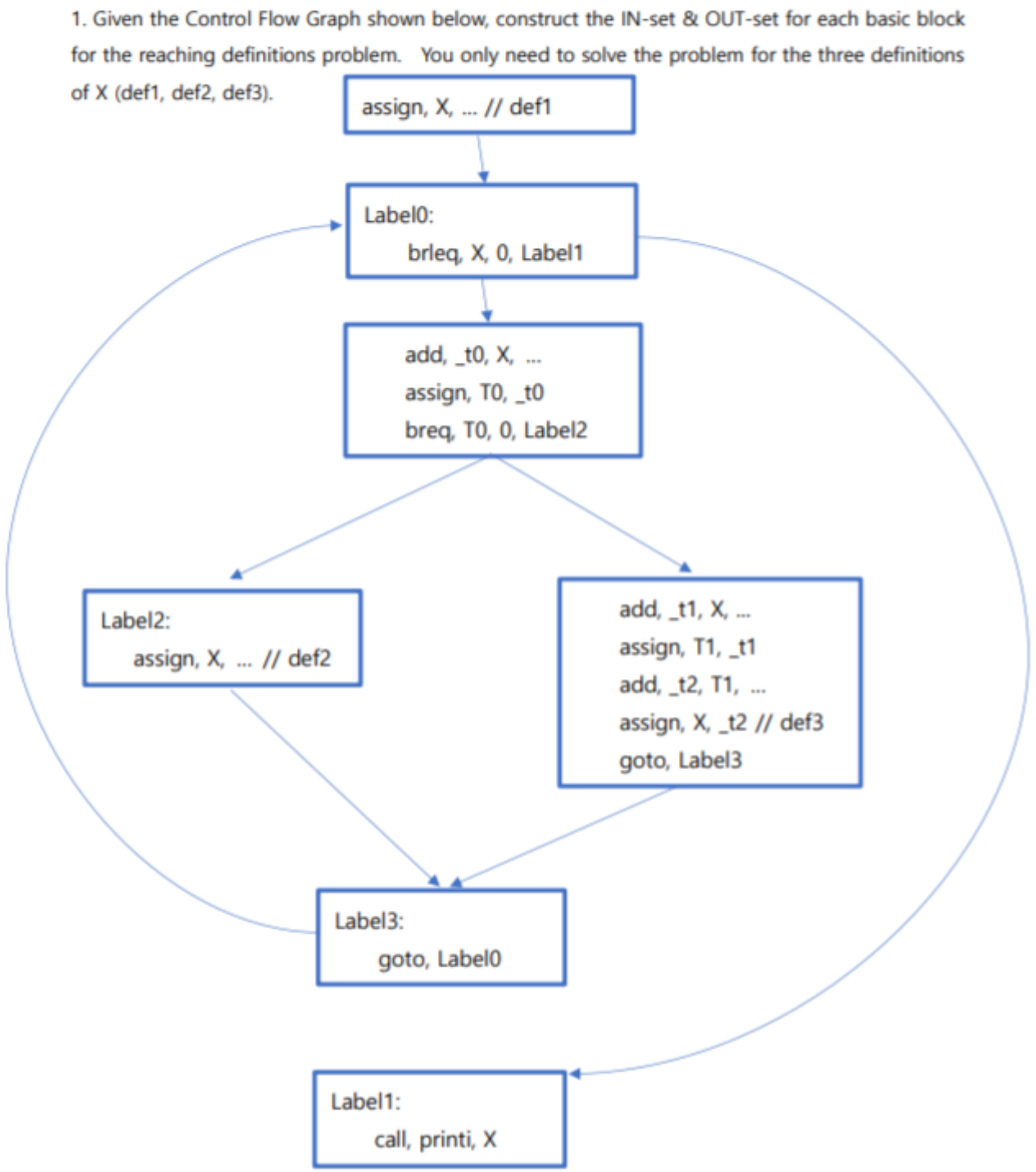
Worksheet3 Solution

(From Lecture 3 given on 01/14/2019)

Q1

- Given the Control Flow Graph shown below, construct the **IN-set & OUT-set** for each basic block for the reaching definitions problem.
  You only need to solve the problem for the three definitions of X (def1, def2, def3).



Solution: 1st Step, Initialization

- For each BB(Basic Block) in the CFG(Control Flow Graph), **calculate GEN(BB) and KILL(BB).**
- For each BB,
  IN(BB) = { } (empty set).
  OUT(BB) = GEN(BB).
- **Using bitString representations would be optional.**

Solution: 1st step, Initialization

B0

```
assign, X, ...  // def1
```

GEN(BB0) = {def1}
KILL(BB0) = {def2, def3}

IN(BB0) = { }
OUT(BB0) = GEN(BB0) = {def1}

B1

```
Label0:
    brleq, X, 0, Label1
```

GEN(BB1) = { }
KILL(BB1) = { }

IN(BB1) = { }
OUT(BB1) = GEN(BB1) = { }

B2

```
add, _t0, X, ...
assign, T0, _t0
breq, T0, 0, Label2
```

GEN(BB2) = { }
KILL(BB2) = { }

IN(BB2) = { }
OUT(BB2) = GEN(BB2) = { }

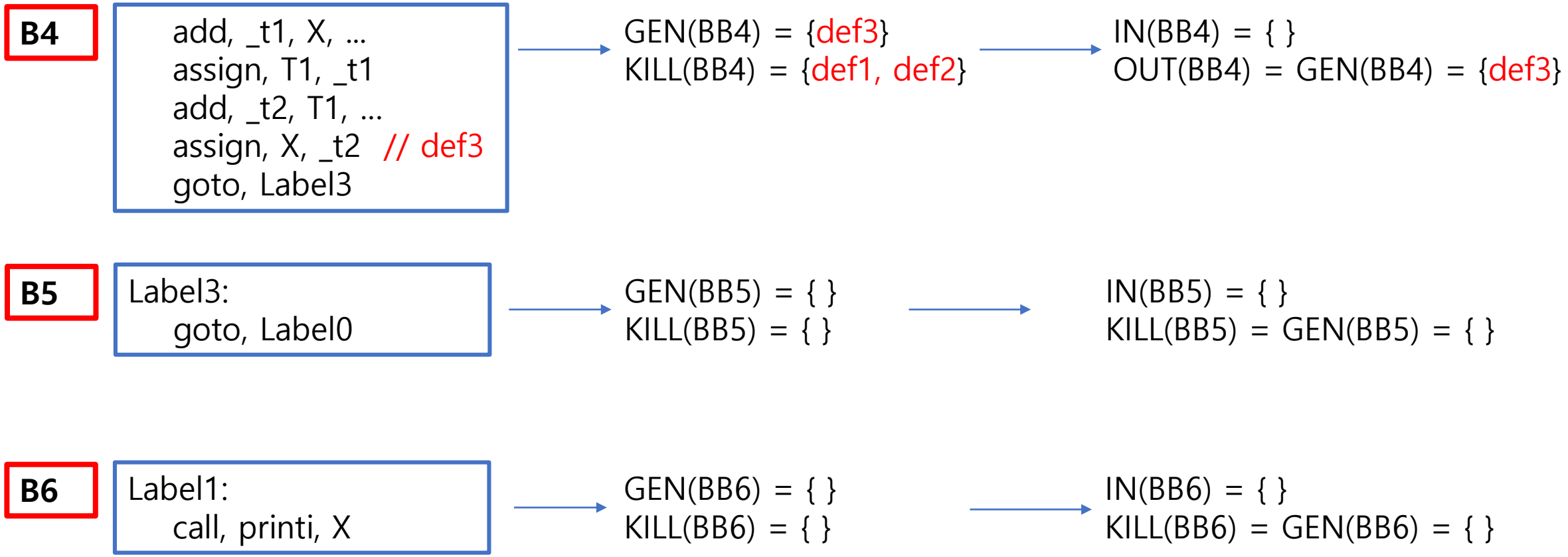
B3

```
Label2:
    assign, X, ...  // def2
```

GEN(BB3) = {def2}
KILL(BB3) = {def1, def3}

IN(BB3) = { }
OUT(BB3) = GEN(BB3) = {def2}

Solution: 1st step, Initialization



Solution: 1st step, Initialization

(Optional) Represent the generated sets with 3-bit.
Each bit : **1 if set contains def, 0 if not.**

$$(def_1)(def_2)(def_3)$$

Block	Initial		GEN(B)	KILL(B)
	IN(B)	OUT(B)		
B0	000	100	100	011
B1	000	000	000	000
B2	000	000	000	000
B3	000	010	010	101
B4	000	001	001	110
B5	000	000	000	000
B6	000	000	000	000

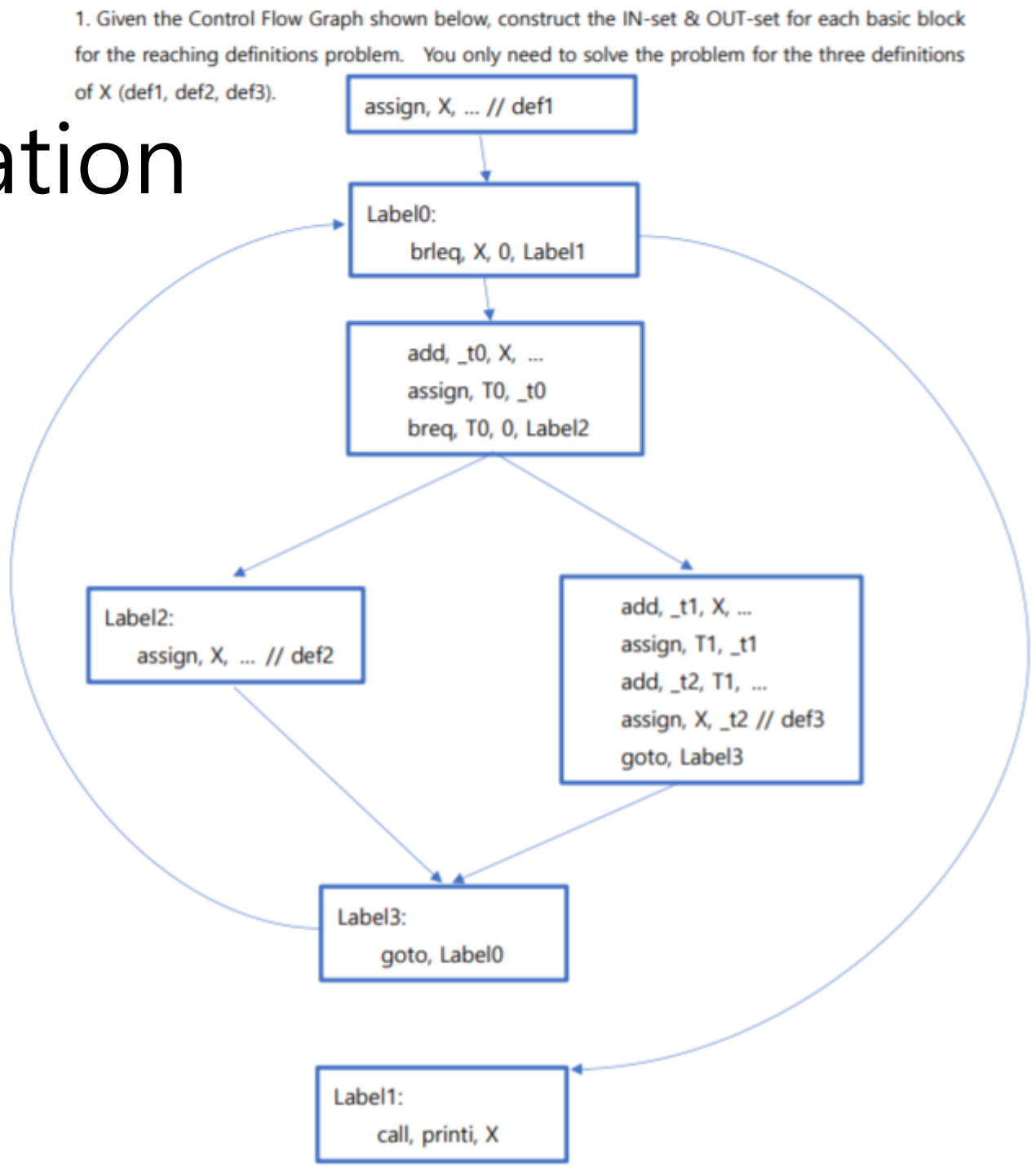
Solution: 2nd step, iteration

- For each block B in CFG
  (starting from the init node(B1)),

$$IN(B) = \cup_{p \in pred(B)} OUT(p)$$

$$OUT(B) = GEN(B) \cup (IN(B) - KILL(B))$$

(pred(B)
= set of predecessors of B)



Answers

Block	FINAL	
	IN(B)	OUT(B)
B0	000	100
B1	111	111
B2	111	111
B3	111	010
B4	111	001
B5	011	011
B6	111	111

Comments

- In this worksheet example,
  the code wasn't very complex, so that it was possible to identify final values for some IN sets and OUT sets even before doing the iteration. That could have helped students to solve the problem more easily.

Comments on students' answers

- 29 students (among 52 submissions) got it correct.
- There were 3 categories of wrong answers
  (23 students, almost evenly distributed into 3)
  1. Almost got everything right, but set the OUT-set of the final node(B6) to empty set.
  2. Student who only calculated IN & OUT sets for blocks containing DEFs. (IN & OUT sets were correct for those blocks)
  3. Students who seemed to need more space for writing all the formal processes (gave up before finishing).