Final Exam

CS 540
Spring 1990
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Problems 1–3 refer to the following three-address program:

```
      v := 2
      w := 1
      x := 1
      if z > 50 goto (D)
(A)   w := w + 5
      y := v + 2
      if w > 10 goto (C)
(B)   z := x + 3
      if x < 20 goto (A)
(C)   w := w − 7
      x := 5 * w
      y := 2 * v
      if w ≠ 0 goto (B)
(D)   continue
```

1 Construct the flow graph which corresponds to the three-address program, and identify the loop in the flow graph.

2

a) Apply strength reduction to the flow graph loop in problem 1. Show all induction variables and the resulting flow graph.

b) Apply induction variable elimination to the flow graph loop in a). Show the resulting flow graph.

3 Apply constant value analysis to the flow graph in problem 1. Define f_B for each block B. Show the values of IN[B] and OUT[B] after each complete iteration of the while-loop.

4 Let L be a set of nodes in a flow graph. Prove that L is an inner loop implies L is a natural loop.

5 Let $(D, \leq)$ be a complete lattice, $A \subseteq D$. Prove there exists exactly one $x \in D$ such that x is a greatest lower bound of A.

6 Let $G = (V, E)$ be a flow graph. Let $(D, \leq, F)$ be a monotonic data flow framework such that for each $B \in V$, there is a transfer function $f_B \in F$. Prove that $\forall k \geq 0$ $\forall B \in V$,

$$\mathrm{IN}_{k+1}[B] \leq \mathrm{IN}_k[B].$$

Use induction on k and assume computation of IN during iteration $k+1$ uses values of OUT computed during iteration k.