# Q1

**(a)**

Prog1 has 4 execution paths.

1. 1->2->3->4->9->11->12->13->17
2. 1->2->3->4->9->14->15->16->17
3. 1->5->6->7->9->11->12->13->17
4. 1->5->6->7->9->14->15->16->17

**(b)**

i)

|  |  |  |
| --- | --- | --- |
| **Edge** | **Symbolic State (P V )** | **Path Condition (P C)** |
| 1->2 | x->Xo, y->Yo | true |
| 2->3 | x->Xo, y->Yo | Xo+Yo>15 |
| 3->4 | x->Xo+7, y->Yo | Xo+Yo>15 |
| 4->9 | x->Xo+7, y->Yo-12 | Xo+Yo>15 |
| 9->11 | x->Xo+9, y->Yo-12 | (Xo+Yo)>15 |
| 11->12 | x->Xo+9, y->Yo-12 | (Xo+Yo)>15∧2\*(Xo+Yo-3)>21 |
| 12->13 | x->(Xo+9)\*3, y->Yo-12 | (Xo+Yo)>15∧2\*(Xo+Yo-3)>21 |
| 13->17 | x->(Xo+9)\*3, y->(Yo-12)\*2 | (Xo+Yo)>15∧2\*(Xo+Yo-3)>21 |

ii)

|  |  |  |
| --- | --- | --- |
| **Edge** | **Symbolic State (P V )** | **Path Condition (P C)** |
| 1->2 | x->Xo, y->Yo | true |
| 2->3 | x->Xo, y->Yo | Xo+Yo>15 |
| 3->4 | x->Xo+7, y->Yo | Xo+Yo>15 |
| 4->9 | x->Xo+7, y->Yo-12 | Xo+Yo>15 |
| 9->14 | x->Xo+9, y->Yo-12 | (Xo+Yo)>15∧2\*(Xo+Yo-3)≤21 |
| 14->15 | x->Xo+9, y->Yo-12 | (Xo+Yo)>15∧2\*(Xo+Yo-3) ≤21 |
| 15->16 | x->(Xo+9)\*4, y->Yo-12 | (Xo+Yo)>15∧2\*(Xo+Yo-3) ≤21 |
| 16->17 | x->(Xo+9)\*4, y->Yo\*3+Xo\*4 | (Xo+Yo)>15∧2\*(Xo+Yo-3) ≤21 |

iii)

|  |  |  |
| --- | --- | --- |
| **Edge** | **Symbolic State (P V )** | **Path Condition (P C)** |
| 1->5 | x->Xo, y->Yo | true |
| 5->6 | x->Xo, y->Yo | Xo+Yo≤15 |
| 6->7 | x->Xo, y->Yo+10 | Xo+Yo≤15 |
| 7->9 | x->Xo-2, y->Yo+10 | Xo+Yo≤15 |
| 9->11 | x->Xo, y->Yo+10 | Xo+Yo≤15 |
| 11->12 | x->Xo, y->Yo+10 | Xo+Yo≤15∧2\*(Xo+Yo+10)>21 |
| 12->13 | x->Xo\*3, y->Yo+10 | Xo+Yo≤15∧2\*(Xo+Yo+10)>21 |
| 13->17 | x->Xo\*3, y->(Yo+10)\*2 | Xo+Yo≤15∧2\*(Xo+Yo+10)>21 |

iv)

|  |  |  |
| --- | --- | --- |
| **Edge** | **Symbolic State (P V )** | **Path Condition (P C)** |
| 1->5 | x->Xo, y->Yo | true |
| 5->6 | x->Xo, y->Yo | Xo+Yo≤15 |
| 6->7 | x->Xo, y->Yo+10 | Xo+Yo≤15 |
| 7->9 | x->Xo-2, y->Yo+10 | Xo+Yo≤15 |
| 9->14 | x->Xo, y->Yo+10 | Xo+Yo≤15 |
| 14->15 | x->Xo, y->Yo+10 | Xo+Yo≤15∧2\*(Xo+Yo+10)≤21 |
| 15->16 | x->Xo\*4, y->Yo+10 | Xo+Yo≤15∧2\*(Xo+Yo+10)≤21 |
| 16->17 | x->Xo\*4, y->(Yo+10)\*3+Xo\*4 | Xo+Yo≤15∧2\*(Xo+Yo+10)≤21 |

**(c)**

i) feasible Xo=15, Yo=5

ii) Infeasible, since (Xo+Yo)>15∧2\*(Xo+Yo-3)≤21 is always false

iii) feasible Xo=3, Yo=3

iv) feasible Xo=1, Yo=-1

# Q2



Since at most one of , , , is true, so it must satisfy:

It is equal to:

, which is the format of CNF

**(b)**

So the FOL sentence is valid

**(d)**

(b)We first assume that x,y,z ∈N, satisfy (P(x, y) ∧ P(z, y) ∧ P(x, z) ∧ ¬P(z, x))

Then we get:

(y=x+1)∧(y=z+1)∧(z=x+1)∧(x≠z+1)

However, its first three equations are contradictory, as (y=x+1)∧(y=x+2)is always false for x,y,z ∈N, so this FOL model violates the formula Φ

(c) We first assume that x,y,z ∈P(N), satisfy (P(x, y) ∧ P(z, y) ∧ P(x, z) ∧ ¬P(z, x))

Then we get:

x ⊆ y, z ⊆ y, x ⊆ z, z x

So we can get (x ⊆ z ⊆ y) ∧ (z x), it is obvious to be true. So M3 |= Φ

**(e)**