ECE 573
Problem Set 7: CFGs and loop optimizations

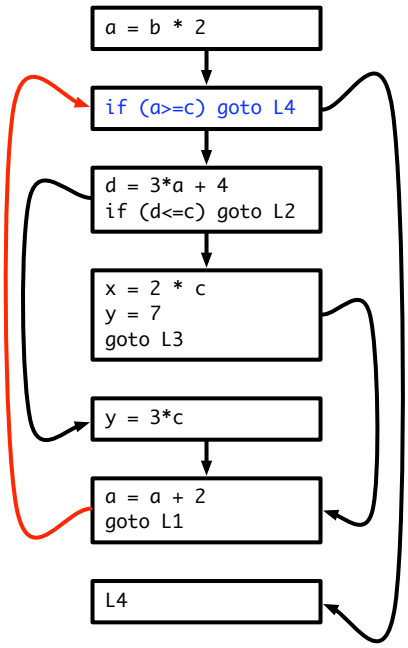
Consider the following code:

```
    1: a = b * 2;
L1: 2: if (a >= c) goto L4;
    3: d = 3*a + 4;
    4:  if (d <= c) goto L2;
    5:  x = 2 * c;
    6:  y = 7;
    7:  goto L3;
L2: 8:  y = 3 * c;
L3: 9:  a = a + 2;
   10:  goto L1;
L4:11:
```

1. What are the basic blocks for this code?

   {1}, {2}, {3, 4}, {5, 6, 7}, {8}, {9, 10}, {11}

2. Draw the basic-block level CFG for this code.



3. What are the loop headers? What are the back edges?

   The back edge is in red, and the loop header is in blue

4. What are the loop-invariant instructions in this code?

   Instructions 5, 6 and 8 are loop-invariant

5. Which instructions could be moved out of the loops?

   Only instruction 5 can be moved out of the loop. Because both instruction 6 and instruction 8 define y, they cannot be moved.

6. What are the induction variables for the loops in the program? The mutual induction variables?

   Induction variable: a Mutual induction variable: d

7. What does this code look like after applying strength reduction?

```
    1: a = b * 2;
   1':  d' = 3*a + 4;
L1: 2: if (a >= c) goto L4;
    3: d = d';
    4:  if (d <= c) goto L2;
    5:  x = 2 * c;
    6:  y = 7;
    7:  goto L3;
L2: 8:  y = 3 * c;
L3: 9:  a = a + 2;
   9':  d' = d' + 6;
   10:  goto L1;
L4:11:
```

8. What does this code look like after applying linear test replacement?

```
    1: a = b * 2;
   1':  d' = 3*a + 4;
L1: 2: if (d' >= 3*c + 4) goto L4;
    3: d = d';
    4:  if (d <= c) goto L2;
    5:  x = 2 * c;
    6:  y = 7;
    7:  goto L3;
L2: 8:  y = 3 * c;
L3: 9:  // a = a + 2;
   9':  d' = d' + 6;
   10:  goto L1;
L4:11:
```