1 Heaps of Fun

(a) Consider an array-based min-heap with $N$ elements. What is the worst case asymptotic runtime of each of the following operations if we ignore resizing? What is the worst case asymptotic runtime if we take resizing into account?

<table>
<thead>
<tr>
<th>Operation</th>
<th>Without Resizing</th>
<th>With Resizing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find Min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove Min</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) What are the advantages of using an array-based heap over a pointer-based heap?

(c) How can you implement a max-heap of integers if you only have access to a min-heap?

(d) Given an array and a min-heap, describe an algorithm that would allow you to sort the elements of the array in ascending order.

2 HashMap Modification (61BL Summer 2010, MT2)

(a) If you modify a key that has been inserted into a HashMap, can you retrieve that entry again? Explain.
   □ Always    □ Sometimes    □ Never

(b) If you modify a value that has been inserted into a HashMap, can you retrieve that entry again? Explain.
   □ Always    □ Sometimes    □ Never
3 Hash Code

In order for a hash code to be valid, objects that are equivalent to each other (i.e. `.equals()` returns true) must return equivalent hash codes. If an object does not explicitly override the `hashCode()` method, it will inherit the `hashCode()` method defined in the `Object` class, which returns the object’s address in memory.

Here are four potential implementations of `Integer`'s `hashCode()` function. Assume that `intValue()` returns the value represented by the `Integer` object. Categorize each `hashCode()` implementation as either a valid or an invalid hash function. If it is invalid, explain why. If it is valid, point out a flaw or disadvantage.

(1) public int hashCode() {
    return -1;
}

(2) public int hashCode() {
    return intValue() * intValue();
}

(3) public int hashCode() {
    Random rand = new Random();
    return rand.nextInt();
}

(4) public int hashCode() {
    return super.hashCode();
}
4 Hashing Practice

Given the provided `hashCode()` implementation, hash the items listed below with external chaining (the first item is already inserted for you). Assume the load factor is 1. Use geometric resizing with a resize factor of 2. You may draw more boxes to extend the array when you need to resize.

```java
/** Returns 0 if word begins with 'a', 1 if it begins with 'b', etc. */
public int hashCode() {
    return word.charAt(0) - 'a';
}
```

`["apple", "cherry", "fig", "guava", "durian", "apricot", "banana"]`

Extra: Suppose that we represent Tic-Tac-Toe boards as 3 × 3 arrays of integers (with each integer in the range [0, 2] to represent blank, ‘X’, and ‘O’, respectively). Describe a hash function for Tic-Tac-Toe boards that are represented in this way such that boards that are not equal will never have the same hash code.