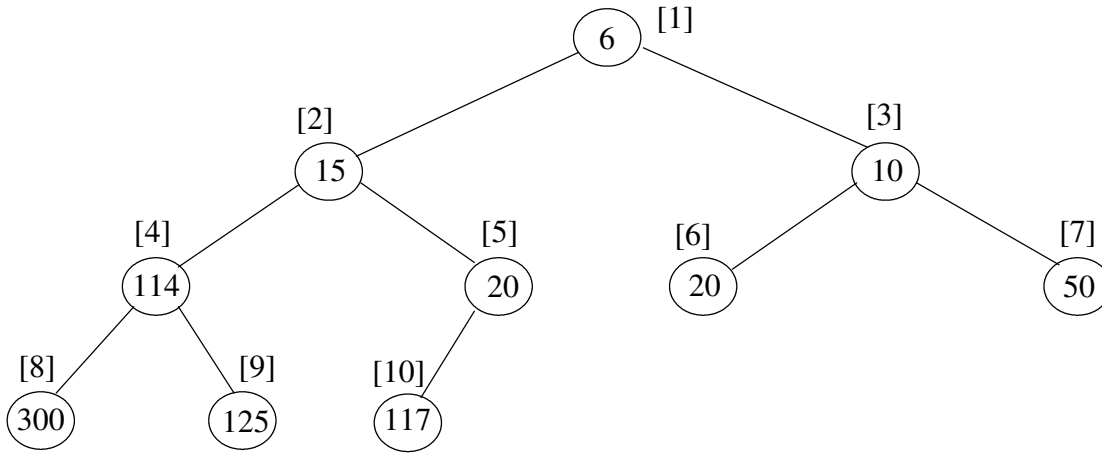


1. Section 6.6 discusses a very “non-intuitive”, but powerful list/array-based approach to implement a priority queue, call a binary heap. The list/array is used to store a *complete binary tree* (a full tree with any additional leaves as far left as possible) with the items being arranged by *heap-order property*, i.e., each node is  $\leq$  either of its children. An example of a *min heap* “viewed” as a complete binary tree would be:



Python List actually used to store heap items

	0	1	2	3	4	5	6	7	8	9	10
	not used	6	15	10	114	20	20	50	300	125	117

a) For the above heap, the list/array indexes are indicated in [ ]'s. For a node at index  $i$ , what is the index of:

- its left child if it exists:
- its right child if it exists:
- its parent if it exists:

b) What would the above heap look like after inserting 13 and then 3? (show the changes on above tree)

General Idea of `insert(newItem)`:

- append `newItem` to the end of the list (easy to do, but violates heap-order property)
- restore the heap-order property by repeatedly swapping the `newItem` with its parent until it *percolates* to correct spot

c) What is the big-oh notation for inserting a new item in the heap?

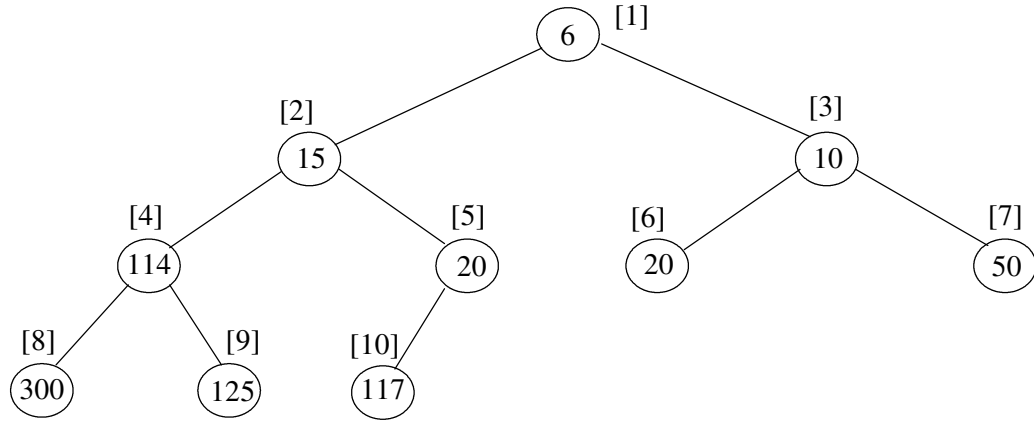
d) Complete the code for the `percUp` method used by `insert`.

```
class BinHeap:
    def __init__(self):
        self.heapList = [0]
        self.currentSize = 0

    def percUp(self, currentIndex):
        parentIndex =
        while

    def insert(self, k):
        self.heapList.append(k)
        self.currentSize = self.currentSize + 1
        self.percUp(self.currentSize)
```

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



Python List actually used to store heap items

	0	1	2	3	4	5	6	7	8	9	10
	not used	6	15	10	114	20	20	50	300	125	117

- What item would `delMin` remove and return from the above heap?
- What is the quickest way to fill the hole left by `delMin`?
- What new problem does this cause?

General Idea of `delMin()`:

- remember the minimum value so it can be returned later (easy to find - at index 1)
- copy the last item in the list to the root, delete it from the right end, decrement size
- restore the heap-order property by repeatedly swapping this item with its smallest child until it *percolates down* to the correct spot
- return the minimum value

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

e) Complete the code for the `percDown` method used by `delMin`.

<pre>class BinHeap:     .     .     .      def minChild(self,i):         if i * 2 + 1 &gt; self.currentSize: # if only left child             return i * 2         else:             if self.heapList[i * 2] &lt; self.heapList[i * 2 + 1]:                 return i * 2             else:                 return i * 2 + 1      def delMin(self):         retval = self.heapList[1]         self.heapList[1] = self.heapList[self.currentSize]         self.currentSize = self.currentSize - 1         self.heapList.pop()         self.percDown(1)         return retval</pre>	<pre>def percDown(self, currentIndex):</pre>
--	--

f) What is the big-oh notation for `delMin`?

Once we have a working BinHeap, then implementing the `PriorityQueue` class using a BinHeap is a piece of cake:

```

### File: priority_queue.py
from binheap import BinHeap

class PriorityQueue:
    def __init__(self):
        self._heap = BinHeap()

    def isEmpty(self):
        return self._heap.isEmpty()

    def enqueue(self, item):
        self._heap.insert(item)

    def dequeue(self):
        return self._heap.delMin()

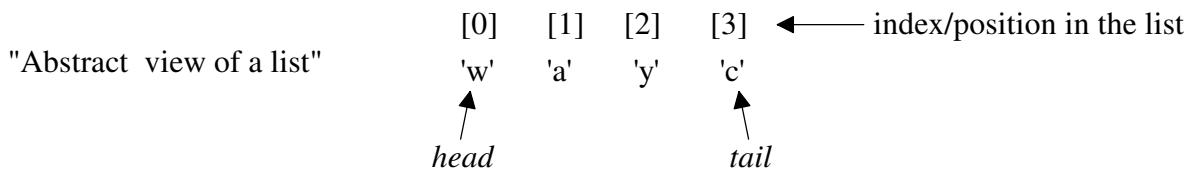
    def size(self):
        return self._heap.size()

    def __str__(self):
        return str(self._heap)
    
```

```

>>> q = PriorityQueue()
>>> print(q)
[]
>>> q.enqueue(5)
>>> q.enqueue(1)
>>> q.enqueue(7)
>>> print(q)
[1, 5, 7]
>>> q.dequeue()
1
>>> print(q)
[5, 7]
    
```

3. A “list” is a generic term for a sequence of items in a linear arrangement. Unlike stacks, queues and dequeues access to list items is not limited to either end, but can be from any position in the list. The general terminology of a list is illustrated by:



There are three broad categories of list operations that are possible:

- **index-based operations** - the list is manipulated by specifying an index location, e.g.,  
`myList.insert(3, item)` # insert item at index 3 in myList
- **content-based operations** - the list is manipulated by specifying some content (i.e., item value), e.g.,  
`myList.add(item)` # adds the item to the list
- **cursor-base operations** - a *cursor* (current position) can be moved around the list, and it is used to identify list items to be manipulated, e.g.,  
`myList.first()` # sets the cursor to the head item of the list  
`myList.next()` # moves the cursor one position toward the tail of the list  
`myList.remove()` # deletes the second item in the list because that’s where the cursor is currently located

The following table summarizes the operations from the three basic categories on a list, L:

Index-based operations	Content-based operations	cursor-based operations
<code>L.insert(index, item)</code> <code>item = L[index]</code> <code>L[index] = newValue</code> <code>L.pop(index)</code>  <code>L.append(item)</code> <code>L.pop()</code>	<code>L.add(item)</code> <code>L.remove(item)</code> <code>L.search(item)</code> #return Boolean <code>i = L.index(item)</code>	<code>L.hasNext()</code> <code>L.next()</code> <code>L.hasPrevious()</code> <code>L.previous()</code> <code>L.first()</code> <code>L.last()</code> <code>L.insert(item)</code> <code>L.replace(item)</code> <code>L.remove()</code>

Built-in Python lists are unordered with a mixture of index-based and content-based operations. We know they are implemented using a contiguous block of memory (i.e., an array). The textbook talks about an unordered list ADT, and a sorted list ADT which is more content-based. Both are implemented using a singly-linked list.

a) Why would a singly-linked list be a bad choice for implementing a cursor-based list ADT?