An instruction \( T \) is a \textit{semantic reaching definition} at instruction \( U \) if, for some execution starting at \( S_1 \), instruction \( T \) writes to a variable \( x \) which does not suffer an intervening assignment when execution reaches instruction \( U \). We write \( RD(i) \) for the set of instructions \( S_j \) whose definitions reach instruction \( S_i \).

(a) By analogy with live variable analysis or available expression analysis, derive dataflow equations for \( RD \) and give an algorithm for solving these. Explain any approximation you make, carefully justifying the form of this approximation. \textit{[Hint: you may find it useful to define gen and kill for instructions.]} \[8\] marks

(b) Is your analysis for reaching definitions flow-sensitive or flow-insensitive? Give a one-sentence justification of your answer. \[2\] marks

(c) One use of reaching definitions is for constant propagation: when we know that reading a variable in an operand in a given instruction will always result in the same value \( k \), we may replace the operand with \( k \). Carefully explain how we can use the result of reaching-definitions analysis to perform constant propagation. \textit{[Hint: you may find it useful to consider the instruction form \( z:=x+y \).]} \[3\] marks

(d) Explain how your constant-propagation algorithm would react to the following flowgraph expressed as C code:

```c
int t,r,x;
x = read();
if (x>91) t=7; else t=6;
r = t/2;
return r+39;
```

Either explain why your resulting code is optimal, or indicate the source of any information loss which precludes it being optimal. \[3\] marks

(e) Suppose now the 3-address code were in SSA (single static assignment) form. How would this affect the result of reaching-definitions analysis? \[4\] marks