ECE 468
Problem Set 7: Loop optimizations (Solutions)

Consider the following code:

```
    1: READ(x);
    2: READ(y);
    3: READ(b);
L1  4: if (x > 100) goto L4
    5:   b = y + 7;
    6    z = y + 2;
    7:   x = x + z;
    8:   goto L1;
L4  9: WRITE(b)
   10: WRITE(x)
   11: halt
```

1. Which line(s) are loop invariant? Explain.

   Lines 5 and 6 are loop invariant (y is only defined outside the loop)

2. Which line(s) can be moved outside of the loop? Explain.

   Line 6 can be moved outside the loop (only one definition of z, not live before or after the loop). Line 5 cannot be moved outside the loop (b is live at a loop exit that line 5 does not dominate – note that WRITE(b) in line 9 may not see the definition of b in line 5.)

Consider the following code:

```
    1: READ(x);
    2: READ(y);
    3: READ(z);
L1  4:   w = y * x + 5;
    5:   WRITE(w);
    6:   x = x + z;
    7: if (x < 200) goto L1
    8: halt;
```

1. What are the induction variable(s)? What are the mutual induction variable(s)?

   Induction variable: x (increments by a loop-invariant amount each iteration); mutual induction variable: w (linear function of x, and y is loop invariant)

2. Perform strength reduction on any mutual induction variables.

```
    1: READ(x);
    2: READ(y);
    3: READ(z);
       w' = y * x + 5;
L1  4:   w = w';
    5:   WRITE(w);
    6:   x = x + z;
         w' = w' + y * z;
    7: if (x < 200) goto L1
    8: halt;
```

3. Perform linear test replacement if possible.

```
    1: READ(x);
    2: READ(y);
    3: READ(z);
       w' = y * x + 5;
L1  4:   w = w';
    5:   WRITE(w);
    6:   x = x + z;
         w' = w' + y * z;
    7: if (w' < 200 * y + 5) goto L1
    8: halt;
```

at which point, the increment of x in line 6 is no longer necessary.