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These problems were given on exams for this course. Some older problems did not make use of generics in Java, but generic implementations are now required in this course.

Problem 1 A generic priority queue is implemented as a heap so that n entries of comparable type K occupy elements $1, 2, 3, \dots, (n + 1)$ of an array *data* in the heap. Usual heap order and heap shape requirements are in force. (Note this uses slightly different array elements from the implementation described in class and in the textbook.) A skeleton for the class is as follows:

```
public class HeapPriorityQueue // class title line to be completed as (a)
{ private K data[]; private int size = 0; private int capacity = 100;
  // constructor to be coded as (b)
  public void insert(K x) throws Exception {
    if (size >= capacity - 2) throw new Exception("Priority Queue Full");
    data[++size] = x;
    bubbleUp(size);
  }
  public K removeMin() throws Exception { // omitted
  private void swapData(int n, int m) { // omitted, swaps entries n and m
  private void bubbleUp(int n) { // omitted to be coded as (c)
  private void bubbleDown(int n) { // omitted
}
```

- (a) Write the complete class title line, including a clause that makes it implement a *PriorityQueue*.
- (b) Implement a constructor with no arguments.
- (c) Implement the method `bubbleUp`.

Problem 2 (a) What two properties of a binary tree make it a heap?

(b) Give a Java implementation method for the method:

```
public static <K extends Comparable<K>> boolean hasHeapOrder(BNode<K> r)
```

Here r is a node in a Binary Tree, so that r has instance variables *data*, *parent*, *left* and *right*. The method should return true if the subtree rooted at r satisfies the heap ordering requirement.

Problem 3 (a) What two properties of a binary tree make it a heap?

(b) Give either a pseudocode outline (or for extra credit, a Java method) for an algorithm:

```
public static <K> boolean hasHeapShape(BNode<K> r)
```

That returns true, if the subtree rooted at r satisfies the heap shape requirement.