1 2-3 Trees and LLRB’s

1.1 Draw what the following 2-3 tree would look like after inserting 18, 38, 12, 13, and 20.

1.2 Now, convert the resulting 2-3 tree to a left-leaning red-black tree.

1.3 Extra: If a 2-3 tree has depth $H$ (that is, the leaves are at distance $H$ from the root), what is the maximum number of comparisons done in the corresponding red-black tree to find whether a certain key is present in the tree?
Here are three potential implementations of the Integer's `hashCode()` function. Categorize each 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.

```java
1  public int hashCode() {
2      return -1;
3  }

1  public int hashCode() {
2      return intValue() * intValue();
3  }

1  public int hashCode() {
2      return super.hashCode();
3  }
```

Extra, but highly recommended: For each of the following questions, answer Always, Sometimes, or Never.

(a) When you modify a key that has been inserted into a `HashMap` will you be able to retrieve that entry again? Explain.

(b) When you modify a value that has been inserted into a `HashMap` will you be able to retrieve that entry again? Explain.
3 Heaps of Fun

3.1 Assume that we have a binary min-heap (smallest value on top) data structure called Heap that stores integers, and has properly implemented insert and removeMin methods. Draw the heap and its corresponding array representation after each of the operations below:

```java
Heap<Character> h = new Heap<>();
h.insert('f');
h.insert('h');
h.insert('d');
h.insert('b');
h.insert('c');
h.removeMin();
h.removeMin();
```

3.2 Your friendly TA Tina challenges you to quickly implement an integer max-heap data structure. “Hah! I’ll just use my min-heap implementation as a template to write MaxHeap.java,” you think to yourself. Unfortunately, due to following the instructions of a shady stackoverflow post, you manage to permanently delete your MinHeap.java file. Luckily, you notice that you still have MinHeap.class. Can you still complete the challenge before time runs out?

Hint: Although you cannot alter them, you can still use methods from MinHeap.