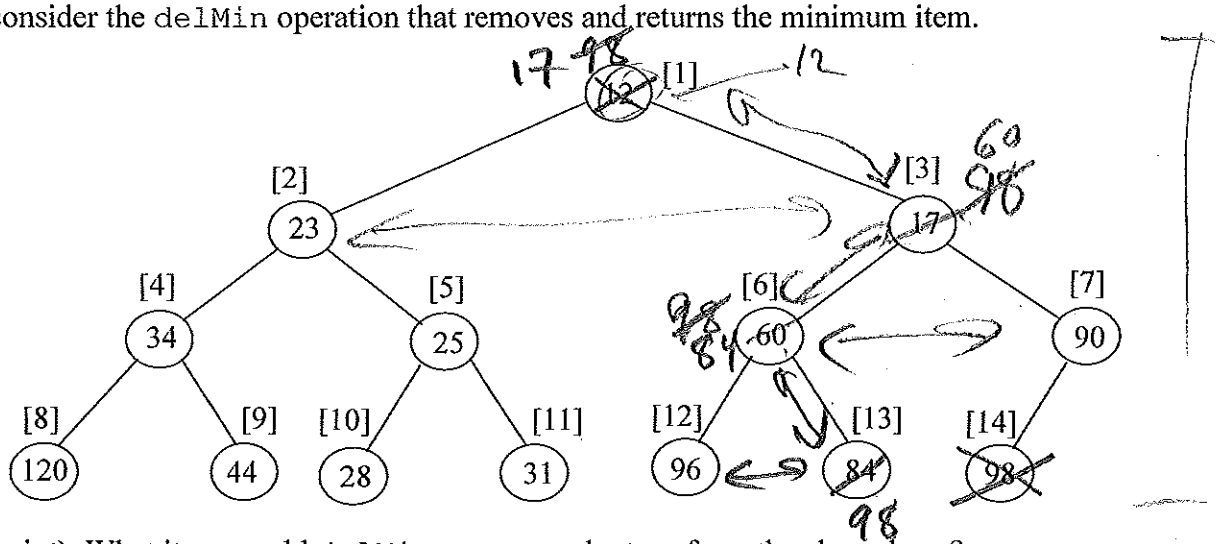


a) (3 points) For the above heap, the list indexes are indicated in [ ]'s. For a node at index *i*, what is the index of:

- 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 40 **and then** 20 (show the changes on above tree)

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



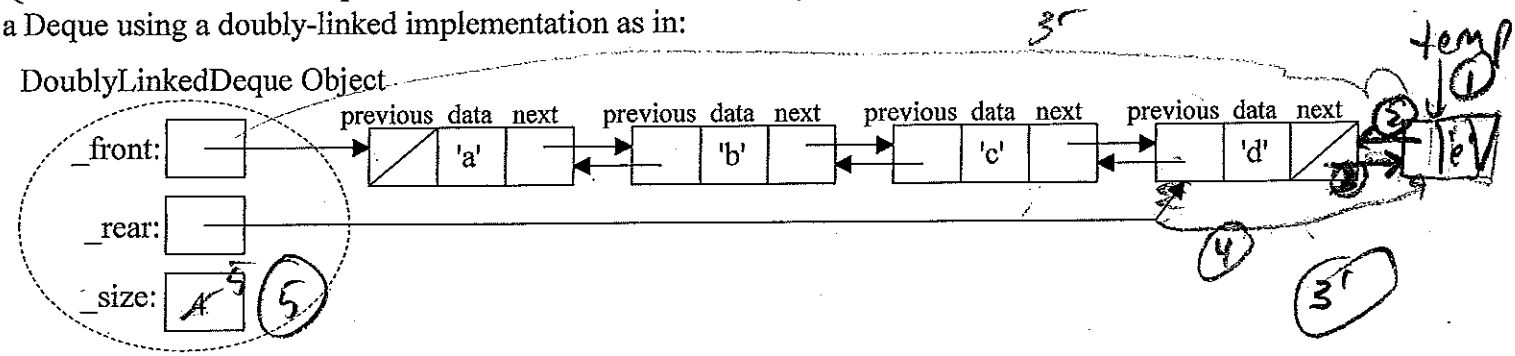
c) (2 point) What item would `delMin` remove and return from the above heap?

d) (7 points) What would the heap look like after `delMin`? (show the changes on tree in the middle of the page)

e) (6 points) Performing 20,000 `inserts` into an initially empty binary heap takes 0.23 seconds. Now, if we perform 20,000 `delMin` operations, it takes 0.39 seconds. Explain why 20,000 `delMin` operations take more time than the 20,000 `insert` operations?

Insert does one compare per level and delMin does two compares per level (compare two children to find min. then compare with min. child). Plus, inserted item rarely percolates to root, but leaf item moved to root likely percolated back down to being a leaf.

Question 8. The `Node2Way` and `Node` classes 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) Complete the big-oh expected $O(\ )$, for each DoublyLinkedDeque operation, assuming the above implementation. Let n be the number of items in the DoublyLinkedDeque.

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

b) (16 points) Complete the `addRear` method for the above DoublyLinkedDeque implementation.

```
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)
temp.setPrevious(self._rear)
if self._size == 0:
    self._front = temp
else:
    self._rear.setNext(temp)
self._rear = temp
self._size += 1
```

```
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
```

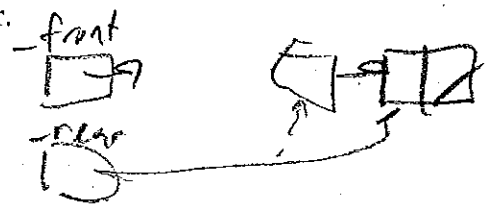
```
from node import Node

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
```

c) (5 points) Why would using singly-linked nodes (i.e., only Node objects with data and next) to implement the Deque lead to poor performance (i.e., cause some Deque operations to have worse big-oh notations)? Justify your answer.



The removeRear method would be O(n) because resetting the _rear pointer requires traversing from _front to find next to last Node.