1. 1. O(NlogN)
   2. O(NlogN)
   3. O(NlogN)
2. 1. O(NlogN)
   2. In lines 19 and 20 of the main quicksort routine in the textbook, the while loops need to be changed to
      1. while (a[++i] <= pivot && i < j)
      2. while (pivot <= a[--j] && j > i)
      3. Running time is O(N^2) when all the keys are equal
   3. In line 20 on the main quicksort routine the line needs to be changed to
      1. While (a[--j] >= pivot && j > i)
      2. Running time is O(N^2) when all the keys are equal

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | a[0] | A[1] | A[2] | A[3] | A[4] | A[5] | A[6] | A[7] |
| Left, center, right | 3 | 1 | 4 | 1 | 5 | 9 | 2 | 6 |
| 0, 1, 1 | 1 | 3 | 4 | 1 | 5 | 9 | 2 | 6 |
| 2, 3, 3 | 1 | 3 | 1 | 4 | 5 | 9 | 2 | 6 |
| 0, 2, 3 | 1 | 1 | 3 | 4 | 5 | 9 | 2 | 6 |
| 4, 5, 5 | 1 | 1 | 3 | 4 | 5 | 9 | 2 | 6 |
| 6, 7, 7 | 1 | 1 | 3 | 4 | 5 | 9 | 2 | 6 |
| 4, 6, 7 | 1 | 1 | 3 | 4 | 2 | 5 | 6 | 9 |
| 0, 4, 7 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 9 |

4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Initial | Sorted by 1’s | Sorted by 10’s | Sorted by 100’s | Sorted by 1000’s |
| 1693 | 1950 | 1612 | 2020 | 1072 |
| 1950 | 2020 | 2020 | 1072 | 1453 |
| 1612 | 1612 | 1950 | 1453 | 1612 |
| 2020 | 1072 | 1453 | 1612 | 1693 |
| 1072 | 1693 | 1072 | 1693 | 1950 |
| 1453 | 1453 | 1693 | 1950 | 2020 |