CIS263 Assignment Four

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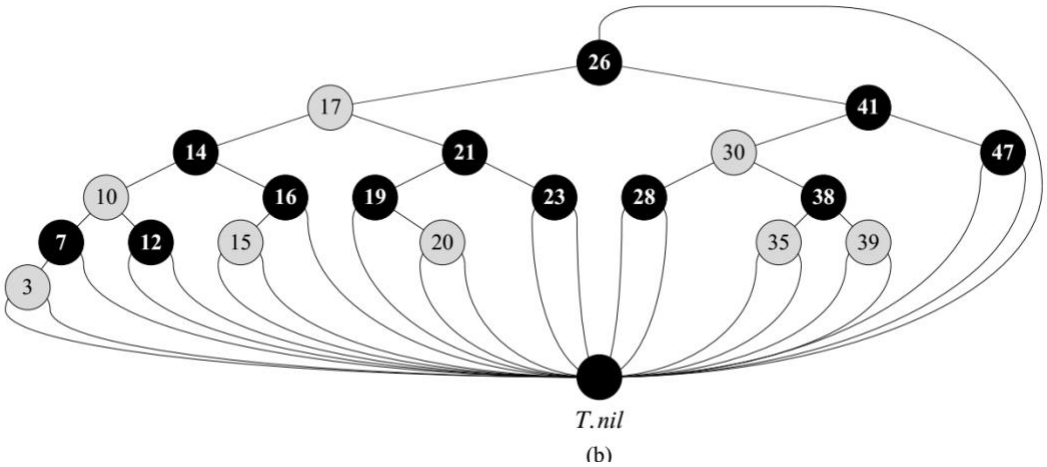
Create a red-black tree data structure and implement the below methods based on the pseudocode given.



The program should create a print method that prints the red-black tree in an easy to read/follow format.

Create a red black tree data structure based on the pseudocode from the methods listed in the textbook (and below) and create a red-black tree by inserting the keys/values show in in figure 13.1b of the textbook. Minimal methods implemented should be: leftRotate, rightRotate, rbInsert, rbInsertFixup, rbTransplant, rbDelete, rbDeleteFixup.

Extra Credit: Determine the sequence that the keys must be entered to generate the RB tree shown in Figure 13.1b from the textbook (displayed above for convenience).

Psuedocode from CRLS Textbook:

RB-INSERT(T, z)

```
 1  y = T.nil
 2  x = T.root
 3  while x ≠ T.nil
 4       y = x
 5       if z.key < x.key
 6            x = x.left
 7       else x = x.right
 8  z.p = y
 9  if y == T.nil
10       T.root = z
11  elseif z.key < y.key
12       y.left = z
13  else y.right = z
14  z.left = T.nil
15  z.right = T.nil
16  z.color = RED
17  RB-INSERT-FIXUP(T, z)
```

LEFT-ROTATE(T, x)

```
 1  y = x.right              // set y
 2  x.right = y.left         // turn y's left subtree into x's right subtree
 3  if y.left ≠ T.nil
 4       y.left.p = x
 5  y.p = x.p                // link x's parent to y
 6  if x.p == T.nil
 7       T.root = y
 8  elseif x == x.p.left
 9       x.p.left = y
10  else x.p.right = y
11  y.left = x               // put x on y's left
12  x.p = y
```

RB-INSERT-FIXUP(T, z)

```
 1  while z.p.color == RED
 2      if z.p == z.p.p.left
 3          y = z.p.p.right
 4          if y.color == RED
 5              z.p.color = BLACK                    // case 1
 6              y.color = BLACK                      // case 1
 7              z.p.p.color = RED                    // case 1
 8              z = z.p.p                            // case 1
 9          else if z == z.p.right
10                  z = z.p                          // case 2
11                  LEFT-ROTATE(T, z)                // case 2
12              z.p.color = BLACK                    // case 3
13              z.p.p.color = RED                    // case 3
14              RIGHT-ROTATE(T, z.p.p)               // case 3
15      else (same as then clause
                with "right" and "left" exchanged)
16  T.root.color = BLACK
```

RB-TRANSPLANT(T, u, v)

```
1  if u.p == T.nil
2      T.root = v
3  elseif u == u.p.left
4      u.p.left = v
5  else u.p.right = v
6  v.p = u.p
```

```
RB-DELETE(T, z)
 1  y = z
 2  y-original-color = y.color
 3  if z.left == T.nil
 4      x = z.right
 5      RB-TRANSPLANT(T, z, z.right)
 6  elseif z.right == T.nil
 7      x = z.left
 8      RB-TRANSPLANT(T, z, z.left)
 9  else y = TREE-MINIMUM(z.right)
10      y-original-color = y.color
11      x = y.right
12      if y.p == z
13          x.p = y
14      else RB-TRANSPLANT(T, y, y.right)
15          y.right = z.right
16          y.right.p = y
17      RB-TRANSPLANT(T, z, y)
18      y.left = z.left
19      y.left.p = y
20      y.color = z.color
21  if y-original-color == BLACK
22      RB-DELETE-FIXUP(T, x)
```

```
RB-DELETE-FIXUP(T, x)
 1  while x ≠ T.root and x.color == BLACK
 2      if x == x.p.left
 3          w = x.p.right
 4          if w.color == RED
 5              w.color = BLACK                          // case 1
 6              x.p.color = RED                          // case 1
 7              LEFT-ROTATE(T, x.p)                      // case 1
 8              w = x.p.right                            // case 1
 9          if w.left.color == BLACK and w.right.color == BLACK
10              w.color = RED                            // case 2
11              x = x.p                                  // case 2
12          else if w.right.color == BLACK
13                  w.left.color = BLACK                 // case 3
14                  w.color = RED                        // case 3
15                  RIGHT-ROTATE(T, w)                   // case 3
16                  w = x.p.right                        // case 3
17              w.color = x.p.color                      // case 4
18              x.p.color = BLACK                        // case 4
19              w.right.color = BLACK                    // case 4
20              LEFT-ROTATE(T, x.p)                      // case 4
21              x = T.root                               // case 4
22      else (same as then clause with "right" and "left" exchanged)
23  x.color = BLACK
```

Approved programming languages: C, C++, C#, Python, Java.

Hand-in:
The output demonstrating the functionality of your program
A file containing the implementation source code (no zip files).

Grading Rubric

	0%	50%	100%
Insert (10%)	Not implemented	Implemented but doesn't follow the pseudocode	Implemented and follows the pseudocode
Left Rotate (10%)	-	-	-
Right Rotate (10%)	-	-	-
RB-Insert-Fixup (10%)	-	-	-
RB-Transplant (10%)	-	-	-
RB-Delete (10%)	-	-	-
RB-Delete-Fixup (10%)	-	-	-
Tree Print Method (10%)	Not implemented	Tree output, but difficult to understand structure	Tree output and structure is clearly represented visually
Demonstrate functionality of red black tree implementation (20%)	Not clearly demonstrated	Some functionality demonstrated	Functionality demonstrated clearly

See blackboard for point breakdown.