Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.035, Fall 2006 | Practice Quiz 2 and Solutions | Saturday, November 4

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1. For the basic block:

```
q = 3
r = 10
s = q + r
t = 2*r+s
t = q
u = q + r
v = q + t
w = 3 + x
```

   State for each of the basic blocks on the following page which optimization was performed on the above:

   - Constant Propagation/Folding
   - Copy Propagation
   - Common Subexpression Elimination
   - Dead Code Elimination.

(a)
```
q = 3
r = 10
s = q + r
t1 = s
t = 2*r+s
t = q
u = t1
v = q + t
w = 3 + x
```
CSE

(b)
```
q = 3
r = 10
s = q + r
t = 2*r+s
t = q
u = q + r
v = q + q
w = 3 + x
```
Copy Propagation

(c)
```
q = 3
r = 10
s = 13
t = 33
t = 3
u = 13
v = 36
w = 3 + x
```
Constant Propagation

(d)
```
q = 3
r = 10
s = q + r
t = q
u = q + r
v = q + t
w = 3 + x
```
Dead Code Elimination

2. In class we discussed *available expression* dataflow analysis. Recall that an expression e is available at point p if:

   - Every path from the initial node to p evaluates e before reaching p, and
   - There are no assignments to any operand of e after evaluation but before p.

   In the table below, fill in the final values of **IN** obtained after performing available expression analysis on the CFG of Figure 1 (next page). A '1' should indicate the expression is available on entry to the block.

	`a + b`	`c * d`	`e / f`
B1	0	0	0
B2	1	0	0
B3	1	0	0
B4	1	0	1
B5	0	0	1
B6	1	0	0
B7	1	1	0

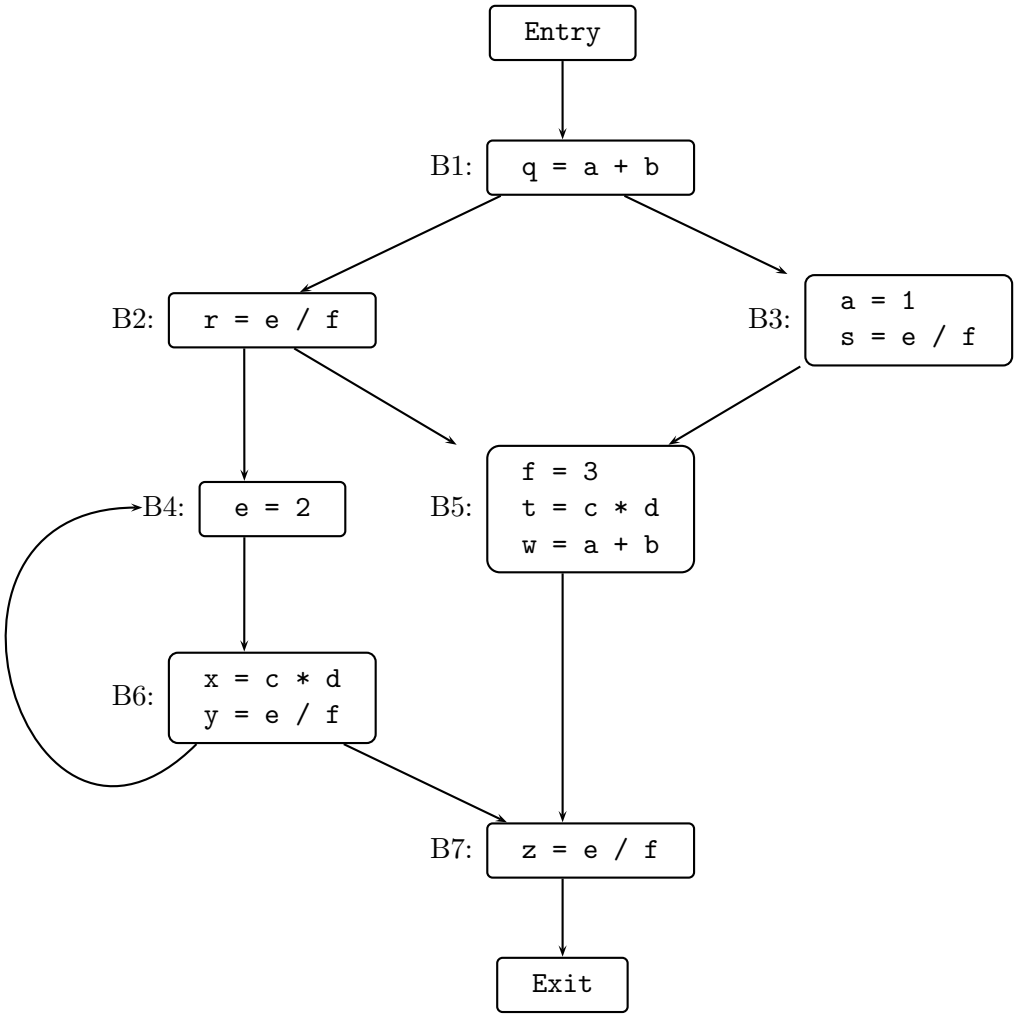

Figure 1: CFG for problem 2.

3. Recall from lecture that a variable v is live at point p if:

   - v is used along some path starting at p, and
   - There is no definition of v along p before its use.

   In the table below, fill in the final values of **OUT** obtained after performing liveness analysis on the CFG of Figure 2 (next page). A '1' should indicate the variable is live on exit from the block. Assume all variables are visible outside the procedure.

	a	b	c
B1	1	1	1
B2	0	0	0
B3	0	0	0
B4	1	0	0
B5	1	1	0
B6	1	1	0
B7	1	1	1

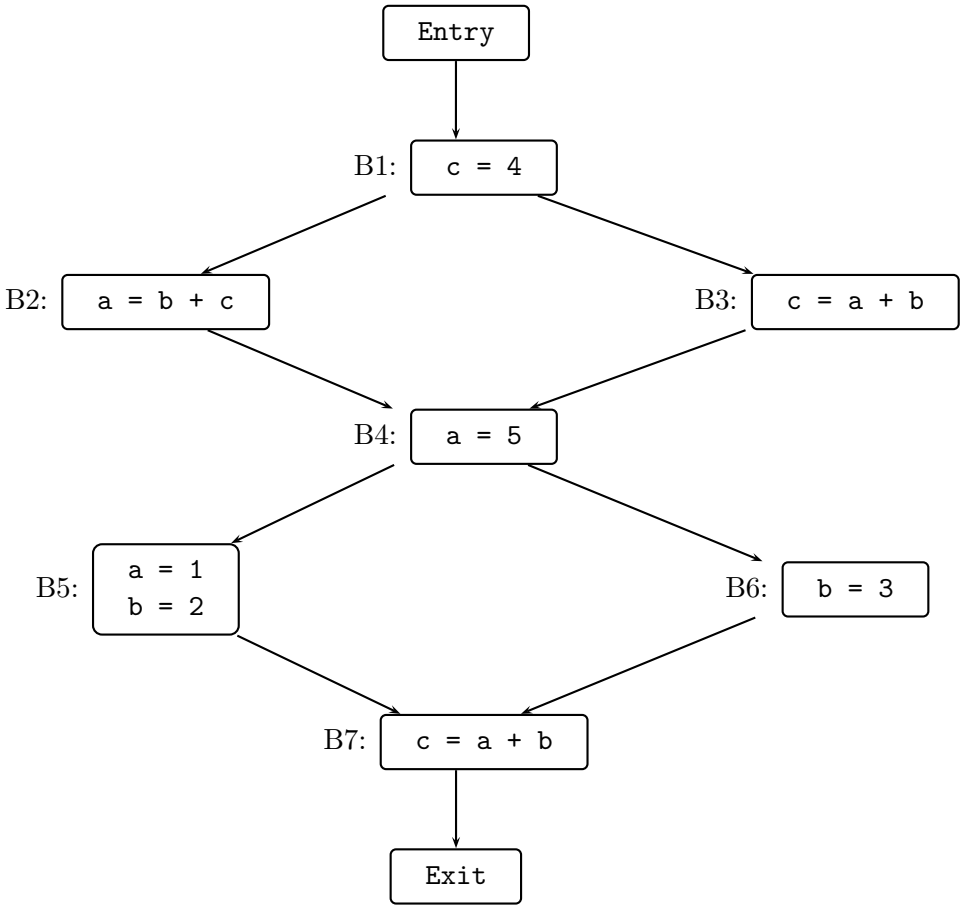

Figure 2: CFG for problem 3.

4. A compiler hacker writes an analysis to compute values of integer variables in a program. The hacker's analysis maintains a set for each variable at each program point, the set contains the possible values for that variable. The hacker uses set union to combine values at the control-flow join points.

   The hacker tests the analysis on several acyclic control flow graphs and it is shipped in the compiler. One of the customers tries to compile a program that contains a loop, and the analysis fails to terminate. What is the problem?

   The issue is that the lattice has infinite ascending chains and lacks a top element. (IE. We can construct the chain of sets 0, 0,1, 0,1,2, 0,1,2,3....)

   Describe the changes that the compiler hacker must make to fix the analysis.

   The compiler hacker uses a widening operation to truncate the infinite ascending chains. This would be done by bounding the sizes of the sets, and widening any sets over this size to the top element.