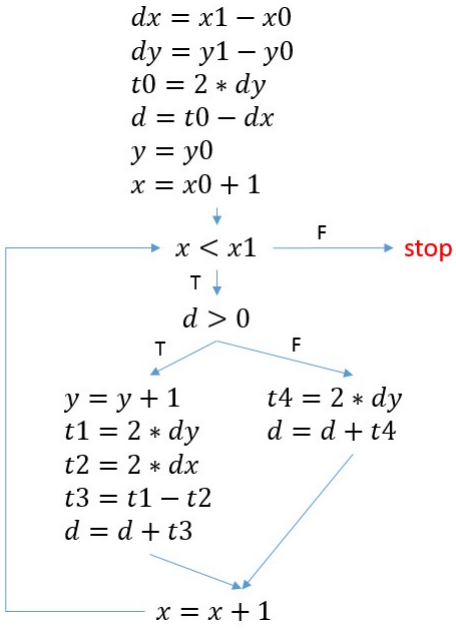
Practice Problems – Data Flow Analysis
Sample Solution

1.

```
     dx=x1-x0
     dy=y1-y0
     t0=2*dy
     d=t0-dx
     y=y0
     x=x0+1
L1   if not (x<x1) then goto L4
     if d>0 then goto L2
     t4=2*dy
     d = d+t4
     goto L3
L2   y=y+1
     t1=2*dy
     t2=2*dx
     t3=t1-t2
     d=d+t3
L3   x=x+1
     goto L1
L4
```

Three-address code



Control-flow graph

2.

1 : 1
2 : 1, 2
3 : 1, 2, 3, 4, 5, 6, 9
4 : 1, 2, 3, 4, 5, 6
5 : 1, 3, 4, 5, 6, 9, 11
6 : 1, 3, 4, 5, 6, 9
7 : 3, 4, 5, 6, 7, 9
8 : 3, 4, 6, 7, 8, 9
9 : 1, 2, 3, 5, 6, 9, 11
10: 1, 2, 3, 5, 6, 10, 11
11: 1, 2, 3, 5, 10, 11
Reaching Definitions

1 :
2 :
3 : a+b
4 : a+b, c-a
5 : c-a
6 : c-a
7 : b*d
8 : a-d
9 : a+b, c-a
10: a+b, c-a
11: a+b, c-a
Available Expressions

1 : e
2 : a, e
3 : a, b, e
4 : a, b, c, e
5 : a, b, c, d
6 : a, b, c, d
7 : b, d
8 : a, d
9 : a, b, c, d, e
10: a, b, c, e
11: a, b, c, d, e
Live variables

1 :
2 :
3 : a+b
4 : c-a, a+b
5 : c-a, a+b
6 : c-a
7 : b*d
8 : a-d
9 : b*d, a+b, c-a
10: a+b, e+1, c-a
11: b*d, a+b, e+1, c-a
Very Busy Expressions

3. (a) Forward.

   (b) Lattice is $\langle L, \preceq_L \rangle$, where L is the set of sets of variables, and $\preceq_L = \{(A, B) : A \subseteq B\}$. Meet operation is set intersection, i.e. $A \sqcap B = A \cap B$. Top $\top$ is the universe set containing all variables.

   (c) Initialize the entry point to be $\bot = \emptyset$, and all other points to be $\top$.

   (d) The transfer function for all of them is $f(X) = \{a\} \cup X$.

   (e) $f(X \sqcap Y) = \{a\} \cup (X \cap Y) = (\{a\} \cup X) \cap (\{a\} \cup Y) = f(X) \sqcap f(Y)$, therefore the function is distributive and monotonic.