1 Question 1

By definition-
The immediate dominator or idom of a node N is the unique node that strictly dominates N but does not strictly dominate any other node that strictly dominates N.

Let there be two idom of node N is A and B. A and B both strictly dominates N and no node is between A $\rightarrow$ N and B $\rightarrow$ N. This suggests that there are two paths from ENTRY to N, one goes through A and another goes through B. This implies that A and B does not strictly dominate N. For A and B to strictly dominate N, A and B should appear along same path and no nodes between A $\rightarrow$ N and B $\rightarrow$ N implies A and B is same unique node.

2 Question 2

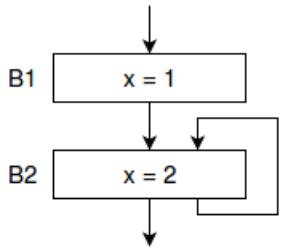


Figure 1: Q. 2

Counter Example:

For Original definition:
Dominance Frontier of B1 = ϕ
Dominance Frontier of B2 = B2
Def(x) = { B1 , B2 }
DF^1 = { B2 }
so it will insert ϕ statement in block B2.

For Modified definition:
Dominance Frontier of B1 = ϕ
Dominance Frontier of B2 = ϕ
Def(x) = { B1 , B2 }
$DF^1 = \phi$
so it will not insert any ϕ statement.

3 Question 3

Lattice:

Figure 2: Q. 3

Meet:
Lock $\wedge$ Lock = Lock
Lock $\wedge$ Unlock = Lock
Unlock $\wedge$ Unlock = Unlock

BoundaryInfo:
All variables will have top value(Unlock).
$Out(ENTRY)$ = { (v $\rightarrow$ unlock)— v $\in$ variables }

Flow functions:
Out_n = Gen $\cup$(In_n - Kill)
Stmt = x.Lock
Gen = {(x $\rightarrow$ lock)}
Kill = {(x $\rightarrow$ *)} (* can be Lock or Unlock)
Stmt = x.Unlock
Gen = {(x $\rightarrow$ unlock)}
Kill = {(x $\rightarrow$ *)} (* can be Lock or Unlock)

If Stmt = x.secureComp and In_n has (x $\rightarrow$ unlock)
then it is unsafe secure computation
Otherwise safe computation

Direction:
Forward

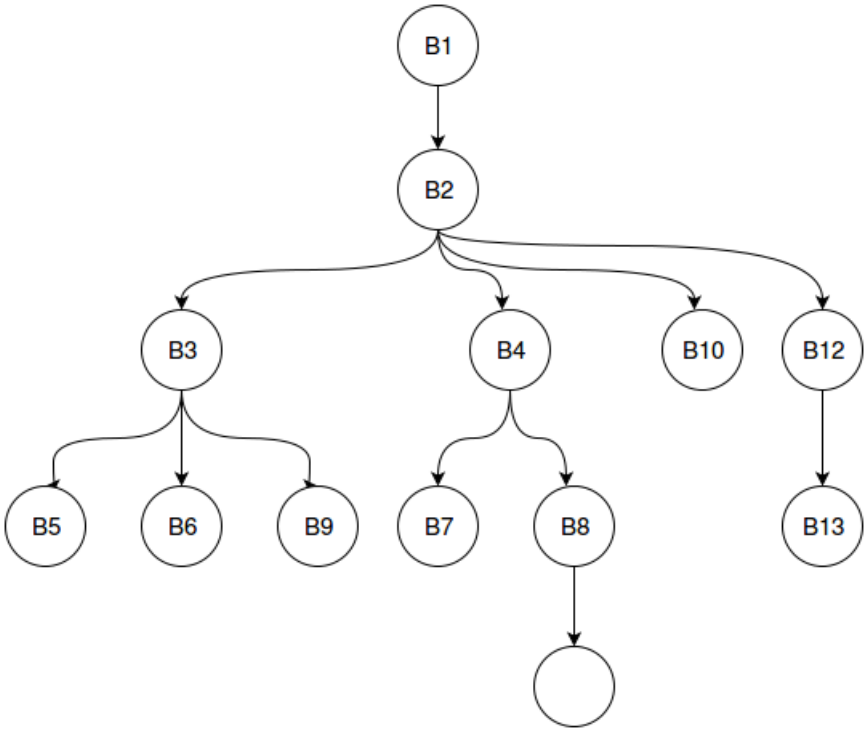


Figure 3: Q. 5

4 Question 4

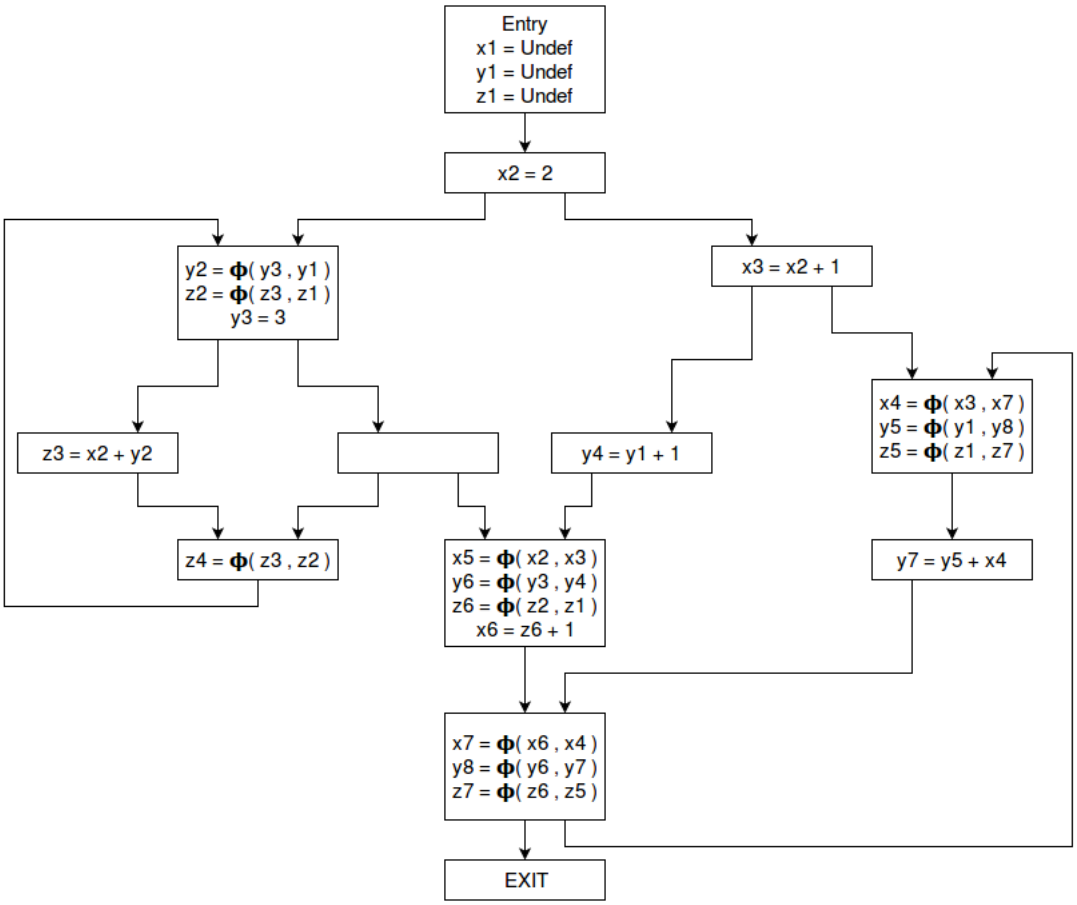
Block Number	Dominance Frontier
B1	ϕ
B2	ϕ
B3	{ B3 , B10 }
B4	{ B10 , B12 }
B5	{ B9 }
B6	{ B9 , B10 }
B7	{ B10 }
B8	{ B12 }
B9	{ B3 }
B10	{ B12 }
B11	{ B12 }
B12	{ B8 }
B13	ϕ

Def(x) = { B2 , B4 , B10 }
$DF^1(x)$ = { B10 , B12 }

$DF^2(x) = \{$ B8 , B10 , B12 $\}$
$DF^3(x) = \{$ B8 , B10 , B12 $\}$

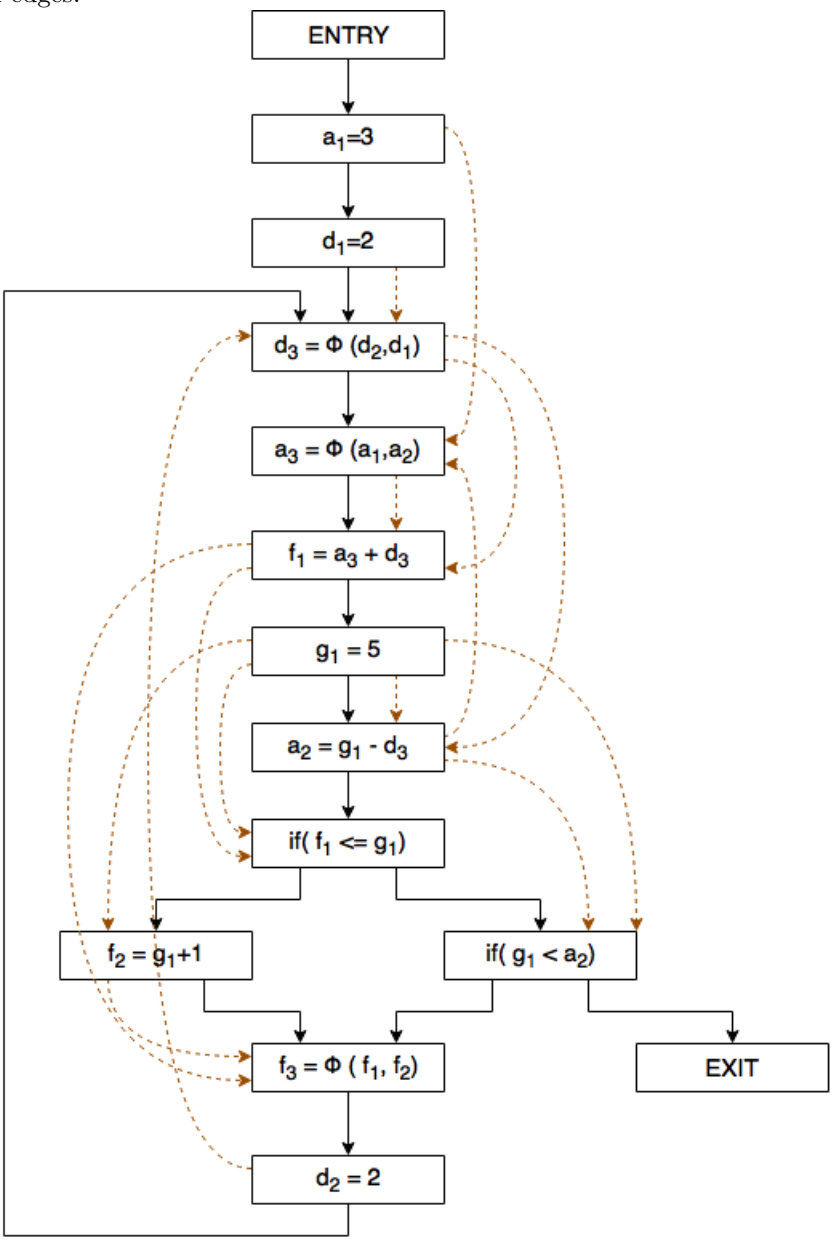
Def(y) $= \{$ B3 , B7 , B11 $\}$
$DF^1(y) = \{$ B3 , B10 , B12 $\}$
$DF^2(y) = \{$ B3 , B8 , B10 , B12 $\}$
$DF^3(y) = \{$ B3 , B8 , B10 , B12 $\}$

Def(z) $= \{$ B5 $\}$
$DF^1(z) = \{$ B9 $\}$
$DF^2(z) = \{$ B3 , B9 $\}$
$DF^3(z) = \{$ B3 , B9 , B10 $\}$
$DF^4(z) = \{$ B3 , B9 , B10 , B12 $\}$
$DF^5(z) = \{$ B3 , B8 , B9 , B10 , B12$\}$
$DF^6(z) = \{$ B3 , B8 , B9 , B10 , B12$\}$



5 Question 5

In figure 5, black edges represent flow graph edges and brown edges represent SSA edges.



FWL	SWL	Change in Values

{(B0 → B1)}	ϕ	$a_1 = 3$
{(B1 → B2)}	{(B1 → B4)}	$d_1 = 2$
{(B2 → B3)}	{(B1 → B4) , (B2 → B3)}	$d_3 = 2$
{(B3 → B4)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7)}	$a_3 = 3$
{(B4 → B5)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5)}	$f_1 = 5$
{(B5 → B6)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11)}	$g_1 = 5$
{(B6 → B7)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10)}	$a_2 = 3$
{(B7 → B8)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10)}	condition is true so chooses edge B8 → B9
{(B8 → B9)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10)}	$f_2 = 6$
{(B9 → B11)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11)}	$f_3 = 6$
{(B11 → B12)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11)}	$d_2 = 2$
{(B12 → B3)}	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$d_3 = 2$
ϕ	{(B1 → B4) , (B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$a_3 = 3$
ϕ	{(B2 → B3) , (B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$d_3 = 2$

ϕ	{(B3 → B5) , (B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$f_1 = 5$
ϕ	{(B3 → B7) , (B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$a_2 = 3$
ϕ	{(B4 → B5) , (B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$f_1 = 5$
ϕ	{(B5 → B8) , (B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	
ϕ	{(B5 → B11) , (B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$f_3 = 6$
ϕ	{(B6 → B9) , (B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$f_2 = 6$
ϕ	{(B6 → B7) , (B6 → B8) , (B6 → B10) , (B7 → B4) , (B7 → B10) , (B9 → B11) , (B12 → B3)}	$a_2 = 3$

After processing of remaining edges the values will remain same.