Problem Set 5
Fall 23
Due: Sunday, November 19th

1. Dataflow Analysis

Consider the following code:

```plaintext
READ(x)
READ(y)
L11  if (x <= 2) goto L3
     x = x - 1
L21  if (x <= 10) goto L22
     y = y + 1
     goto L21
L22  x = x - 2
     if (y <= 2) goto L31
     x = x - 2
L31  x = x - 3
     goto L11
L3   WRITE(x)
      halt
```

(a) Draw the CFG for this piece of code.

Solution:
The CFG is shown below:
(b) Show the results of running a reaching definitions analysis on this code. For each

\begin{itemize}
  \item READ(x)
  \item READ(y)
  \item if (x <= 2)
    \begin{itemize}
      \item False
      \item x = x - 1
    \end{itemize}
  \item if (x <= 10)
    \begin{itemize}
      \item False
      \item y = y + 1
      \item x = x - 2
    \end{itemize}
  \item if (y <= 2)
    \begin{itemize}
      \item False
      \item x = x - 2
      \item x = x - 3
    \end{itemize}
  \item WRITE(x)
\end{itemize}
line of code, show that definitions reach that line. Assume this is the only code in the program.

Solution:
We will represent a definition by $<v, n>$, meaning variable $v$ was defined at line $n$. 
(c) Show the results of running a liveness analysis on this code. For each line of
code, show what variables are live \textit{out} for that line (i.e., what variables are live immediately after that line would execute).

\textbf{Solution:}

The liveness analysis result is shown below.
1. READ(x)
   
   \{x\}

2. READ(y)
   
   \{x, y\}

3. if (x <= 2)
   
   \{x, y\}

4. x = x - 1
   
   \{x, y\}

5. if (x <= 10)
   
   \{x, y\}

6. y = y + 1
   
   \{x, y\}

7. x = x - 2
   
   \{x, y\}

8. if (y <= 2)
   
   \{x, y\}

9. x = x - 2
   
   \{x, y\}

10. x = x - 3
    
    \{x, y\}

11. WRITE(x)
    
    \{x\}