VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

VARUN R(1BM24CS430)

in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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B.M.S. College of Engineering,
Bull Temple Road, Bangalore 560019
(Affiliated To Visvesvaraya Technological University, Belgaum)
Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **VARUN R (1BM24CS430),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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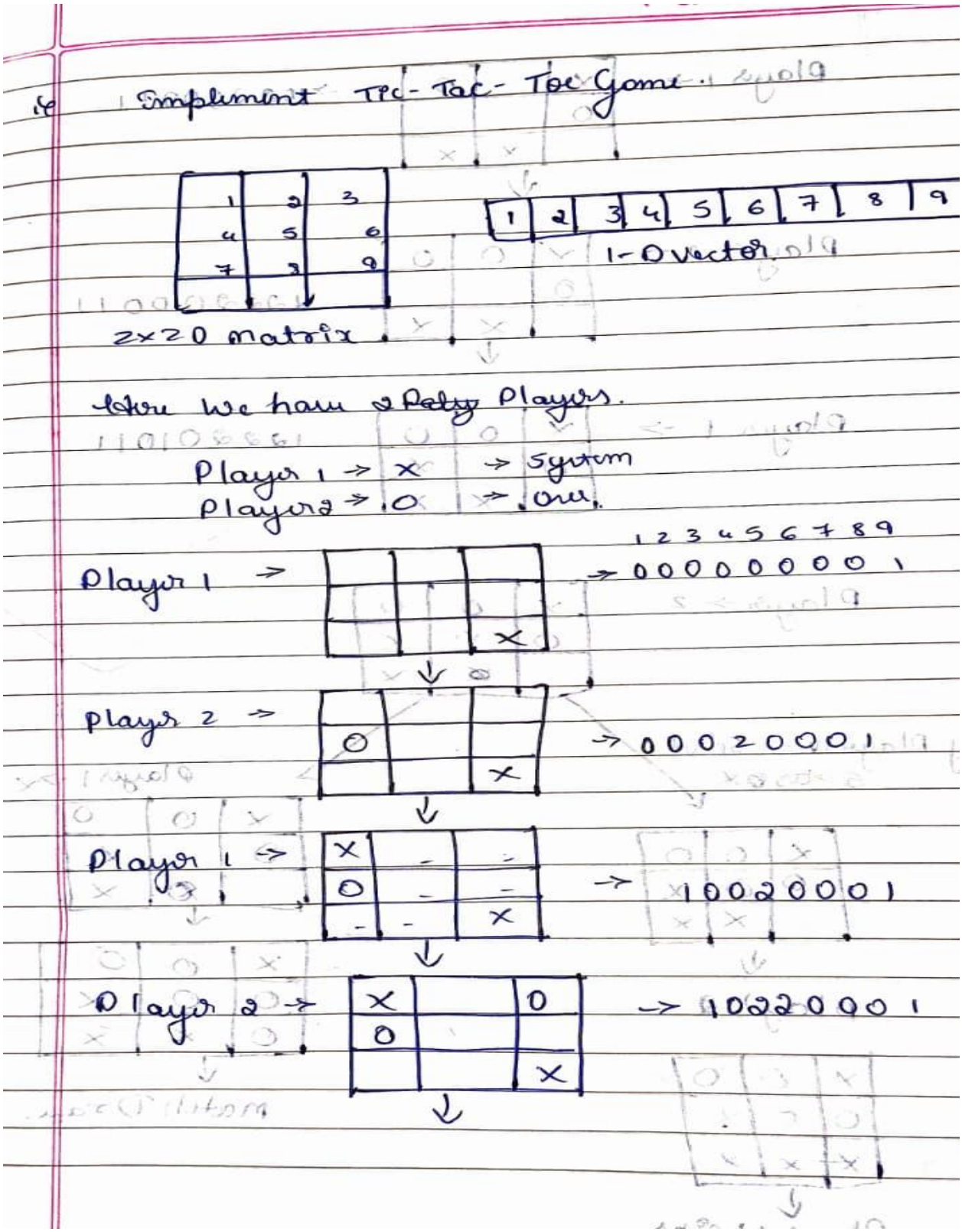
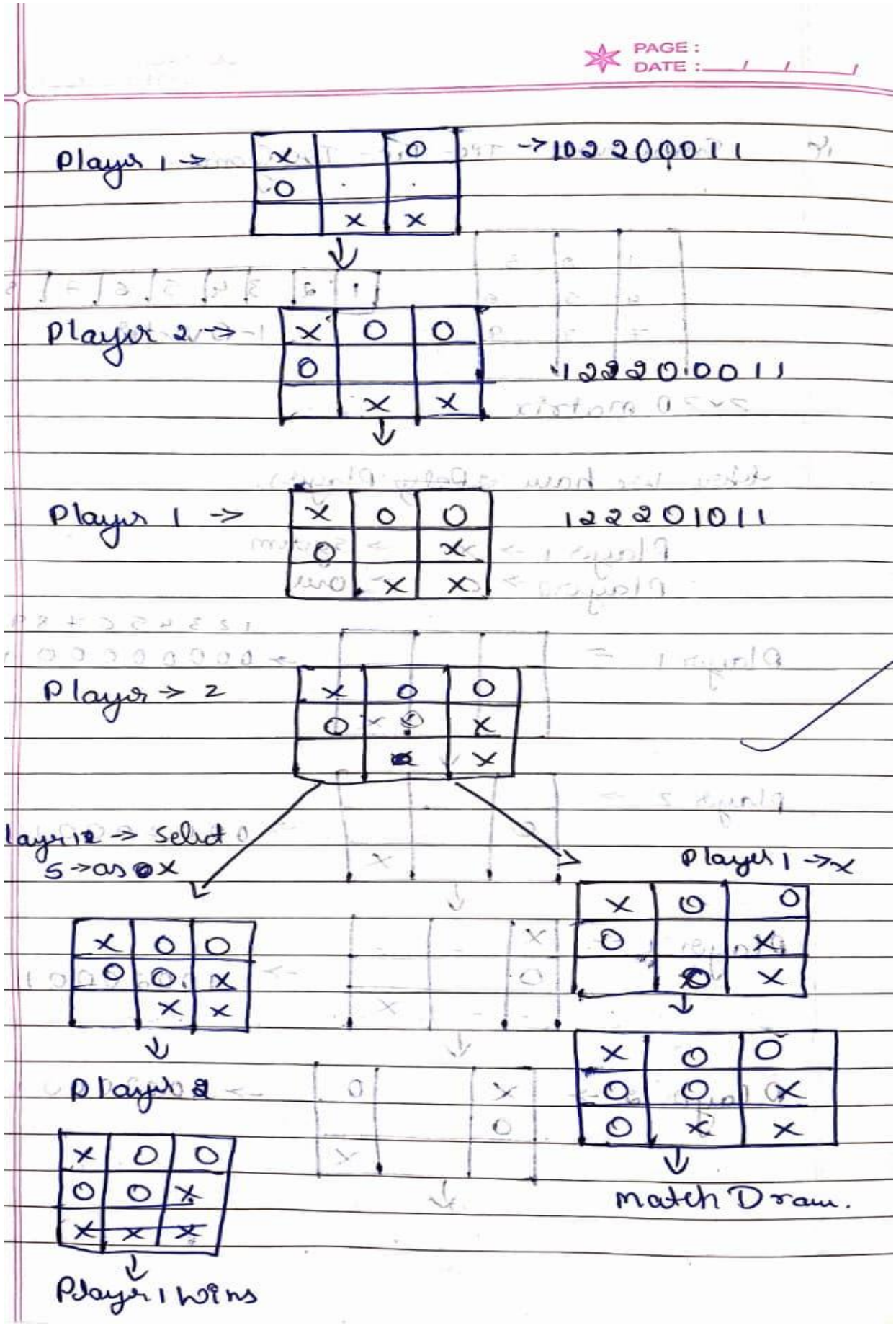
Program 1 - Tic Tac toe and Vacum Cleaner

Algorithm

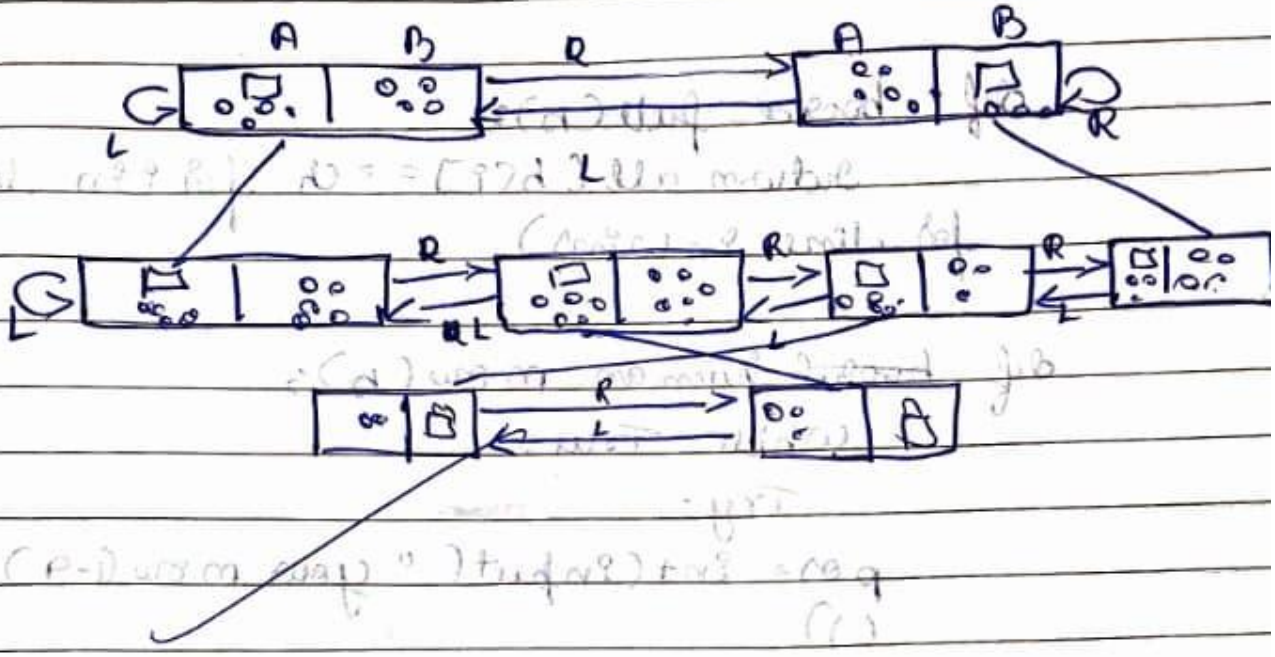


Code


PAGE :
DATE :
Player 1 →
→10220011
Player 2 →
12220011
Player 1 →
12201011
Player → 2
Player 2 → Select
5 → as X
Player 1 → X
Player 2
Player 1 wins
match Draw.

PAGE :
DATE : / /

Vaccum clean



→ import random

```
def print board(b):
    Print()
Print(f" {b[1]} | {b[0]} | {b[3]} ")
Print("---+---+---")
Print(f" {b[4]} | {b[5]} | {b[6]} ")
Print("---+---+---")
Print(f" {b[7]} | {b[8]} | {b[9]} ")
Print()
```

```
return any(all(b[i] == ch for i in line) for line in
    wins)
def board_full(b):
    return all(b[i] == ch for i in line)
    for line in wins)

def human_move(b):
    while True:
        try:
    pos = int(input("your move (1-9): ").strip
    ())
    if pos not in range(1,10):
        print("Enter a number from 1 to 9:")
        Continue
    if b[pos] in ('X', 'O'):
        print("Enter a not from 1 to 9.")
        Continue spot is taken. Try another."
    Continue
    return pos
    except ValueError:
        print("Please enter a valid number")

def Computer_move(b):
    free = [i for i in range(1,10) if b[i] not in
    ('X', 'O')]
    return random.choice(free)

def play():
    Print("Tic Tac Toe - You(X) vs Computer(O)
    print("positions")
```

Vacuum Cleaner:

```
Rooms = ["D", "D"];
def fullclean(rooms):
    if (rooms[0] == "ND" and rooms[1] ==
        return True
    else:
        return False

def clean_room():
    V=0
    while not fullclean(rooms):
        if(rooms[V] == "D"):
            rooms[V] = "ND"
            Print("Room ", V, "cleaned!")
        elif (rooms[V] == "ND"):
            if (V == 0):
                V+ = 1
            else:
                V- = 1
            Print ("All rooms cleaned!")
    clean_room()
```

Output:-

```
Room 0 cleaned!
Room 1 cleaned!
All rooms cleaned!
```

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Code

```
import random
class TicTacToe:
def _init_(self):
    self.board = []
    def create_board(self):
        for i in range(3):
            row = []
            for j in range(3):
                row.append('-')
            self.board.append(row)
    def get_random_first_player(self):
        return random.randint(0, 1)
    def fix_spot(self, row, col, player):
        self.board[row][col] = player
    def is_player_win(self, player):
        win = None
        n = len(self.board)
        for i in range(n):
            win = True
            for j in range(n):
                if self.board[i][j] != player:
                    win = False
                    break
            if win:
                return win
        for i in range(n):
            win = True
            for j in range(n):
                if self.board[j][i] != player:
                    win = False
                    break
            if win:
                return win
        win = True
        for i in range(n):
            if self.board[i][i] != player:
                win = False
                break
        if win:
            return win
        win = True
```

```
for i in range(n):
                if self.board[i][n - 1 - i] != player:
                    win = False
                    break
            if win:
                return win
            return False
            for row in self.board:
                for item in row:
                    if item == '-':
                        return False
            return True
        def is_board_filled(self):
            for row in self.board:
                for item in row:
                    if item == '-':
                        return False
            return True
        def swap_player_turn(self, player):
            return 'X' if player == 'O' else 'O'
        def show_board(self):
            for row in self.board:
                for item in row:
                    print(item, end=" ")
                print()
        def start(self):
            self.create_board()
            player = 'X' if self.get_random_first_player() == 1 else 'O'
            while True:
                print(f"Player {player} turn")
                self.show_board()
                row, col = list(
                    map(int, input("Enter row and column numbers to fix spot: ").split()))
                print()
                self.fix_spot(row - 1, col - 1, player)
                if self.is_player_win(player):
                    print(f"Player {player} wins the game!")
                    break
                if self.is_board_filled():
```

```
            print("Match Draw!")
            break
        player = self.swap_player_turn(player)
    print()
    self.show_board()
tic_tac_toe = TicTacToe()

tic_tac_toe.start()
```

Output Snapshot

```
Player O turn
- - -
- - -
- - -
Enter row and column numbers to fix spot: 0 3
Player X turn
- - -
- - -
- - O
Enter row and column numbers to fix spot: 1 2
Player O turn
- X - - - -
- - O
Enter row and column numbers to fix spot: 3 0
Player X turn
- X -
- - -
- - O
Enter row and column numbers to fix spot: 3 2
Player O turn
- X -
- - -
- X O
Enter row and column numbers to fix spot: 2 1
Player X turn
- X -
O - -
- X O
Enter row and column numbers to fix spot: 2 2
Player X wins the game!
```

Program 2 - Vacuum Cleaner

Code

```
def vacuum_world():

    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input+ " : ")
    status_input_complement = input("Enter status of other room : ")

print("Initial Location Condition {A : " + str(status_input_complement) + ", B : " + str(status_input) + " }"
    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1 #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving right to the Location B. ")
                cost += 1
                print("COST for moving RIGHT " + str(cost))
                goal_state['B'] = '0'
                cost += 1
                print("COST for SUCK " + str(cost))
                print("Location B has been Cleaned. ")
            else:
                print("No action" + str(cost))
                print("Location B is already clean.")

        if status_input == '0':
            print("Location A is already clean ")
            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving RIGHT to the Location B. ")
                cost += 1
                print("COST for moving RIGHT " + str(cost))
                goal_state['B'] = '0'
                cost += 1
```

```
            print("Cost for SUCK" + str(cost))
            print("Location B has been Cleaned. ")
        else:
            print("No action " + str(cost))
            print(cost)
            print("Location B is already clean.")

else:
    print("Vacuum is placed in location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'
        cost += 1
        print("COST for CLEANING " + str(cost))



        print("Location B has been Cleaned.")

        if status_input_complement == '1':
            print("Location A is Dirty.")
            print("Moving LEFT to the Location A. ")
            cost += 1
            print("COST for moving LEFT " + str(cost))
            goal_state['A'] = '0'
            cost += 1
            print("COST for SUCK " + str(cost))
            print("Location A has been Cleaned.")

    else:
        print(cost)
        print("Location B is already clean.")

        if status_input_complement == '1':
            print("Location A is Dirty.")
            print("Moving LEFT to the Location A. ")
            cost += 1
            print("COST for moving LEFT " + str(cost))
            goal_state['A'] = '0'
            cost += 1
            print("Cost for SUCK " + str(cost))
            print("Location A has been Cleaned. ")
        else:
```

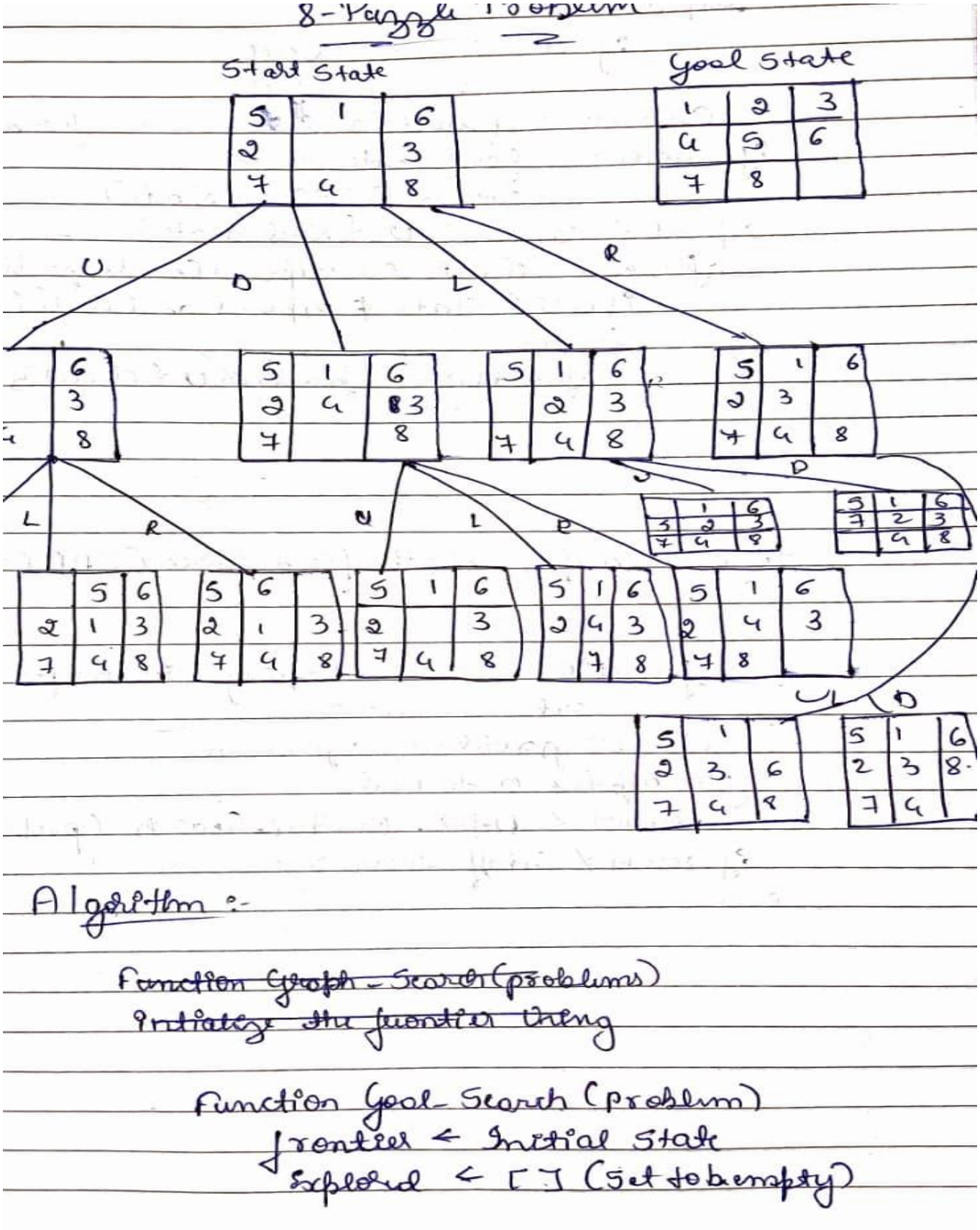
```
            print("No action " + str(cost))
            print("Location A is already clean.")

print("GOAL STATE: ")
print(goal_state)
print("Performance Measurement: " + str(cost))
vacuum_world()
```

Output Snapshot

```
Enter Location of Vacuum: A
Enter status of A : 0
Enter status of other room : 1
Initial Location Condition {A : 1, B : 0 }
Vacuum is placed in Location A
Location A is already clean
Location B is Dirty.
Moving RIGHT to the Location B.
COST for moving RIGHT 1
Cost for SUCK2
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 2
```

Program 3 - 8 Puzzle Using BFS



Algorithm

loop do
if frontier == Null
return fail.
Choose a leaf node and remove it from fron
if node == goal state. then
return Solution (Node)
expand ← explored ∪ {Node State}
for each child in expand (node, problem)
if child state ∉ expand and child ∉ fr
then
frontier ← frontier ∪ {child}.

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Iterative deepening depth first search (IDDFS)

function Iterative Deepening_Search (problem
return Solution
Inputs : problem, a problem
for depth ← 0 to ∞ do
result ← Depth-limited-Search (problem
if result ≠ Cutoff then return result
end

-

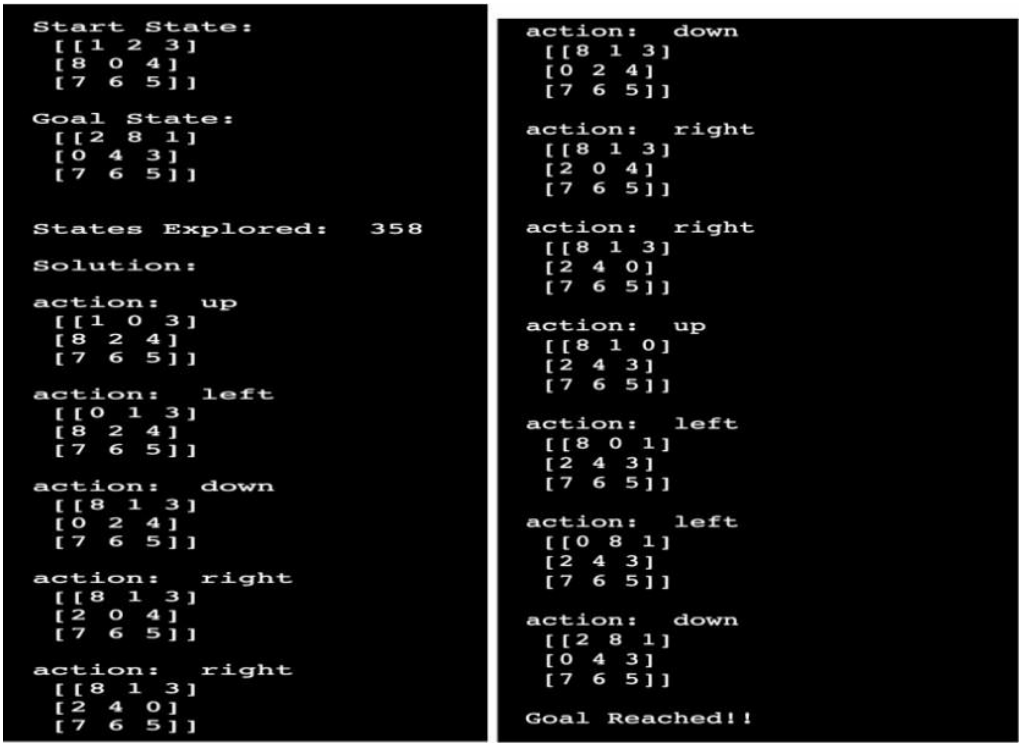
Code

```
import sys
import numpy as np
class Node:
        def __init__(self, state, parent, action):
                self.state = state
                self.parent = parent
                self.action = action
class StackFrontier:
        def __init__(self):
                self.frontier = []
        def add(self, node):
                self.frontier.append(node)
        def contains_state(self, state):
                return any((node.state[0] == state[0]).all() for node in self.frontier)
        def empty(self):
                return len(self.frontier) == 0
        def remove(self):
                if self.empty():
                        raise Exception("Empty Frontier")
                else:
                        node = self.frontier[-1]
                        self.frontier = self.frontier[:-1]
                        return no
class QueueFrontier(StackFrontier):
        def remove(self):
                if self.empty():
                        raise Exception("Empty Frontier")
                else:   node = self.frontier[0]
                        self.frontier = self.frontier[1:]
                        return node
class Puzzle:
        def __init__(self, start, startIndex, goal, goalIndex):
                self.start = [start, startIndex]
                self.goal = [goal, goalIndex]
                self.solution = None

        def neighbors(self, state):
                mat, (row, col) = state
```

```
results = [] if row > 0:
                    mat1 = np.copy(mat)
                    mat1[row][col] = mat1[row - 1][col]
                    mat1[row - 1][col] = 0
                    results.append(('up', [mat1, (row - 1, col)]))
            if col > 0:
                    mat1 = np.copy(mat)
                    mat1[row][col] = mat1[row][col - 1]
                    mat1[row][col - 1] = 0
                    results.append(('left', [mat1, (row, col - 1)]))
            if row < 2:
                    mat1 = np.copy(mat)
                    mat1[row][col] = mat1[row + 1][col]
                    mat1[row + 1][col] = 0
                    results.append(('down', [mat1, (row + 1, col)]))
            if col < 2:
                    mat1 = np.copy(mat)
                    mat1[row][col] = mat1[row][col + 1]
                    mat1[row][col + 1] = 0
                    results.append(('right', [mat1, (row, col + 1)]))
            return results
    def print(self):
            solution = self.solution if self.solution is not None else None



            print("Start State:\n", self.start[0], "\n")
            print("Goal State:\n", self.goal[0], "\n")
            print("\nStates Explored: ", self.num_explored, "\n")
            print("Solution:\n ")
            for action, cell in zip(solution[0], solution[1]):
                    print("action: ", action, "\n", cell[0], "\n")
            print("Goal Reached!!")
    def does_not_contain_state(self, state):
            for st in self.explored:
                    if (st[0] == state[0]).all():
                    return False
            return True
    def solve(self):
            self.num_explored = 0
            start = Node(state=self.start, parent=None, action=None)
```

```
                frontier = QueueFrontier()
                frontier.add(start)
                self.explored = []
                while True:
                        if frontier.empty():
                                raise Exception("No solution")
                        node = frontier.remove()
                        self.num_explored += 1
                         if (node.state[0] == self.goal[0]).all():
                                actions = []
                                cells = []
                                while node.parent is not None:
                                        actions.append(node.action)
                                        cells.append(node.state)
                                        node = node.parent
                                actions.reverse()
                                cells.reverse()
                                 self.solution = (actions, cells)
                                return
                        self.explored.append(node.state)
                        for action, state in self.neighbors(node.state):
        if not frontier.contains_state(state) and self.does_not_contain_state(state): child =
                                        Node(state=state, parent=node, action=action)
                                        frontier.add(child)
start = np.array([[1, 2, 3], [8, 0, 4], [7, 6, 5]])



goal = np.array([[2, 8, 1], [0, 4, 3], [7, 6, 5]])
startIndex = (1, 1)
goalIndex = (1, 0)
p = Puzzle(start, startIndex, goal, goalIndex)
p.solve() p.print()
```

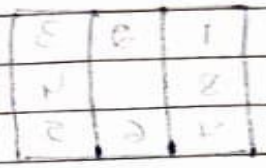
Output Snapshot



Program 04 - 8 Puzzle Using A*

Algorithm

A* (Star) on 8 puzzle



Algorithm:

Function A* (Start, Goal)
open_list ← priority queue ordered by f(n) = g(n) + h(n)
closed_list ← Empty set

g(Start) ← 0
f(Start) ← g(Start) + h(Start)
open_list.insert(Start, f(Start))

while open_list is not empty:
current ← node in open_list with lowest f value

if current = goal:
return path from Start to Goal
remove current from open_list
add current to closed_list

for each neighbor of current:
if neighbor is closed_list:
continue

tentative_g ← g(current) + Cost(current, neighbor)

if neighbor not in open_list or
tentative_g < g(neighbor):
g(neighbor) ← tentative_g
f(neighbor) ← g(neighbor) + h(neighbor)

Step 6:- Move Right

1	2	3
8		4
7	6	5

h=0

Moved Sequence are → R, U, U, L, D, R

→ Manhattan distance Algorithm:-

1. Start with initial State.
2. Calculate the ~~Mah~~ manhattan distance of the Current State.
3. While the Current State is not goal a genoate
a. Valid neighbouring state by sliding the blank tile up/down/left/right.
b. Calculate the manhattan distance for each neighbour
c. Choose the neighbor with lowest maintanance manhattan distance.
d. If the neigbours manhattan distance.
4. If the manhattan distance is zero (0) then goal reached.

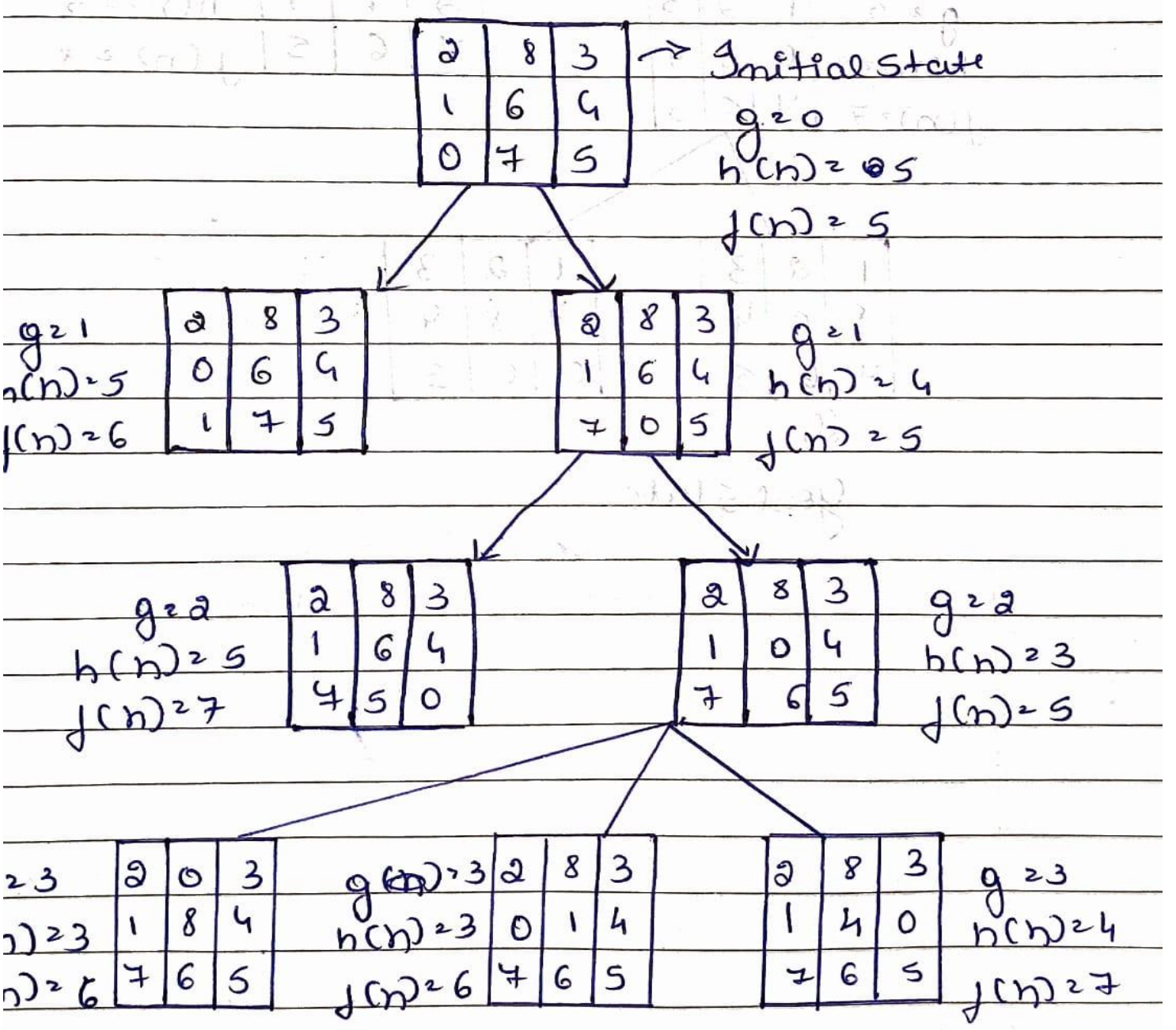
Ex:-

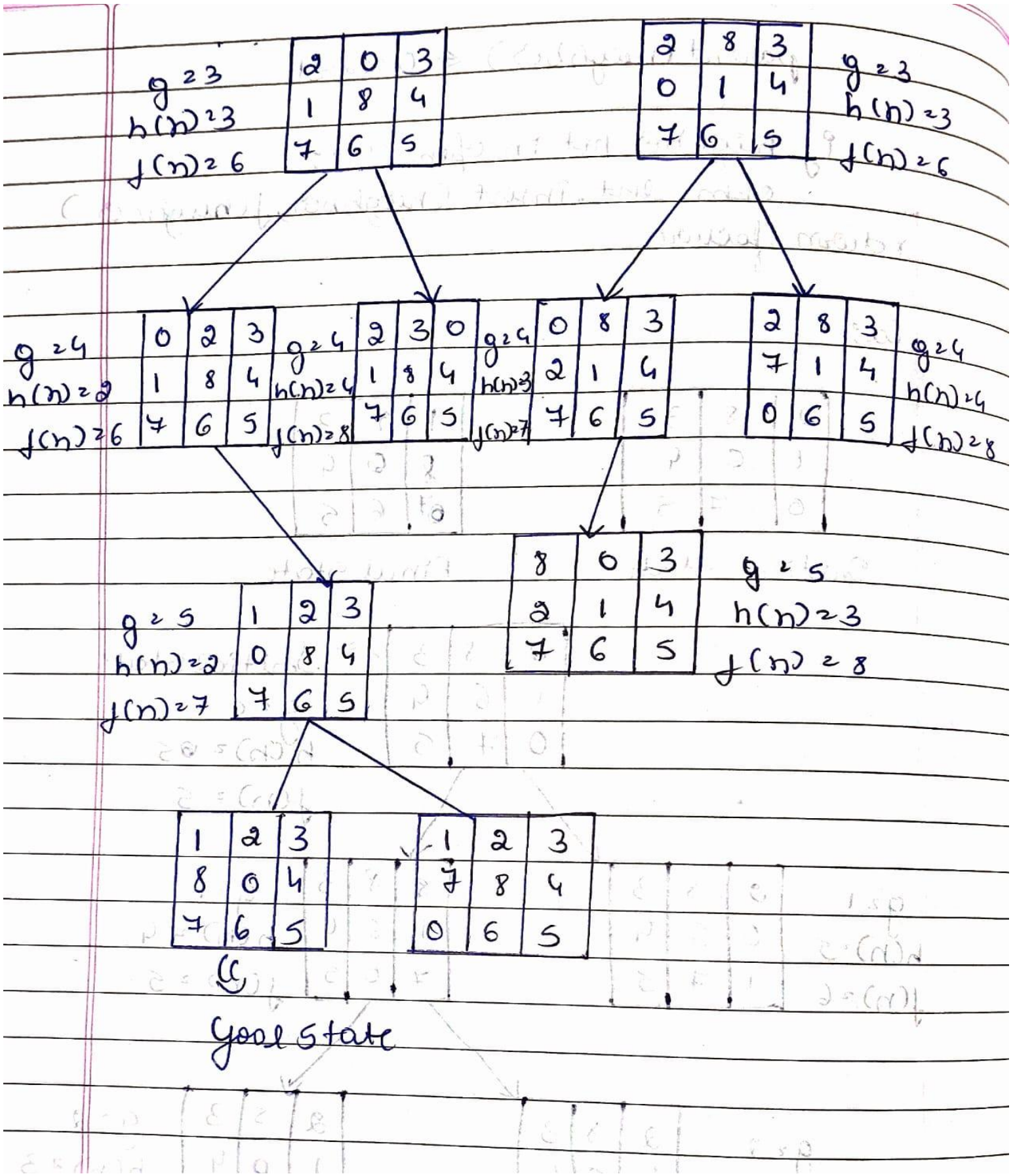
2	8	3
1	6	4
0	7	5

Initial State

1	2	3
8	0	4
7	6	5

Final State




g=3
h(n)=3
f(n)=6
2 0 3
1 8 4
7 6 5
2 8 3
0 1 4
7 6 5
g=3
h(n)=3
f(n)=6
g=4
h(n)=2
f(n)=6
0 2 3
1 8 4
7 6 5
g=4
h(n)=4
f(n)=8
2 3 0
1 8 4
7 6 5
g=4
h(n)=3
f(n)=7
0 8 3
2 1 4
7 6 5
2 8 3
7 1 4
0 6 5
g=4
h(n)=4
f(n)=8
g=5
h(n)=2
f(n)=7
1 2 3
0 8 4
7 6 5
8 0 3
2 1 4
7 6 5
g=5
h(n)=3
f(n)=8
1 2 3
8 0 4
7 6 5
1 2 3
7 8 4
0 6 5
Goal state

-

Code

```
def print_b(src):
    state = src.copy()
    state[state.index(-1)] = ' '
    print(
f"""
 {state[0]} {state[1]} {state[2]}
 {state[3]} {state[4]} {state[5]}
 {state[6]} {state[7]} {state[8]}
 “””
    )
def h(state, target):
    count = 0
    i = 0
    for j in state:
        if state[i] != target[i]:
            count = count+1
    return count
def astar(state, target):
    states = [src]
    g = 0
    visited_states = []
    while len(states):
        print(f"Level: {g}")
        moves = []
        for state in states:
            visited_states.append(state)
            print_b(state)
            if state == target:
                print("Success")
                return
            moves += [move for move in possible_moves(
                state, visited_states) if move not in moves]
        costs = [g + h(move, target) for move in moves]
        states = [moves[i]
                  for i in range(len(moves)) if costs[i] == min(costs)]
        g += 1
    print("Fail")
def possible_moves(state, visited_state):
```

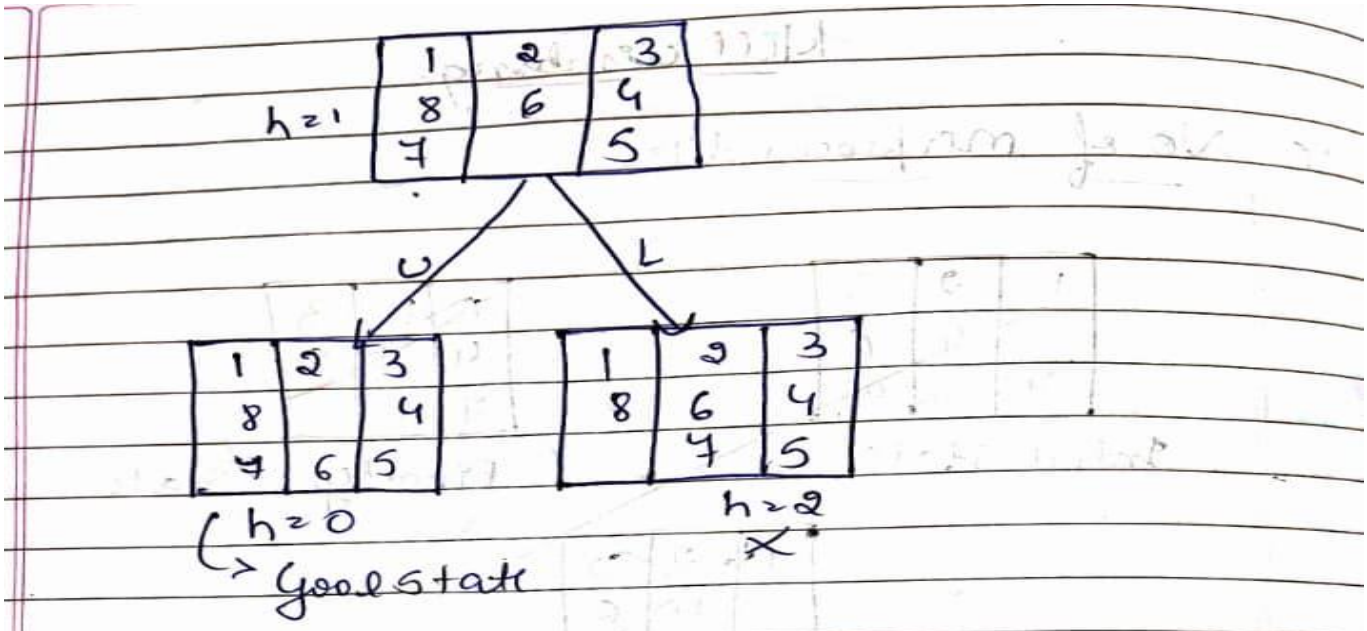
```
    b = state.index(-1)
    d = []
    if b - 3 in range(9):
        d.append('u')
    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')
    if b + 3 in range(9):
        d.append('d')
    pos_moves = []
    for m in d:
        pos_moves.append(gen(state, m, b))
    return [move for move in pos_moves if move not in visited_state]
def gen(state, m, b):
    temp = state.copy()
    if m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    if m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    if m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]
    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
    return temp
src = [1, 2, 3, -1, 4, 5, 6, 7, 8]
target = [1, 2, 3, 4, 5,6, 7, 8,-1]
astar(src, target)
```

Output Snapshot

```
Enter the start state matrix

1 0 1 0
1 0 0 1
1 1 1 1
Enter the goal state matrix

1 1 0 1
1 0 0 1
1 1 1 0
|
  |
 \'/

1 0 1 0
1 0 0 1
1 1 1 1
```

Program 05 – Hill Climbing

Algorithm



Move Sequence → D L U

Hill climbing Algorithm:

```
Current_State = Initial_State
While True:
    neighbors = generate_neighbours(Current_S
best_neighbor = None
best_heuristic = float('inf')
    for neighbor in neighbors:
        heuristic = Calculate_manhattan_distance
    if heuristic < best_heuristic:
        best_heuristic = heuristic
        best_neighbour = neighbour
if Current_State == goal_State:
    Print("Solution found!")
    return Current_State
if best_heuristic >= Calculate_manhattan_distance(C
    Print("No Solution found (local maximum
```

Code

```
from random import randint
N = 8
def configureRandomly(board, state):
        for i in range(N):
                state[i] = randint(0, 100000) % N;
                board[state[i]][i] = 1;
    def printBoard(board):
        for i in range(N):
                print(*board[i])
def printState( state):
        print(*state)
def compareStates(state1, state2):
        for i in range(N):
                if (state1[i] != state2[i]):
                        return False;
        return True;
    def fill(board, value):
        for i in range(N):
                for j in range(N):
                        board[i][j] = value;
 def calculateObjective( board, state):
        for i in range(N):
                row = state[i]
                col = i - 1;
                while (col >= 0 and board[row][col] != 1) :
                        col -= 1
                if (col >= 0 and board[row][col] == 1) :
                        attacking += 1;
                row = state[i]
                col = i + 1;
                while (col < N and board[row][col] != 1):
                        col += 1;
                if (col < N and board[row][col] == 1) :
                        attacking += 1;
                row = state[i] - 1
                col = i - 1;
                while (col >= 0 and row >= 0 and board[row][col] != 1) :
                        col-= 1;
                        row-= 1;
```

```
            if (col >= 0 and row >= 0 and board[row][col] == 1) :
                attacking+= 1;

            # Diagonally to the right down
            # (row and col simultaneously
            # increase)
            row = state[i] + 1
            col = i + 1;
            while (col < N and row < N and board[row][col] != 1) :
                col+= 1;
                row+= 1;

            if (col < N and row < N and board[row][col] == 1) :
                attacking += 1;
            row = state[i] + 1
            col = i - 1;
            while (col >= 0 and row < N and board[row][col] != 1) :
                col -= 1;
                row += 1;
            if (col >= 0 and row < N and board[row][col] == 1) :
                attacking += 1;
            row = state[i] - 1
            col = i + 1;
            while (col < N and row >= 0 and board[row][col] != 1) :
                col += 1;
                row -= 1;
            if (col < N and row >= 0 and board[row][col] == 1) :
                attacking += 1;
        return int(attacking / 2);
def generateBoard( board, state):
        fill(board, 0);
        for i in range(N):
            board[state[i]][i] = 1;
    def copyState( state1, state2):

        for i in range(N):
            state1[i] = state2[i];

    def getNeighbour(board, state):
```

```
    opBoard = [[0 for _ in range(N)] for _ in range(N)]
    opState = [0 for _ in range(N)]

    copyState(opState, state);
    generateBoard(opBoard, opState);
    opObjective = calculateObjective(opBoard, opState);
    NeighbourBoard = [[0 for _ in range(N)] for _ in range(N)]

    NeighbourState = [0 for _ in range(N)]
    copyState(NeighbourState, state);
    generateBoard(NeighbourBoard, NeighbourState);
    for i in range(N):
            for j in range(N):
                    if (j != state[i]) :
                            NeighbourState[i] = j;
                            NeighbourBoard[NeighbourState[i]][i] = 1;
                            NeighbourBoard[state[i]][i] = 0;
                            temp = calculateObjective( NeighbourBoard, NeighbourState)
                            if (temp <= opObjective) :
                                    opObjective = temp;
                                    copyState(opState, NeighbourState);
                                    generateBoard(opBoard, opState);
                            NeighbourBoard[NeighbourState[i]][i] = 0;
                            NeighbourState[i] = state[i];
                            NeighbourBoard[state[i]][i] = 1;
    copyState(state, opState);
    fill(board, 0);
    generateBoard(board, state);

def hillClimbing(board, state):
    neighbourBoard = [[0 for _ in range(N)] for _ in range(N)
    neighbourState = [0 for _ in range(N)]
    copyState(neighbourState, state);
    generateBoard(neighbourBoard, neighbourState);

    while True:
            copyState(state, neighbourState);
            generateBoard(board, state);
            # Getting the optimal neighbour
            getNeighbour(neighbourBoard, neighbourState);
```

```
        if (compareStates(state, neighbourState)) :

                printBoard(board);
                break;

        elif (calculateObjective(board, state) == calculateObjective(
neighbourBoard,neighbourState)):
                # Random neighbour
                neighbourState[randint(0, 100000) % N] = randint(0, 100000) % N;
                generateBoard(neighbourBoard, neighbourState);

# Driver code
state = [0] * N
board = [[0 for _ in range(N)] for _ in range(N)]
configureRandomly(board, state);
hillClimbing(board, state);
```

OUTPUT

```
Step 0: Initial state
. . . Q
. Q . .
. . Q .
Q . . .

Cost = 2

Step 1: Move to better neighbour
. . . Q
Q . . .
. . Q .
. Q . .

Cost = 1

Step 2: Move to better neighbour
. . Q .
Q . . .
. . . Q
. Q . .

Cost = 0

Step 3: Reached local minimum
Final state:
. . Q .
Q . . .
. . . Q
. Q . .

Final cost = 0
```

Program-07 Knowledge-Base

Algorithm

Lab-05

Propotional logic

Function TT-Entails? (KB, α) returns true or false.
inputs: KB, the Knowledge base, a sentence in propotional logic α, the query, a sentance in propotional logic

Symbols ← a list of the propotion symbols in KB and α
return TT-check-All (KB, α, Symbols, {})

function TT-check-All (KB, α, Symbols, model)
return true or false
if Empty? (Symbols) then
if PL-True? (KB, model) then
return PL-True? (α, model)
else return true // When KB is false always return true
else do
P ← first (symbols)
rest ← Rest (symbols)
return (TT-check-All (KB, α, rest, Model ∪ {P = true}))
and
TT-Check-All (KB, α, rest, model ∪ {P = false}))

Code

```
combinations=[(True,True, True),(True,True,False),(True,False,True),(True,False,
False),(False,True, True),(False,True, False),(False, False,True),(False,False, False)]
variable={'p':0,'q':1, 'r':2}
kb=''
q=''
priority={'~':3,'v':1,'^':2}
def input_rules()
        global kb, q
    kb = (input("Enter rule: "))
    q = input("Enter the Query: ")
def entailment():
    global kb, q
    print("*10+"Truth Table Reference"+"*10)
    print('kb','alpha')
    print('*'*10)
    for comb in combinations:
        s = evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(q), comb)
        print(s, f)
        print('-'*10)
        if s and not f:
            return False
    return True
def isOperand(c):
    return c.isalpha() and c!='v'

def isLeftParanthesis(c):
    return c == '('

def isRightParanthesis(c):
    return c == ')'

def isEmpty(stack):
    return len(stack) == 0

def peek(stack):
    return stack[-1]

def hasLessOrEqualPriority(c1, c2):
    try:
        return priority[c1]<=priority[c2]
    except KeyError:
```

```
        return False
def toPostfix(infix):
    stack = []
    postfix = ''
    for c in infix:
        if isOperand(c):
        postfix += c
        else:
            if isLeftParanthesis(c):
                stack.append(c)
            elif isRightParanthesis(c):
                operator = stack.pop()
                while not isLeftParanthesis(operator):
                    postfix += operator
                    operator = stack.pop()
            else:
                while (not isEmpty(stack)) and hasLessOrEqualPriority(c, peek(stack)):
                    postfix += stack.pop()
                stack.append(c)
    while (not isEmpty(stack)):
        postfix += stack.pop()

    return postfix
def evaluatePostfix(exp, comb):
    stack = []
    for i in exp:
        if isOperand(i):
            stack.append(comb[variable[i]])
        elif i == '~':
            val1 = stack.pop()
            stack.append(not val1)
        else:
            val1 = stack.pop()
            val2 = stack.pop()
            stack.append(_eval(i,val2,val1))
    return stack.pop()
def _eval(i, val1, val2):
    if i == '^':
        return val2 and val1
    return val2 or val1
#Test 1
input_rules()
ans = entailment()
```

```
    if ans:
print("Knowledge Base entails query") else:
        print("Knowledge Base does not entail query")
    #Test 2
    input_rules()
    ans = entailment()



    if ans:
        print("Knowledge Base entails query")
    else:
        print("Knowledge Base does not entail query")
```

OUTPUT

```
Enter rule: (~qv~pvr)^(~q^p)^q
Enter the Query: r
Truth Table Reference
kb alpha
**********
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
Knowledge Base entails query
```

Program-08 Unification in first order logic

Algorithm

Unification in FOL

Algorithm: unify (ψ_1, ψ_2)

Step 1: if ψ_1 or ψ_2 is a variable or Constant, then:
a) if ψ_1 or ψ_2 are identical, then return NIL
b) else if ψ_1 is available,
a) then if ψ_1 occurs in ψ_2, then return Failure
b) else Return (ψ_2/ψ_1)
c) else if ψ_2 is available,
a) if ψ_2 occurs in ψ_1 then return failure.
b) Else return {(ψ_1/ψ_2)}
d) else return failure.

Step 2: if the initial predicate symbol in ψ_1 and ψ_2 are not same, then return failure.

Step 3: if ψ_1 and ψ_2 have a different number of arguments, then return failure.

Step 4: Set Substitution set (Subst) to NIL

Step 5: For i=1 to the number of Elements in ψ_1,
a) Call unify function with the ith element of ψ_1 and ith element of ψ_2 and put the result into S
b) if S= failure then return failure.
c) if S ≠ NIL then do,
a) apply S to the remainder of both L_1 & L_2
b) Subst = append (S, Subst)

Step 6: Return Subst.

Code

```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression.split(")")[:-1]
    expression = ")".join(expression)
    attributes = expression.split(',')
    return attributes

def getInitialPredicate(expression):
    return expression.split("(")[0]

def isConstant(char):
    return char.isupper() and len(char) == 1

def isVariable(char):
    return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):



    attributes = getAttributes(exp)
    predicate = getInitialPredicate(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    return predicate + "(" + ",".join(attributes) + ")"

def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp

def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True
def getFirstPart(expression):
```

```
    attributes = getAttributes(expression)
    return attributes[0]
def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression
def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            print(f"{exp1} and {exp2} are constants. Cannot be unified")
            return []

    if isConstant(exp1):
        return [(exp1, exp2)]

    if isConstant(exp2):
        return [(exp2, exp1)]

    if isVariable(exp1):
      return [(exp2, exp1)] if not checkOccurs(exp1, exp2) else [] if isVariable(exp2):
        return [(exp1, exp2)] if not checkOccurs(exp2, exp1) else []

    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Cannot be unified as the predicates do not match!")
        return []

    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        print(f"Length of attributes {attributeCount1} and {attributeCount2} do not match. Cannot
be unified")
        return []

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return []
```

```
    if attributeCount1 == 1:
        return initialSubstitution

    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)

    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)

    remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return []

    return initialSubstitution + remainingSubstitution

if __name___== "__main__":
    print("Enter the first expression")
    e1 = input()



print("Enter the second expression")
e2 = input()
substitutions = unify(e1, e2)
print("The substitutions are:")
print([' / '.join(substitution) for substitution in substitutions])
```

Output Snapshot

```
Enter the first expression
king(x)
Enter the second expression
king(john)
The substitutions are:
['john / x']
```

Program-9 Forward Reasoning

Algorithm

First Order logic : Forward chaining

Example:

As per the law, it is a crime for an american to sell weapons to hostile nations, Country A, an enemy of America, has some missiles, and all the missiles were sold to it by Robert, who is an American Citizen, prove that "Robert is a Criminal".

Representation in FOL:

* It is a Crime for an american to Sell weapons to hostile Nations.

lets say p, q and r are variable.

American (p) ∧ weapon (q) ∧ Sells (p, q, r) ∧ Hostile (r) => Criminal (p)

* Country A has some missiles.

∃x owns (A, x) ∧ missile (x)

* Existential instantiation, introducing a new constant T1:

owns (A, T1)

missile (T1)

* All missiles were Should sold to Country A by Robert.

∀x missile (x) ^ owns (A, x) => Sells (Robert, x, A)

* missiles are weapons

missile (x) => weapon (x)

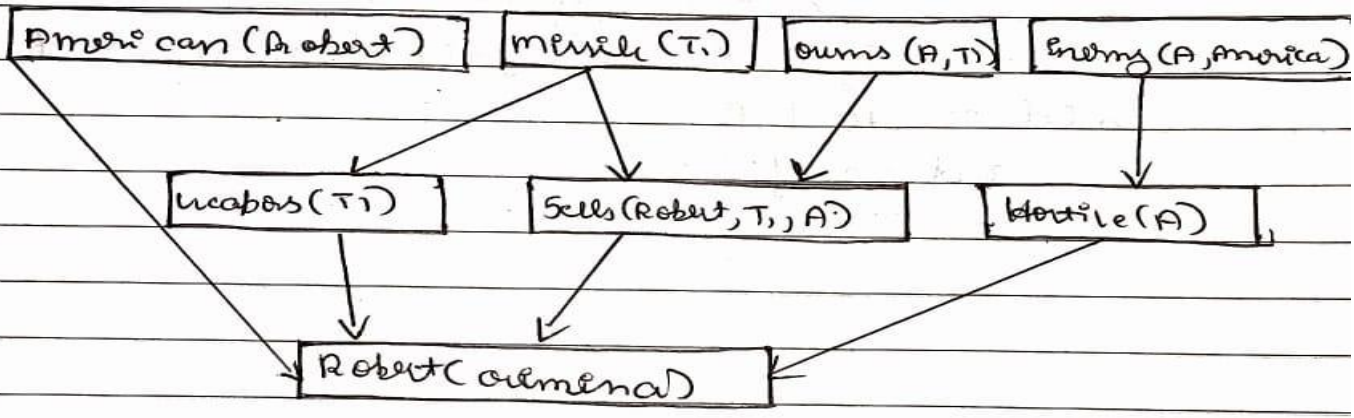
* Enemy of America is known as hostile

∀x Enemy (x, America) => Hostile (x)

* Robert is an American
  American (Robert)
* The country A, an enemy of America
  Enemy (A, America)

To prove:
  Robert is a criminal
  Criminal (Robert)

Forward chaining :



American(p) ∧ Weapon(q) ∧
Sells (p, q, r) ∧ Hostile (r)
=> Criminal (p)

Forward chaining Algorithm :

function (FOL - FC, Ask) (KB, α) return a substitute or false
  Inputs: KB: the knowledge base
    α, the query
  local variables: new, the new sentences inferred on each iteration.

repeat until new is empty

new ← { }

for each rule in KB do

(P1 ∧ ... ∧ Pn => q) ← Standardize-Variables(rule)

for each θ such that SUBST(θ, P1 ∧ ... ∧ Pn)

SUBST(θ, P1' ∧ ... ∧ Pn')

for some P1' ... Pn' in KB

q' ← SUBST(θ, q)

if q' does not clarify unify with some sentence already in KB or new then

KB or new then

add q' to new

φ ← unify(q', α)

if φ is not fail then return φ

add new to KB

return false

Code

```
import re
def isVariable(x):
    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-z~]+)\([^&|]+\)'
    return re.findall(expr, string)

class Fact:

    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip('()').split(',')
        return [predicate, params]
    def getResult(self):
    return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]

    def substitute(self, constants):
        c = constants.copy()
        f = f"{self.predicate}({','.join([constants.pop(0) if isVariable(p) else p for p in
self.params])})"
        return Fact(f)

class Implication:
```

```
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]
                    new_lhs.append(fact)
        predicate, attributes = getPredicates(self.rhs.expression)[0],
str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
                attributes = attributes.replace(key, constants[key])

        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs]) else None

class KB:

    def __init__(self):
        self.facts = set()
        self.implications = set()

    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

    def ask(self, e):
        facts = set([f.expression for f in self.facts])
```

```
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1

    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')

def main():
    kb = KB()
    print("Enter the number of FOL expressions present in KB:")
    n = int(input())
    print("Enter the expressions:")
    for i in range(n):
        fact = input()
kb.tell(fact)
print("Enter the query:")
query = input()
kb.ask(query)
kb.display()

main()
```

Output Snapshot

```
Querying criminal(x):
1. criminal(West)
All facts:
    1. american(West)
    2. sells(West,M1,Nono)
    3. owns(Nono,M1)
    4. missile(M1)
    5. enemy(Nono,America)
    6. weapon(M1)
    7. hostile(Nono)
    8. criminal(West)
Querying evil(x):
    1. evil(John)
```

Program-10 KnowledgeBase - Resolution

Algorithm

Resolution in FOL

Steps for proving in Resolution
premise, --- premise
Call expressed in FOL

① Convert all Sentences to CNF
② Negate Conclusion, S and to the premise clauses
③ Repeat until Contradiction or no progress is made.
a. Select 2 clauses (Call them parent clauses)
b. Resolve them together, performing all required unification.
c. If Resolvent is the empty clause, a Contradiction has been found (i.e, S follows from the premises)
d. If not, add Resolved to the premises.
④ Add Negated Conclusions to the premise clauses.

If we succeed in Steps 4, we have proved the Conclusion.

Example:
a) John likes all kind of food.
b) Apple and Vegetables are food.
c) Anything anyone eats and not killed is food.
d) Anil eats peanuts and still alive.
e) Harry eats everything that Anil eats.
f) Anyone who is alive implies not killed.
g) Anyone who is not killed implies alive.

Prove by resolution that:

1. John likes peanuts.

Step 1:- Representation in FOL:

a. $\forall x$: food (x) → likes (John, x)
b. food (Apple) ∧ food (Vegetables)
c. $\forall x \forall y$: eats (x, y) ∧ ¬ killed (x) → food(y)
~~c. eats $\forall x$: eats (Anil~~
d. eats (Anil, peanuts) ∧ alive (Anil)
e. $\forall x$: eats (Anil, x) → eats (Harry, x)
f. $\forall x$: ¬ killed (x) → alive (x)
g. $\forall x$: alive (x) → ¬ killed (x)
h. likes (John, peanuts)

Step 2: Elemenate implication.

$\alpha \rightarrow \beta$ with $\neg \alpha \vee \beta$

a. $\forall x$ ¬ food (x) ∨ likes (John, x)
b. food (Apple) ∧ food (Vegtatobles)
c. $\forall x \forall y$ ¬ [eats (x, y) ∧ ¬ killed (x)] ∨ food (y)
d. eats (Anil, peanut) ∧ Alive (Anil)
e. $\forall x$ ¬ eats (Anil, x) ∨ eats (Harry, x)
f. $\forall x$ ¬ [¬ killed (x)] ∨ alive (x)
g. $\forall x$ ¬ alive (x) ∨ ¬ killed (x)
h. likes (John, peanuts)

Step 3: Move negation inwards and rewrite.

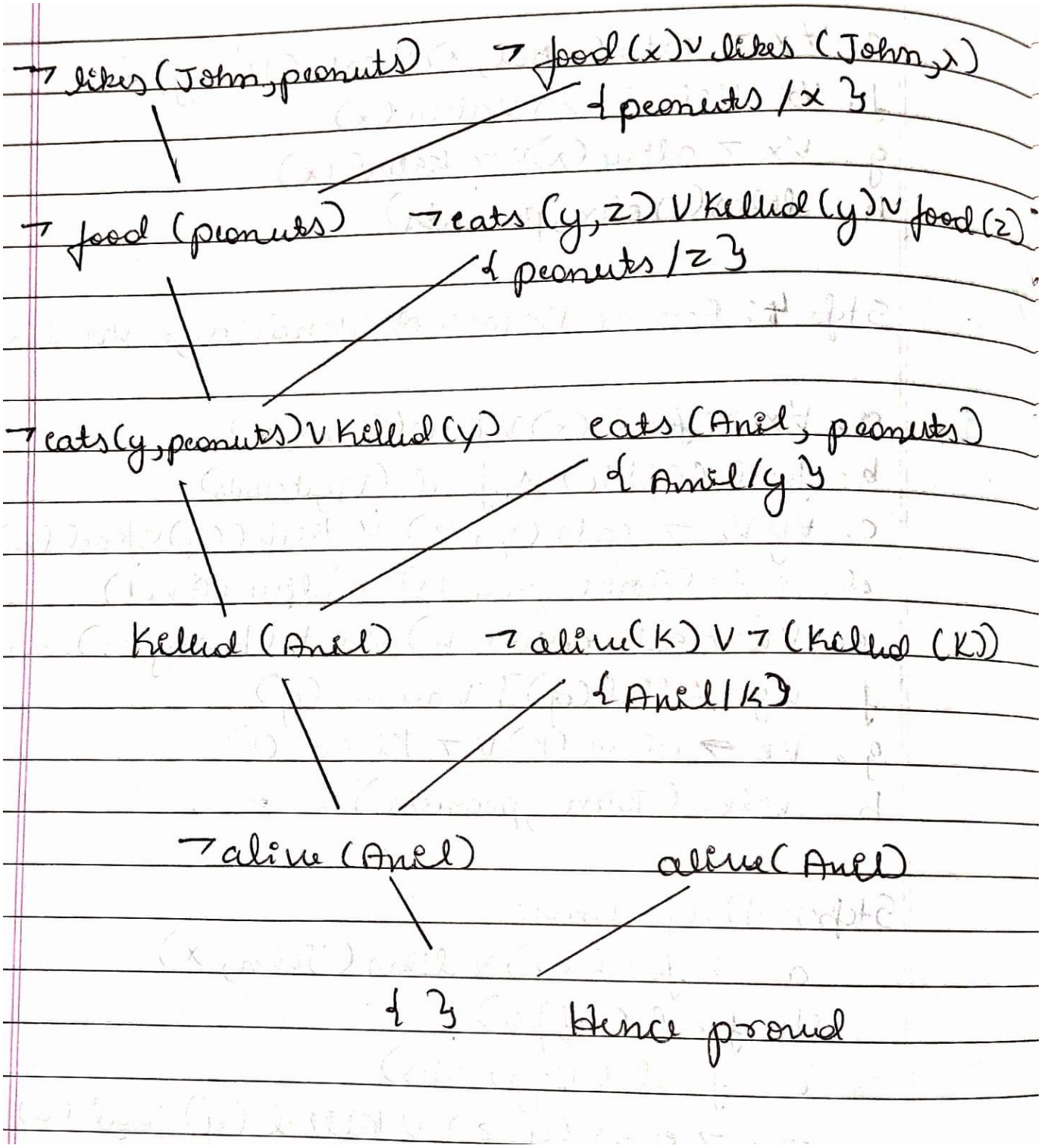
a. $\forall x$ ¬ food (x) ∨ likes (John, x)
b. food (Apple) ∧ food (Vegtables)
c. $\forall x \forall y$ ¬ eats (x, y) ∨ killed (x) ∨ food (y)
d. eats (Anil, peanuts) ∧ alive (Anil)

c. $\forall x \neg$ eats (Anil, x) $\vee$ eats (Harry, x)
f. $\forall x$ Killed (x) $\vee$ alive (x)
g. $\forall x \neg$ alive (x) $\vee \neg$ killed (x)
h. likes (John, peanuts)

Step 4: Rename Variable or Standardize Variable.

a. $\forall x \neg$ food (x) $\vee$ likes (John, x)
b. food (Apple) $\wedge$ food (Vegetables)
c. $\forall y \forall z \neg$ eats (y, z) $\vee$ killed (y) $\vee$ food (z)
d. eats (Anil, peanuts) $\wedge$ alive (Anil)
e. $\forall w \neg$ eats (Anil, w) $\vee$ eats (Harry, w)
f. $\forall g$ killed (g)] $\vee$ alive (g)
g. $\forall k \rightarrow$ alive (k) $\vee \neg$ killed (k)
h. likes (John, peanuts)

Step 5: Drop quantifiers.
a. $\neg$ food (x) $\vee$ likes (John, x)
b. food (Apple)
c. food (Vegetables)
d. $\neg$ eats (y, z) $\vee$ killed (y) food (z)
e. eats (Anil, peanuts)
f. alive (Anil)
g. $\neg$ eats (Anil, w) $\vee$ eats (Harry, w)
h. killed (g) $\vee$ alive (g)
i. $\neg$ alive (k) $\vee \neg$ killed (k)
j. likes (John, peanuts)


¬ likes (John, peanuts)
¬ food (x) ∨ likes (John, x)
{peanuts / x}
¬ food (peanuts)
¬ eats (y, z) ∨ killed (y) ∨ food (z)
{peanuts / z}
¬ eats (y, peanuts) ∨ killed (y)
eats (Anil, peanuts)
{Anil / y}
killed (Anil)
¬ alive (K) ∨ ¬ (killed (K))
{Anil / K}
¬ alive (Anil)
alive (Anil)
{ }
Hence proved

Code

```
def disjunctify(clauses):
    disjuncts = []
    for clause in clauses:
        disjuncts.append(tuple(clause.split('v')))
return disjuncts

def getResolvant(ci, cj, di, dj):
    resolvant = list(ci) + list(cj)
    resolvant.remove(di)
    resolvant.remove(dj)
    return tuple(resolvant)

def resolve(ci, cj):
    for di in ci:
        for dj in cj:
            if di == '~' + dj or dj == '~' + di:
                return getResolvant(ci, cj, di, dj)

def checkResolution(clauses, query):
    clauses += [query if query.startswith('~') else '~' + query]
    proposition = '^'.join(['(' + clause + ')' for clause in clauses])
    print(f'Trying to prove {proposition} by contradiction.  ')

    clauses = disjunctify(clauses)
    resolved = False
    new = set()

    while not resolved:
        n = len(clauses)



pairs = [(clauses[i], clauses[j]) for i in range(n) for j in range(i + 1, n)]
for (ci, cj) in pairs:
resolvant = resolve(ci, cj)
if not resolvant:
resolved = True
break
new = new.union(set(resolvents))
if new.issubset(set(clauses)):
break
for clause in new:
```

```
if clause not in clauses:
clauses.append(clause)

if resolved:
print('Knowledge Base entails the query, proved by resolution')
else:
print("Knowledge Base doesn't entail the query, no empty set produced after resolution") clauses
= input('Enter the clauses ').split()
query = input('Enter the query: ')
checkResolution(clauses, query)
```

Output Snapshot

```
Enter the clauses (~qv~pvr)^(~q^p)^q
Enter the query: r
Trying to prove ((~qv~pvr)^(~q^p)^q)^(~r) by contradiction....
Knowledge Base entails the query, proved by resolution
```

Program-11

Alpha Beta PruningAlgorithm

Alpha-Beta Algorithm

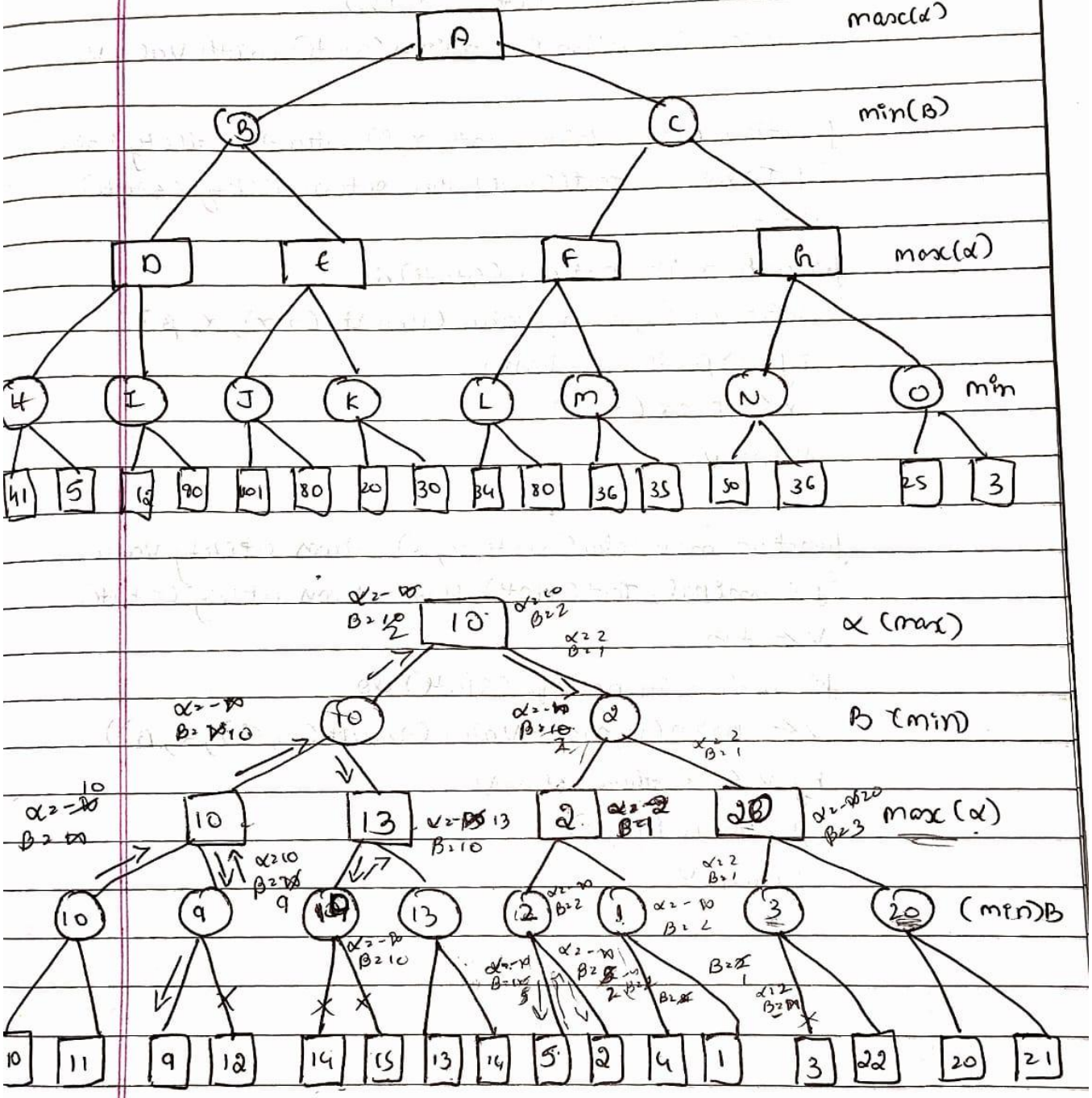
function Alpha-Beta-Search (state) return an action
$v \leftarrow$ max-value (state, $-\infty$, $+\infty$)
return the action in Actions (state) with value v

function max-value (state, α, β) returns a utility value
if Terminal-Test (state) then return utility (state)
$v \leftarrow -\infty$
for each a in Actions (state) do
$v \leftarrow$ max (v, min-value (Result (s, a), α, β))
if $v \geq \beta$ then return v
$\alpha \leftarrow$ max (α, v)
return v

function min-value (state, α, β) returns utility value
if terminal-Test (state) then returns utility (state)
$v \leftarrow +\infty$
for each a in Actions (state) do
$v \leftarrow$ min (v, max-value (Result (s, α), α, β))
if $v \leq \alpha$ then return v
$\beta \leftarrow$ min (β, v)
return v.

lab-06

Alpha-Beta pruning



α ≥ β

Prune

Code

```
import math
# Alpha-Beta Pruning Functions
def alpha_beta_search(state):
    """ Alpha-Beta Search to get the optimal action """
    value = max_value(state, -math.inf, math.inf)
    print("Optimal Value:", value)
    return value

def max_value(state, alpha, beta):
    """ Function to calculate the MAX value node """
    if terminal_test(state):  # If leaf node, return utility value
        return utility(state)
    v = -math.inf
    for child in state["children"]:  # Iterate through child nodes
        v = max(v, min_value(child, alpha, beta))
        if v >= beta:
            return v  # Beta cutoff
        alpha = max(alpha, v)
    return v

def min_value(state, alpha, beta):
    """ Function to calculate the MIN value node """
    if terminal_test(state):  # If leaf node, return utility value
        return utility(state)
    v = math.inf
    for child in state["children"]:  # Iterate through child nodes
        v = min(v, max_value(child, alpha, beta))
        if v <= alpha:
            return v  # Alpha cutoff
        beta = min(beta, v)
    return v

# Utility Functions
def terminal_test(state):
    """ Check if the node is a leaf node """
    return "value" in state  # Leaf node if it contains 'value'

def utility(state):
    """ Return the utility value of a leaf node """
    return state["value"]

# Build the Binary Tree Based on Leaf Nodes
def build_tree(values):
    """ Recursively build a binary tree from a list of leaf node values """
    if len(values) == 1:  # Single value -> Leaf node
        return {"value": values[0]}
    mid = len(values) // 2
    left_subtree = build_tree(values[:mid])
```

```
    right_subtree = build_tree(values[mid:])
    return {"children": [left_subtree, right_subtree]}

# Main Program
if __name__ == "__main__":
    leaf_nodes = [10, 9, 14, 18, 5, 4, 50, 3]
    tree = build_tree(leaf_nodes)  # Build the binary tree
    print("Alpha-Beta Pruning Search:")
    alpha_beta_search(tree)
```

Output

```
Alpha-Beta Pruning Search:
Optimal Value: 10
```