1. Suppose you had a map of settlements on the planet X
(Assume edges could connecting all vertices with their Euclidean distances as their costs)

We want to build roads that allow us to travel between any pair of cities. Because resources are scarce, we want the total length of all roads build to be minimal. Since all cities will be connected anyway, it does not matter where we start, but assume we start at “a”.

a) Assuming we start at city “a” which city would you connect first? Why this city? closest to ‘a’.

b) What city would you connect next to expand your partial road network? closest to our partial road system.

c) What would be some characteristics of the resulting "graph" after all the cities are connected?
- no cycles ⇒ a tree
- connected graph

d) Does your algorithm come up with the overall best (globally optimal) result?
Yes
Minimum Spanning Tree, MST
2. Prim's algorithm for determining the minimum-spanning tree (MST) of a graph is another example of a greedy algorithm. Unlike divide-and-conquer and dynamic programming algorithms, greedy algorithms DO NOT divide a problem into smaller subproblems. Instead a greedy algorithm builds a solution by making a sequence of choices that look best ("locally" optimal) at the moment without regard for past or future choices (no backtracking to fix bad choices).

a) What greedy criteria does Prim’s algorithm use to select the next vertex and edge to the partial minimum spanning tree?

\[
\text{add closest vertex to any already in partial MST}
\]

b) Consider the textbook's Prim's Algorithm code (Listing 7.12 p. 346) which is incorrect.

```python
def prim(G, start):
    pq = PriorityQueue()
    for v in G:
        v.setDistance(sys.maxsize)
        v.setPred(None)
    start.setDistance(0)
    pq.buildHeap([(v.getDistance(), v) for v in G])
    while not pq.isEmpty():
        currentVert = pq.delMin()
        for nextVert in currentVert.getConnections():
            newCost = currentVert.getWeight(nextVert)
            if v in pq and newCost < nextVert.getDistance():
                nextVert.setPred(currentVert)
                nextVert.setDistance(newCost)
                pq.decreaseKey(nextVert, newCost)
```

c) What is wrong with the code? (Fix the above code.)

1. Creates pq PriorityQueue but calls BinHeap delMin() method.
2. What's v? It must contain uses __eq__
3. NewCost calculation only needs currentVert.getWeight(newVert)
4. What's decreaseKey method?

3. To avoid "massive" changes to the binHeap class, it can store PriorityQueueEntry objects:

```python
class PriorityQueueEntry:
    def __init__(self, x, y):
        self.key = x
        self.val = y

    def getKey(self):
        return self.key

    def getValue(self):
        return self.val

    def setValue(self, newValue):
        self.val = newValue

def __lt__(self, other):
    return self.key < other.key

def __gt__(self, other):
    return self.key > other.key

def __eq__(self, other):
    return self.val == other.val

def __hash__(self):
    return hash(self.key)
```

a) Update the above Prim's algorithm code to use PriorityQueueEntry objects.
b) Why do the __lt__ and __gt__ methods compare key attributes, but __eq__ compare val attributes?

```
<, > need to check key/priority
== needs to compare val/vertex.
```
c) When used for Prim’s algorithm what type of objects are the vals compared by __eq__?

```
vertex
```

d) What changes to the Graph and Vertex classes need to be made?

```
nothing?
```

e) Complete the __contains__ and decreaseKey methods.

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

    def buildHeap(self, alist):
        i = len(alist) // 2
        self.currentSize = len(alist)
        self.heapList = [0] + alist[:]
        while (i > 0):
            self.percDown(i)
            i = i - 1

    def percDown(self, i):
        while (i * 2) <= self.currentSize:
            mc = self.minChild(i)
            if self.heapList[i] > self.heapList[mc]:
                tmp = self.heapList[i]
                self.heapList[i] = self.heapList[mc]
                self.heapList[mc] = tmp
                i = mc
            else:
                return

    def minChild(self, i):
        if i * 2 + 1 > self.currentSize:
            return i * 2
        else:
            if self.heapList[i*2] < self.heapList[i*2+1]:
                return i * 2
            return i * 2 + 1

    def percUp(self, i):
        while i // 2 > 0:
            if self.heapList[i] < self.heapList[i // 2]:
                tmp = self.heapList[i // 2]
                self.heapList[i // 2] = self.heapList[i]
                self.heapList[i] = tmp
                i = i // 2

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

    def delMin(self):
        retval = self.heapList[1]
        self.currentSize = self.currentSize - 1
        self.heapList.pop()
        self.percDown(1)
        return retval

    def isEmpty(self):
        return self.currentSize == 0

    def size(self):
        return self.currentSize

    def __str__(self):
        return str(self.heapList[1:])
```