# VISVESVARAYA TECHNOLOGICAL UNIVERSITY

**"JnanaSangama", Belgaum -590014, Karnataka.**

**LAB REPORT**
**on**

# Artificial Intelligence

***Submitted by***

**VAIBHAV KIRAN P (1BM21CS233)**

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

**B.M.S. COLLEGE OF ENGINEERING**
**(Autonomous Institution under VTU)**
**BENGALURU-560019**
**Nov-2023 to Feb-2024**

# 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**" carried out by **VAIBHAV KIRAN P (1BM21CS233),** 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 during the academic semester June-2023 to Sep-2023. The Lab report has been approved as it satisfies the academic requirements in respect of a **Artificial Intelligence (22CS5PCAIN)** work prescribed for the said degree.


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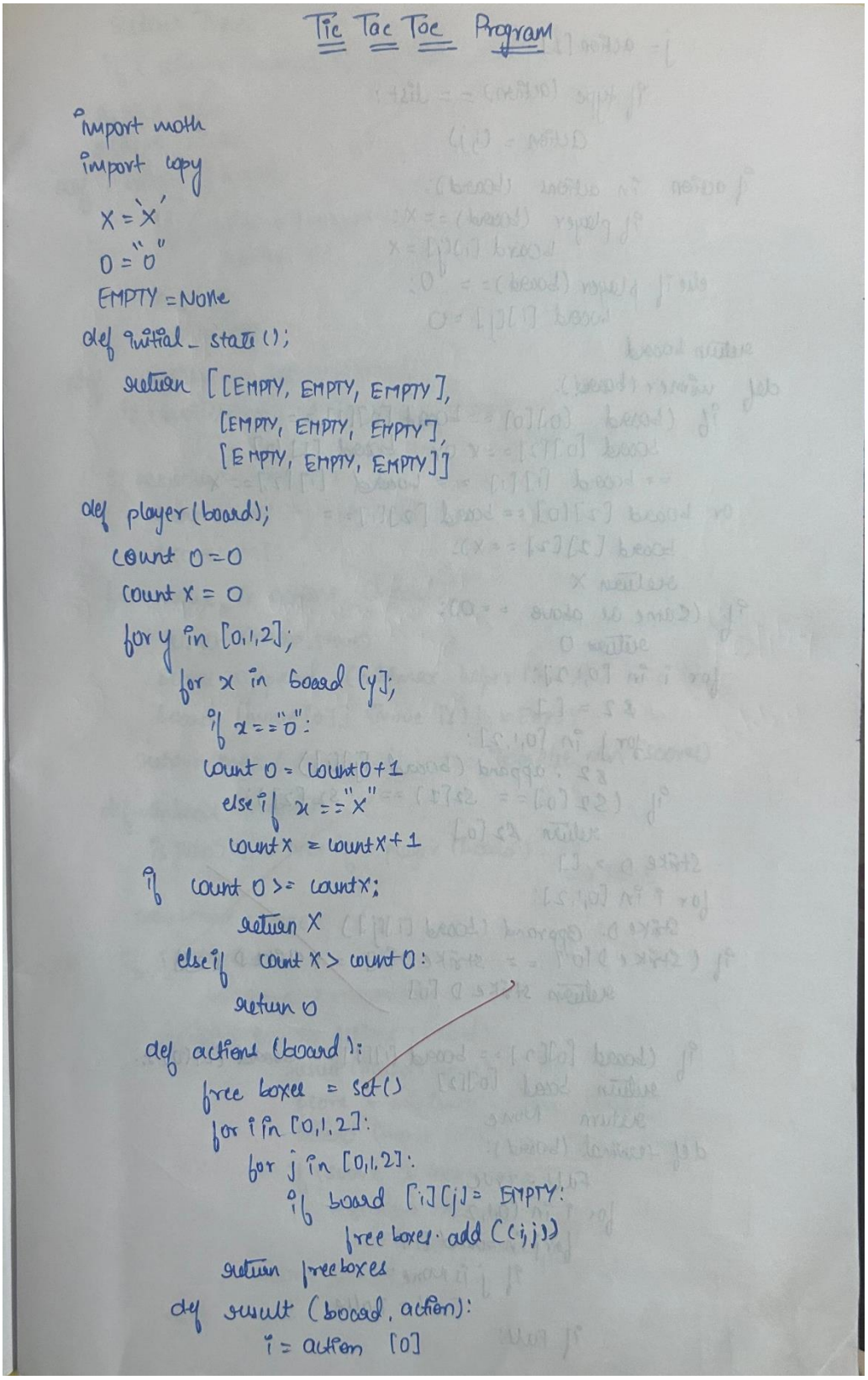
# Index Sheet

## Course Outcome

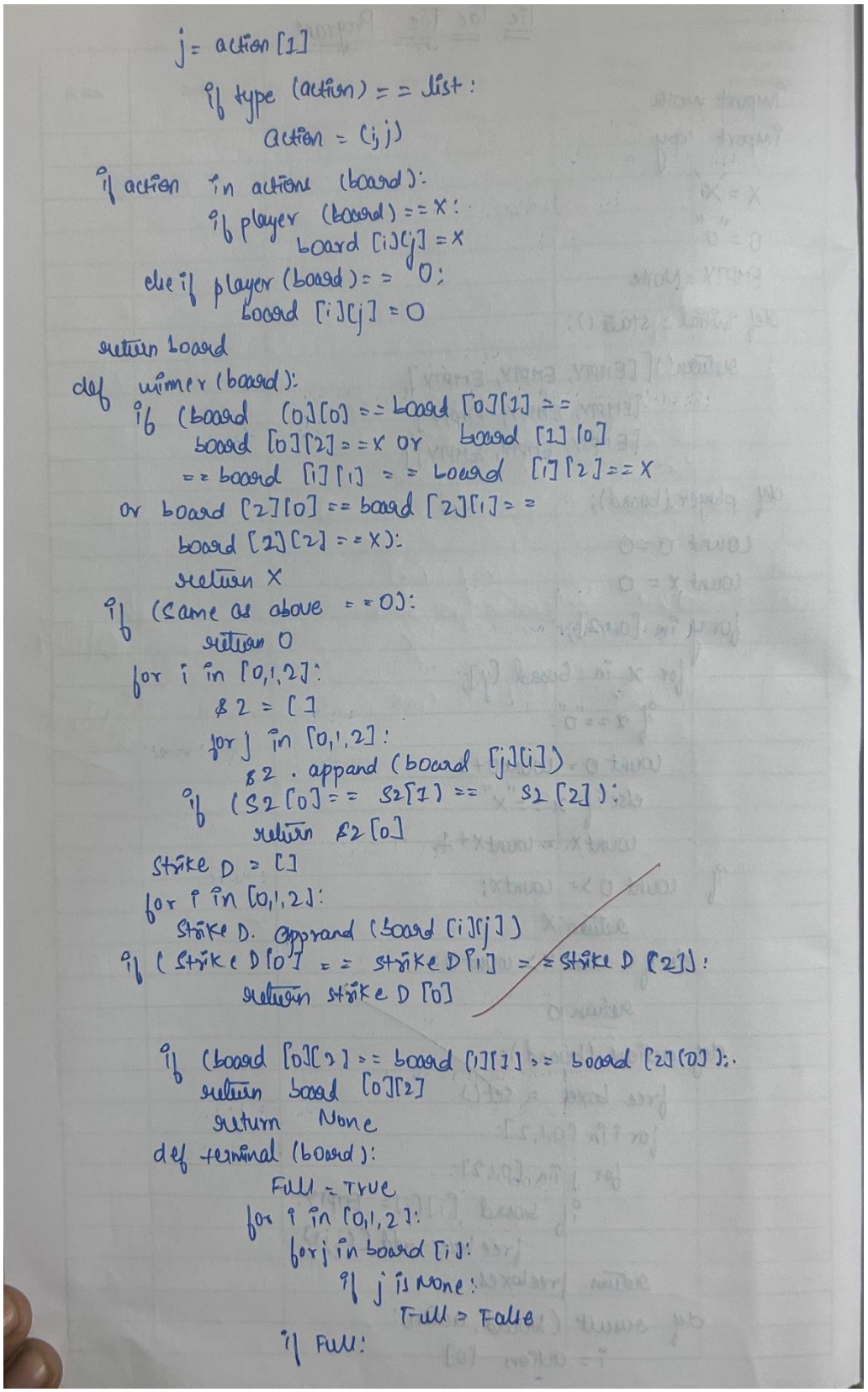
| | |
|---|---|
| CO1 | Apply knowledge of agent architecture, searching and reasoning techniques for different applications. |
| CO2 | Analyse Searching and Inferencing Techniques. |
| CO3 | Design a reasoning system for a given requirement. |
| CO4 | Conduct practical experiments for demonstrating agents, searching and inferencing. |

1. **Implement Tic –Tac –Toe Game.**



Tic Tac Toe Program

```
import math
import copy
X = "X"
O = "O"
EMPTY = None
def initial_state():
    return [[EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY]]
def player(board):
    countO = 0
    countX = 0
    for y in [0,1,2]:
        for x in board[y]:
            if x == "O":
                countO = countO + 1
            elif x == "X":
                countX = countX + 1
    if countO >= countX:
        return X
    elif countX > countO:
        return O
def actions(board):
    free boxes = set()
    for i in [0,1,2]:
        for j in [0,1,2]:
            if board[i][j] = EMPTY:
                freeboxes.add((i,j))
    return freeboxes
def result(board, action):
    i = action[0]
```

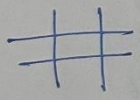


```
    j = action[1]
    if type(action) == list:
        action = (i, j)
if action in actions(board):
    if player(board) == X:
        board[i][j] = X
    else if player(board) == O:
        board[i][j] = O
return board
def winner(board):
    if (board[0][0] == board[0][1] ==
        board[0][2] == X or board[1][0]
        == board[1][1] == board[1][2] == X
    or board[2][0] == board[2][1] ==
        board[2][2] == X):
        return X
    if (same as above == O):
        return O
    for i in [0,1,2]:
        s2 = []
        for j in [0,1,2]:
            s2.append(board[j][i])
        if (s2[0] == s2[1] == s2[2]):
            return s2[0]
    strikeD = []
    for i in [0,1,2]:
        strikeD.append(board[i][j])
    if (strikeD[0] == strikeD[1] == strikeD[2]):
        return strikeD[0]

    if (board[0][2] == board[1][1] == board[2][0]):
        return board[0][2]
    return None
def terminal(board):
        Full = True
        for i in [0,1,2]:
            for j in board[i]:
                if j is None:
                    Full = False
        if Full:
```

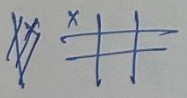
```
    return True
    if (winner(board) in not None):
    return True
    return False
def utility(board):
    if (winner(board) == 0:
        return -1
    else:
        return 0
def minimax-helper(board):
    isMaxTurn = True if player(board) == X
                    else False
    if terminal(board):
        return utility(board)
        scores = []
    for move in actions(board):
        result(board, move)
        scores.append(minimax helper(board))
        board[move[0]][move[1]] = EMPTY
    return max(scores) if isMax Turn else min(scores)
def minimax(board):
    isMaxTurn = True if player(board) == X
                    else False
    bestMove = None
    if isMaxTurn:
        bestScore = -math.inf
        for move in actions(board):
            result(board.move)
            score = minimax.helper(board)
            board[move[0]][move[1]] = EMPTY
            if (score > bestScore):
                bestScore = score
                bestMove = move
        return bestMove
    else:
```

```
while not terminal (game_board):
    if player (game_board) == X:
        user_input = input ("\n Enter your move (row. column):")
        row. col = map (int, user_input . split (:))
        result (game_board, (row.col))
    else:
        print ("\n AI is making a move...")
        move = minimax (copy. deepcopy (game_board);
        result (game_board, move)
    print ("\n Current Board :")
    print_board (game_board)
if winner (game board) is not None:
    print ("\n The winner is: { winner (game board) }");
    else:
        print ("\n It's a tie!")
```

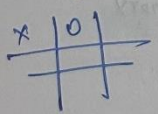
output :-



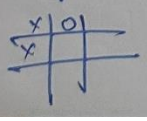
Enter your move (1-9): 1



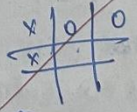
Enter your move (1-9): 2



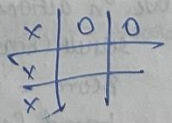
Enter your move (1-9): 4



Enter your move (1-9): 3



Enter your move (1-9): 7



player X wins!

**Implement Tic –Tac –Toe Game.**

```
import math
import copy

X = "X"
O = "O"
EMPTY = None

def initial_state():
    return [[EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY]]

def player(board):
    countO = 0
    countX = 0
    for y in [0, 1, 2]:
        for x in board[y]:
            if x == "O":
                countO = countO + 1
            elif x == "X":
                countX = countX + 1
    if countO >= countX:
        return X
    elif countX > countO:
        return O
```

```
def  actions(board):
    freeboxes = set()
    for i in [0, 1, 2]:
        for j in [0, 1, 2]:
            if board[i][j] == EMPTY:
                freeboxes.add((i, j))
    return freeboxes



def result(board, action):
    i = action[0]
    j = action[1]
    if type(action) == list:
        action = (i, j)
    if action in actions(board):
        if player(board) == X:
            board[i][j] = X
        elif player(board) == O:
            board[i][j] = O
    return board



def winner(board):
    if (board[0][0] == board[0][1] == board[0][2] == X or board[1][0] == board[1][1] ==
board[1][2] == X or board[2][0] == board[2][1] == board[2][2] == X):
        return X
    if (board[0][0] == board[0][1] == board[0][2] == O or board[1][0] == board[1][1] ==
board[1][2] == O or board[2][0] == board[2][1] == board[2][2] == O):
        return O
    for i in [0, 1, 2]:
        s2 = []
```

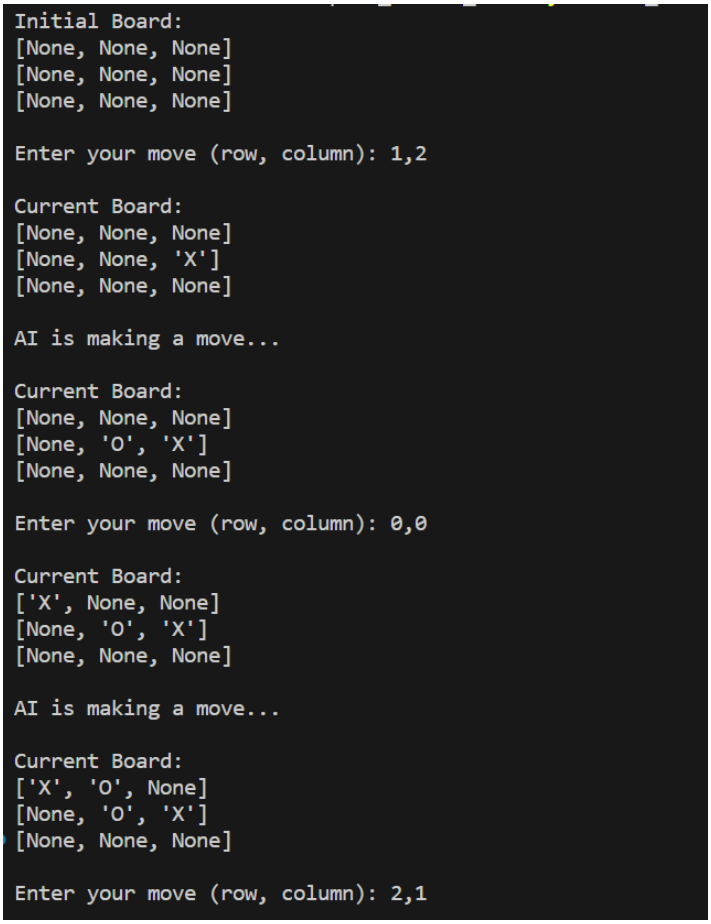
```
        for j in [0, 1, 2]:
            s2.append(board[j][i])
        if (s2[0] == s2[1] == s2[2]):
            return s2[0]
    strikeD = []
    for i in [0, 1, 2]:
        strikeD.append(board[i][i])
    if (strikeD[0] == strikeD[1] == strikeD[2]):
        return strikeD[0]
    if (board[0][2] == board[1][1] == board[2][0]):
        return board[0][2]
    return None


def terminal(board):
    Full = True
    for i in [0, 1, 2]:
        for j in board[i]:
            if j is None:
                Full = False
    if Full:
        return True
    if (winner(board) is not None):
        return True
    return False


def utility(board):
    if (winner(board) == X):
        return 1
```

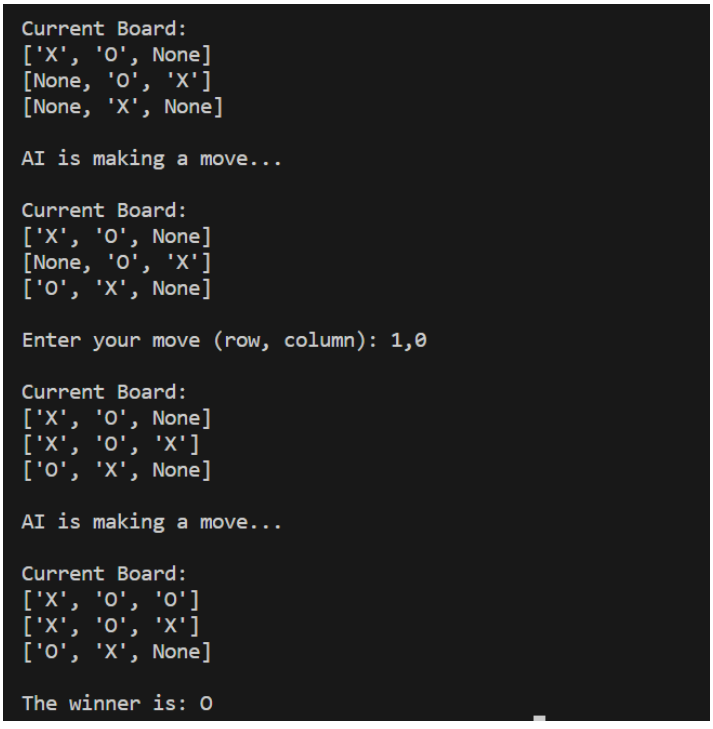
```
    elif winner(board) == O:
        return -1
    else:
        return 0


def minimax_helper(board):
    isMaxTurn = True if player(board) == X else False
    if terminal(board):
        return utility(board)

    scores = []
    for move in actions(board):
        result(board, move)
        scores.append(minimax_helper(board))
        board[move[0]][move[1]] = EMPTY
    return max(scores) if isMaxTurn else min(scores)


def minimax(board):
    isMaxTurn = True if player(board) == X else False
    bestMove = None
    if  isMaxTurn:
        bestScore = -math.inf
        for move in actions(board):
            result(board, move)
            score = minimax_helper(board)
            board[move[0]][move[1]] = EMPTY
            if (score > bestScore):
                bestScore = score
```

```
                bestMove = move
        return bestMove
    else:
        bestScore = +math.inf
        for move in actions(board):
            result(board, move)
            score = minimax_helper(board)
            board[move[0]][move[1]] = EMPTY
            if (score < bestScore):
                bestScore = score
                bestMove = move
        return bestMove


def print_board(board):
    for row in board:
        print(row)


# Example usage:
game_board = initial_state()
print("Initial Board:")
print_board(game_board)

while not terminal(game_board):
    if player(game_board) == X:
        user_input = input("\nEnter your move (row, column): ")
        row, col = map(int, user_input.split(','))
        result(game_board, (row, col))
    else:
```

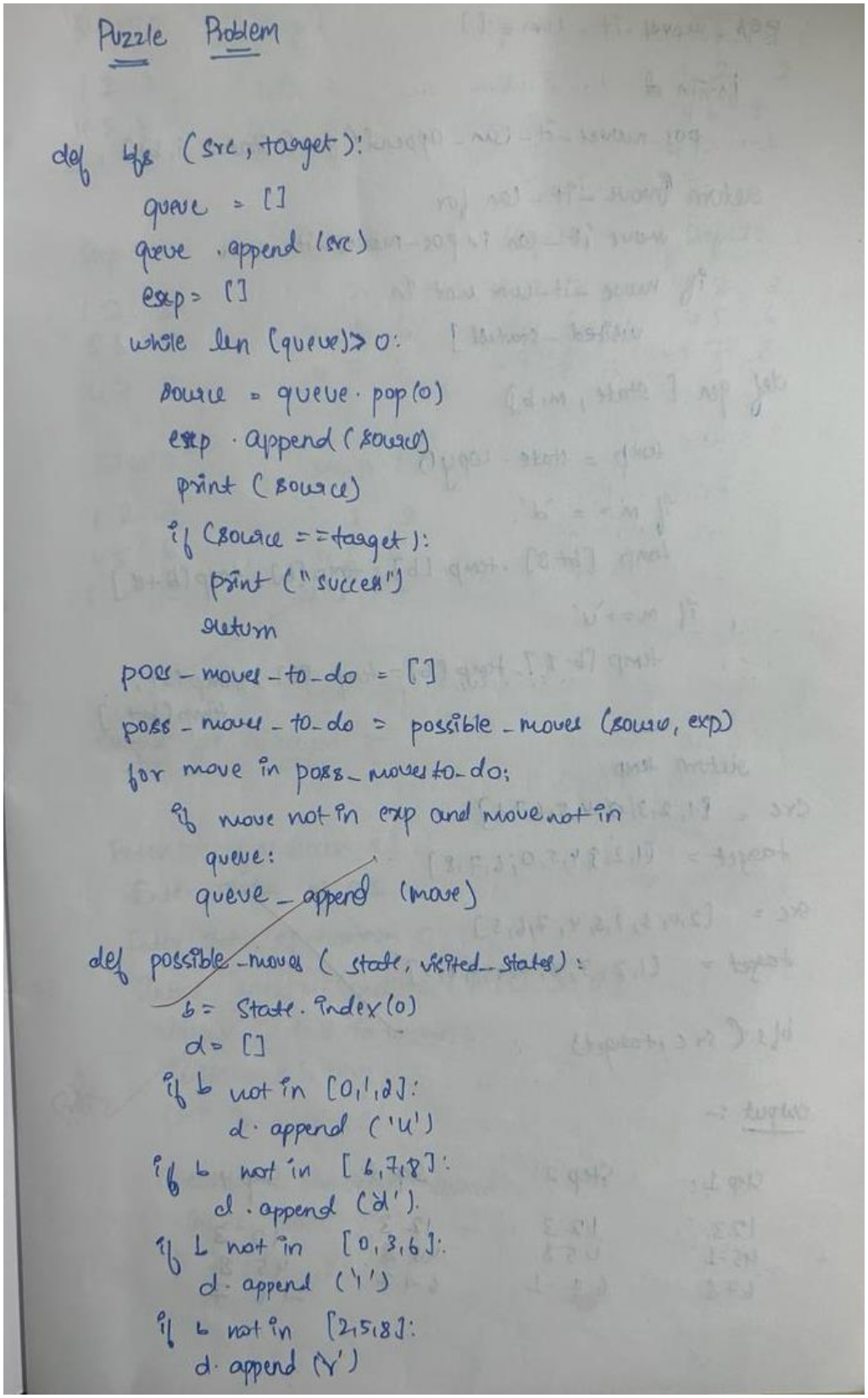
```
        print("\nAI is making a move...")
        move = minimax(copy.deepcopy(game_board))
        result(game_board, move)

    print("\nCurrent Board:")
    print_board(game_board)

# Determine the winner
if winner(game_board) is not None:
    print(f"\nThe winner is: {winner(game_board)}")
else:
    print("\nIt's a tie!")
```

**OUTPUT:**



**2. Solve 8 puzzle problems.**

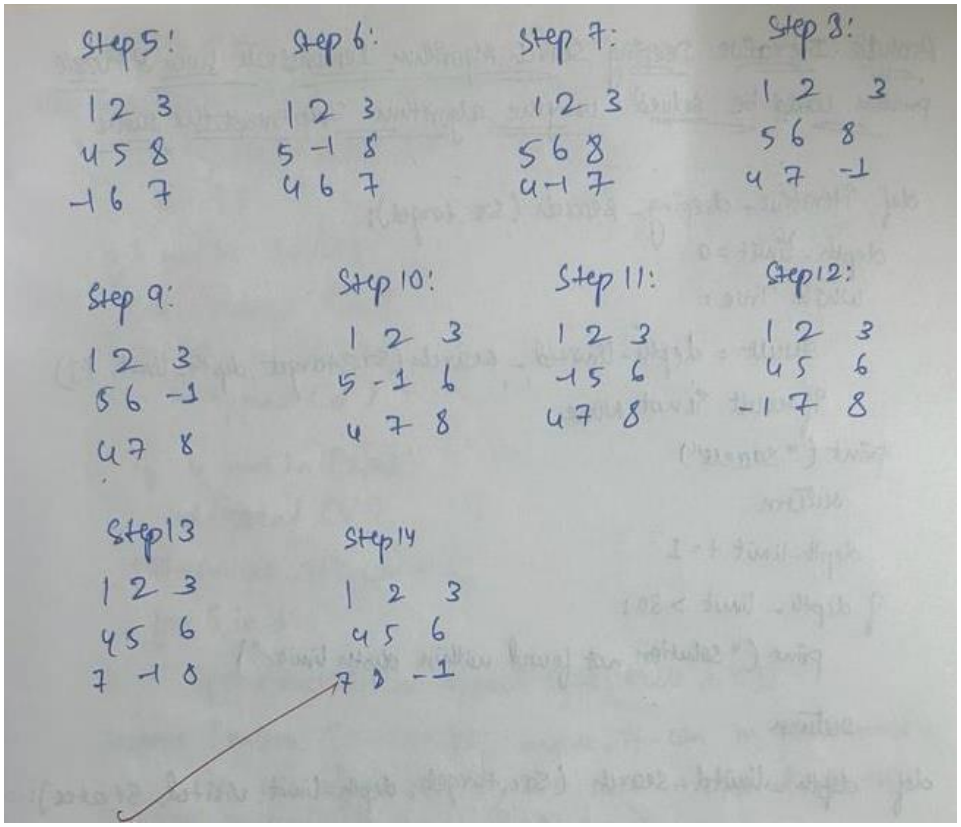


```
Puzzle Problem

def bfs (src, target):
    queue = []
    queue.append (src)
    exp = []
    while len (queue) > 0:
        source = queue.pop(0)
        exp.append (source)
        print (source)
        if (source == target):
            print ("success")
            return
    poss_moves_to_do = []
    poss_moves_to_do = possible_moves (source, exp)
    for move in poss_moves_to_do:
        if move not in exp and move not in
            queue:
            queue_append (move)

def possible_moves ( state, visited_states):
    b = state.index(0)
    d = []
    if b not in [0,1,2]:
        d.append ('u')
    if b not in [6,7,8]:
        d.append ('d')
    if b not in [0,3,6]:
        d.append ('l')
    if b not in [2,5,8]:
        d.append ('r')
```

```
pos_moves_it = cur = []
    for i in d
        pos_moves_it.can.append(gen(state,i,b))
    return (move_it.can for
        move it_can in pos_moves_it_cur
    if move_it_cur not in
        visited_state[]

def gen [state, m, b]
        temp = state.copy()
        if m == 'd'.
        temp [b+3].temp [b] = temp [b], temp [b+3]
    if m == 'u'
        temp [b-1], temp [b] = temp [b], temp [b],
                                temp (b+1]
    return temp
src = [1,2,3,0,4,5,6,7,8]
target = [1,2,3,4,5,0,6,7,8]
src = [2,0,3,1,8,4,7,6,5]
target = [1,2,3,8,0,4,7,6,5]
bfs(src,target)
```

output :-

| Step 1: | Step 2: | Step 3: | Step 4: |
|---|---|---|---|
| 123 | 123 | 123 | 123 |
| 45-1 | 458 | 458 | 458 |
| 678 | 67-1 | 6-17 | -167 |


Step 5:
1 2 3
4 5 8
-1 6 7
Step 6:
1 2 3
5 -1 8
4 6 7
Step 7:
1 2 3
5 6 8
4 -1 7
Step 8:
1 2 3
5 6 8
4 7 -1
Step 9:
1 2 3
5 6 -1
4 7 8
Step 10:
1 2 3
5 -1 6
4 7 8
Step 11:
1 2 3
-1 5 6
4 7 8
Step 12:
1 2 3
4 5 6
-1 7 8
Step 13
1 2 3
4 5 6
7 -1 8
Step 14
1 2 3
4 5 6
7 8 -1

**Solve 8 puzzle problems.**

```
def bfs(src,target):
    queue = []
    queue.append(src)

    exp = []

    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)

        print(source)

        if source==target:
            print("Success")
            return

        poss_moves_to_do = []
        poss_moves_to_do = possible_moves(source,exp)

        for move in poss_moves_to_do:

            if move not in exp and move not in queue:
                queue.append(move)
def possible_moves(state,visited_states):
    #index of empty spot
    b = state.index(0)
```

```
    #directions array
    d = []
    #Add all the possible directions

    if b not in [0,1,2]:
        d.append('u')
    if b not in [6,7,8]:
        d.append('d')
    if b not in [0,3,6]:
        d.append('l')
    if b not in [2,5,8]:
        d.append('r')



    # If direction is possible then add state to move
    pos_moves_it_can = []

    # for all possible directions find the state if that move is played
    ### Jump to gen function to generate all possible moves in the given directions

    for i in d:
        pos_moves_it_can.append(gen(state,i,b))

    return [move_it_can for move_it_can in pos_moves_it_can if move_it_can not in
visited_states]
def gen(state, m, b):
    temp = state.copy()

    if m=='d':
        temp[b+3],temp[b] = temp[b],temp[b+3]
```

```
    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]



    # return new state with tested move to later check if "src == target"
    return temp

print("Example 1")
src= [2,0,3,1,8,4,7,6,5]
target=[1,2,3,8,0,4,7,6,5]
print("Source: " , src)
print("Goal State: " , target)
bfs(src, target)

print("\nExample 2")
src = [1,2,3,0,4,5,6,7,8]
target = [1,2,3,4,5,0,6,7,8]
print("Source: " , src)
print("Goal State: " , target)
bfs(src, target)
```

**OUTPUT:**

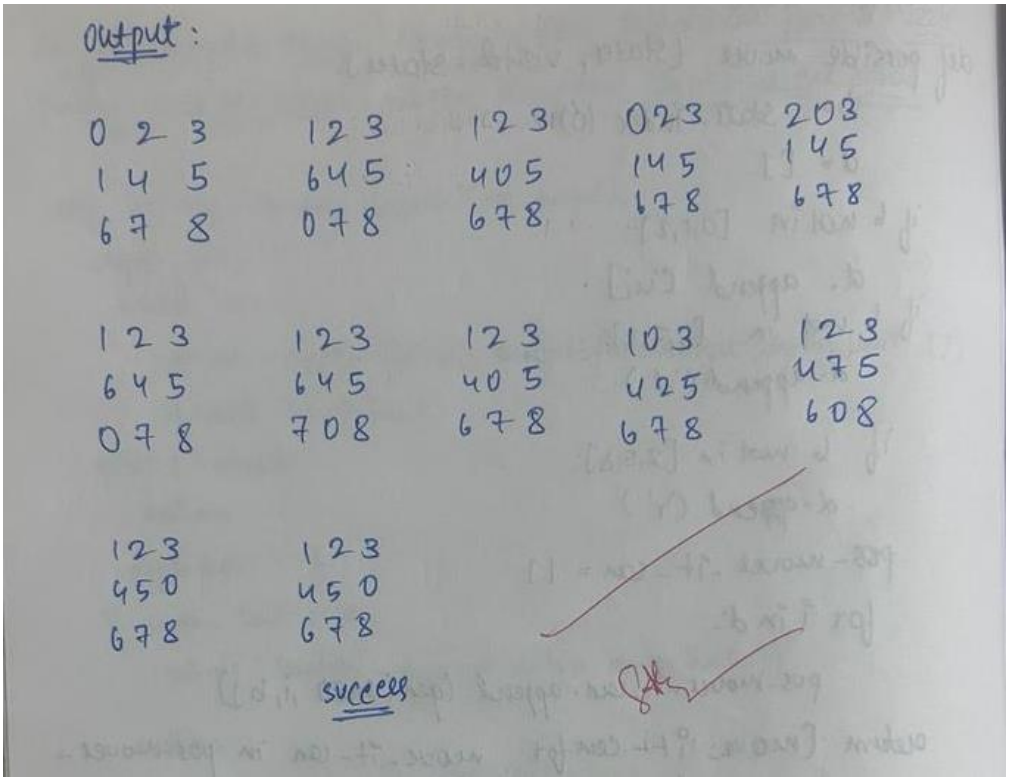
```
Example 1
Source:  [2, 0, 3, 1, 8, 4, 7, 6, 5]
Goal State:  [1, 2, 3, 8, 0, 4, 7, 6, 5]
[2, 0, 3, 1, 8, 4, 7, 6, 5]
[2, 8, 3, 1, 0, 4, 7, 6, 5]
[0, 2, 3, 1, 8, 4, 7, 6, 5]
[2, 3, 0, 1, 8, 4, 7, 6, 5]
[2, 8, 3, 1, 6, 4, 7, 0, 5]
[2, 8, 3, 0, 1, 4, 7, 6, 5]
[2, 8, 3, 1, 4, 0, 7, 6, 5]
[1, 2, 3, 0, 8, 4, 7, 6, 5]
[2, 3, 4, 1, 8, 0, 7, 6, 5]
[2, 8, 3, 1, 6, 4, 0, 7, 5]
[2, 8, 3, 1, 6, 4, 7, 5, 0]
[0, 8, 3, 2, 1, 4, 7, 6, 5]
[2, 8, 3, 7, 1, 4, 0, 6, 5]
[2, 8, 0, 1, 4, 3, 7, 6, 5]
[2, 8, 3, 1, 4, 5, 7, 6, 0]
[1, 2, 3, 7, 8, 4, 0, 6, 5]
[1, 2, 3, 8, 0, 4, 7, 6, 5]
Success

Example 2
Source:  [1, 2, 3, 0, 4, 5, 6, 7, 8]
Goal State:  [1, 2, 3, 4, 5, 0, 6, 7, 8]
[1, 2, 3, 0, 4, 5, 6, 7, 8]
[0, 2, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, 0, 7, 8]
[1, 2, 3, 4, 0, 5, 6, 7, 8]
[2, 0, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, 7, 0, 8]
[1, 0, 3, 4, 2, 5, 6, 7, 8]
[1, 2, 3, 4, 7, 5, 6, 0, 8]
[1, 2, 3, 4, 5, 0, 6, 7, 8]
Success
```

**3. Implement Iterative deepening search algorithm.**

Analyse Iterative Deeping Search Algorithm Demonstrate how 8 Puzzle problem could be solved using the algorithm Implement the same

```
def iterative_deeping_search(src,target):
    depth_limit=0
    while True:
        result = depth_limited_search(src,target,depth_limit,[])
        if result is not None
    print("success")
        return
    depth_limit+=1
    if depth_limit>30:
        print("solution not found within depth limit.")
        return
def depth_limited_search(src,target,depth_limit,visited_States):
    if src==target:
        print_state(src)
    return src
    if depth_limit==0:
        return None
    visited_state.append(src)
    poss_moves_to_do = possible_moves(src, visited_states)
    for moves in poss_moves_todo:
        if move not in visited states:
            print_state(move)
        result = depth_limited_search(move_target, depth_limit-1
        visited_states)
        if result is notNone:
    return result.
```

```
    return None
def possible_moves(state, visited_states):
    b = state.index(0)
    d = []
    if b not in [0,1,2]:
        d.append('u')
    if b not in [6,7,8]:
        d.append('d')
    if b not in [2,5,8]:
        d.append('r')
    pos_moves_it_can = []
    for i in d:
        pos_moves_it_can.append(gen(state,i,b))
    return [move_it_can for move_it_can in pos_moves_
        it_can if move_it_can not in visited_states]
def gen(state,m,b):
    temp = state.copy()
    if m=='d':
        temp[b+3], temp[b] = temp[b], temp[b+3]
    elif m=='u':
        temp[b-3], temp[b] = temp[b], temp[b-3]
    def print_state(state):
print(f"{state[0]} {state[1]}
        {state[2]}\n{state[3]}
        {state[4]} {state[5]}\n{state[6]}
        {state[7]}.\n")
src= [1,2,3,0,4,5,6,7,8]
target = [1,2,3,4,5,0,6,7,8]
```


output:
0 2 3
1 4 5
6 7 8
1 2 3
6 4 5
0 7 8
1 2 3
4 0 5
6 7 8
0 2 3
1 4 5
6 7 8
2 0 3
1 4 5
6 7 8
1 2 3
6 4 5
0 7 8
1 2 3
6 4 5
7 0 8
1 2 3
4 0 5
6 7 8
1 0 3
4 2 5
6 7 8
1 2 3
4 7 5
6 0 8
1 2 3
4 5 0
6 7 8
1 2 3
4 5 0
6 7 8
success

**Implement Iterative deepening search algorithm.**

```
def iterative_deepening_search(src, target):
    depth_limit = 0
    while True:
        result = depth_limited_search(src, target, depth_limit, [])
        if result is not None:
            print("Success")
            return
        depth_limit += 1
        if depth_limit > 30: # Set a reasonable depth limit to avoid an infinite loop
            print("Solution not found within depth limit.")
            return

def depth_limited_search(src, target, depth_limit, visited_states):
    if src == target:
        print_state(src)
        return src

    if depth_limit == 0:
        return None

    visited_states.append(src)
    poss_moves_to_do = possible_moves(src, visited_states)

    for move in poss_moves_to_do:
        if move not in visited_states:
            print_state(move)
            result = depth_limited_search(move, target, depth_limit - 1, visited_states)
```

```
            if result is not None:
                return result

    return None

def possible_moves(state, visited_states):
    b = state.index(0)
    d = []

    if b not in [0, 1, 2]:
        d.append('u')
    if b not in [6, 7, 8]:
        d.append('d')
    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')

    pos_moves_it_can = []

    for i in d:
        pos_moves_it_can.append(gen(state, i, b))

    return [move_it_can for move_it_can in pos_moves_it_can if move_it_can not in
visited_states]

def gen(state, m, b):
    temp = state.copy()

    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
```

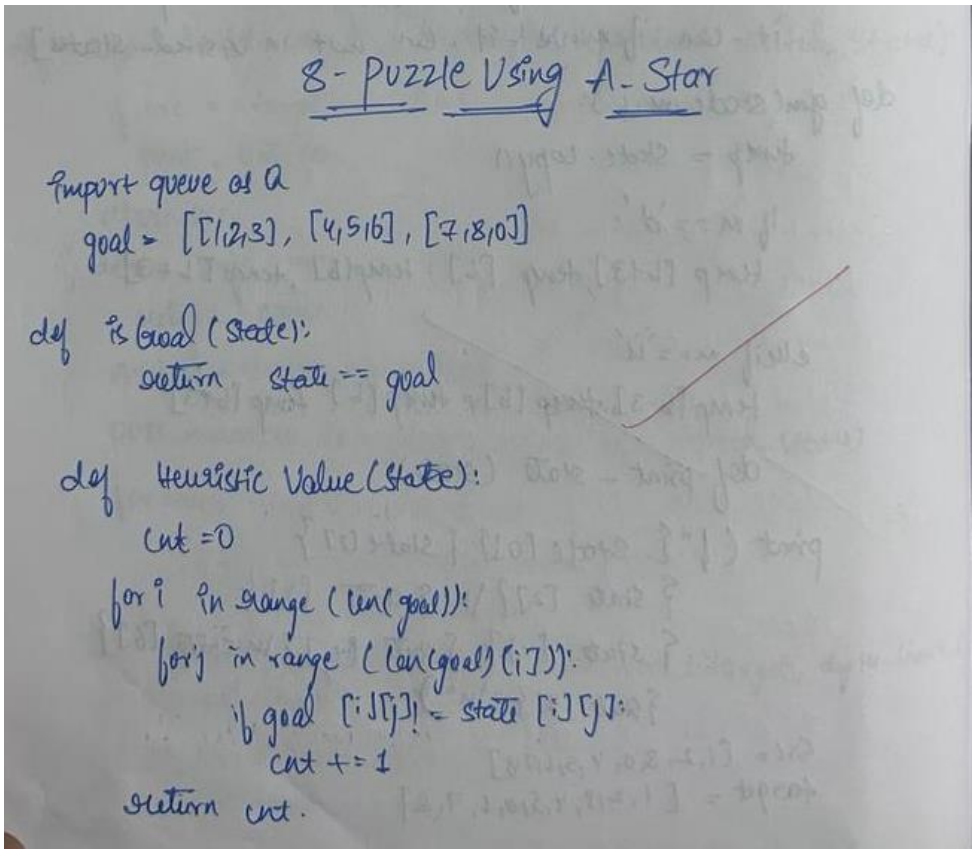
```
    elif m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    elif m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    elif m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]

    return temp

def print_state(state):
    print(f"{state[0]} {state[1]} {state[2]}\n{state[3]} {state[4]} {state[5]}\n{state[6]}
{state[7]} {state[8]}\n")

print("Example 1")
src = [1,2,3,0,4,5,6,7,8]
target = [1,2,3,4,5,0,6,7,8]
print("Source: " , src)
print("Goal State: " , target)
iterative_deepening_search(src, target)
```

**OUTPUT**

```
Example 1
Source:  [1, 2, 3, 0, 4, 5, 6, 7, 8]
Goal State:  [1, 2, 3, 4, 5, 0, 6, 7, 8]
0 2 3
1 4 5
6 7 8

1 2 3
6 4 5
0 7 8

1 2 3
4 0 5
6 7 8

0 2 3
1 4 5
6 7 8

2 0 3
1 4 5
6 7 8

1 2 3
6 4 5
0 7 8

1 2 3
6 4 5
7 0 8

1 2 3
4 0 5
6 7 8
```

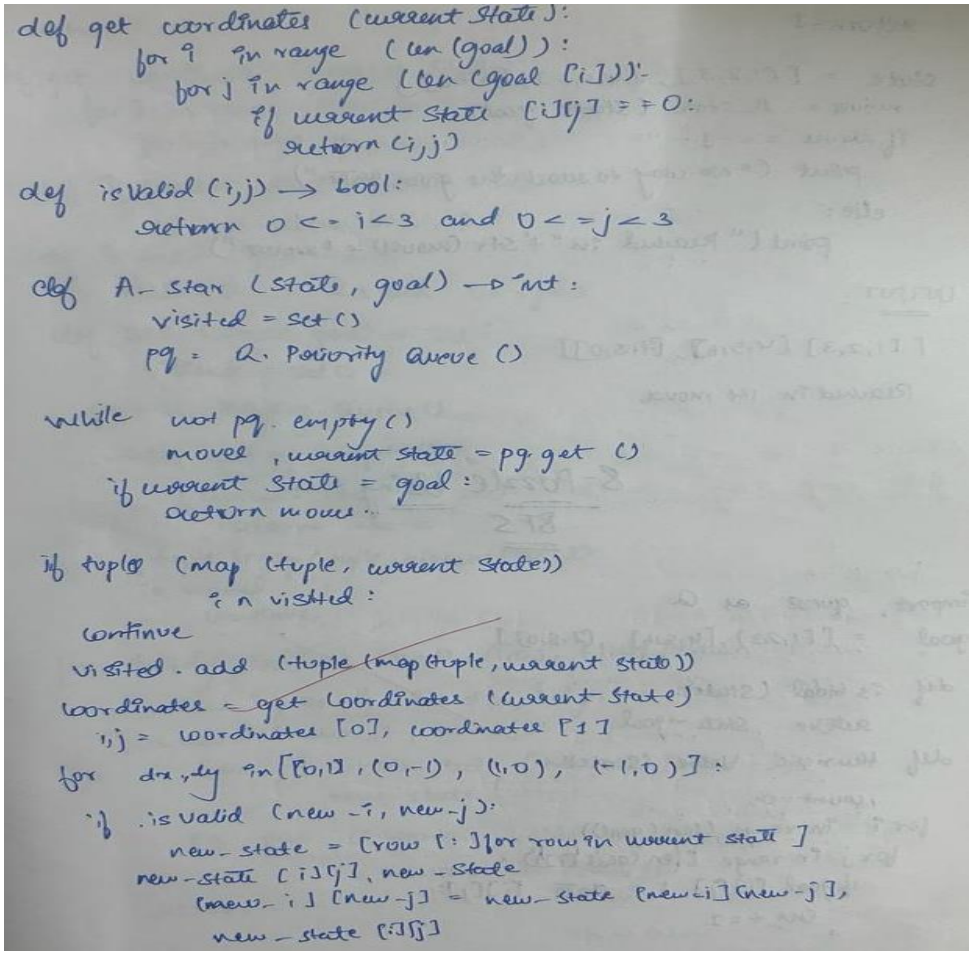
```
1 0 3
4 2 5
6 7 8

1 2 3
4 7 5
6 0 8

1 2 3
4 5 0
6 7 8

1 2 3
4 5 0
6 7 8

Success
```

**4. Implement A* search algorithm.**



8- Puzzle Using A- Star

```
import queue as Q
goal = [[1,2,3], [4,5,6], [7,8,0]]

def isGoal(state):
    return state == goal

def Heuristic Value(state):
    cnt = 0
    for i in range(len(goal)):
        for j in range(len(goal)[i]):
            if goal[i][j] != state[i][j]:
                cnt += 1
    return cnt.
```



```
def get coordinates(current state):
    for i in range(len(goal)):
        for j in range(len(goal[i])):
            if current state[i][j] == 0:
                return (i,j)

def isValid(i,j) -> bool:
    return 0 <= i < 3 and 0 <= j < 3

def A_star(state, goal) -> int:
    visited = set()
    pq = Q.PriorityQueue()

while not pq.empty():
    moves, current state = pq.get()
    if current state = goal:
        return moves.

if tuple(map(tuple, current state))
        in visited:
    continue
visited.add(tuple(map(tuple, current state)))
coordinates = get coordinates(current state)
i,j = coordinates[0], coordinates[1]
for dx,dy in [(0,1), (0,-1), (1,0), (-1,0)]:
    if isValid(new_i, new_j):
        new_state = [row[:] for row in current state]
new_state[i][j], new_state
    [new_i][new_j] = new_state[new_i][new_j],
    new_state[i][j]
```

```
return -1

state = [[1,2,3], [4,0,5], [6,7,8]]
moves = A_star (state, goal)
if moves == -1:
    print ("No way to reach the given state")
else:
    print ("Reached in" + str (moves) + "moves")
```

OUTPUT:

[[1,2,3] [4,5,6], [7,8,0]]

Reached in 14 moves.

**Implement A* search algorithm.**

```
def print_grid(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):
    #Manhattan distance
    dist = 0
    for i in state:
        d1, d2 = state.index(i), target.index(i)
        x1, y1 = d1 % 3, d1 // 3
        x2, y2 = d2 % 3, d2 // 3
        dist += abs(x1-x2) + abs(y1-y2)
    return dist

def astar(src, target):
    states = [src]
    g = 0
    visited_states = set()
    while len(states):
        moves = []
        for state in states:
```

```
            visited_states.add(tuple(state))
            print_grid(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_states):
    b = state.index(-1)
    d = []
    if 9 > b - 3 >= 0:
        d += 'u'
    if 9 > b + 3 >= 0:
        d += 'd'
    if b not in [2,5,8]:
        d += 'r'
    if b not in [0,3,6]:
        d += 'l'
    pos_moves = []
    for move in d:
        pos_moves.append(gen(state,move,b))
    return [move for move in pos_moves if tuple(move) not in visited_states]


def gen(state, direction, b):
    temp = state.copy()
    if direction == 'u':
```

```
        temp[b-3], temp[b] = temp[b], temp[b-3]
    if direction == 'd':
        temp[b+3], temp[b] = temp[b], temp[b+3]
    if direction == 'r':
        temp[b+1], temp[b] = temp[b], temp[b+1]
    if direction == 'l':
        temp[b-1], temp[b] = temp[b], temp[b-1]
    return temp

#Test 1
print("Example 1")
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]
print("Source: " , src)
print("Goal State: " , target)
astar(src, target)


# Test 2
print("Example 2")
src = [1,2,3,-1,4,5,6,7,8]
target=[1,2,3,6,4,5,-1,7,8]
print("Source: " , src)
print("Goal State: " , target)
astar(src, target)


# Test 3
print("Example 3")
src = [1,2,3,7,4,5,6,-1,8]
```

```
target=[1,2,3,6,4,5,-1,7,8]
print("Source: " , src)
print("Goal State: " , target)
astar(src, target)
```

**OUTPUT:**

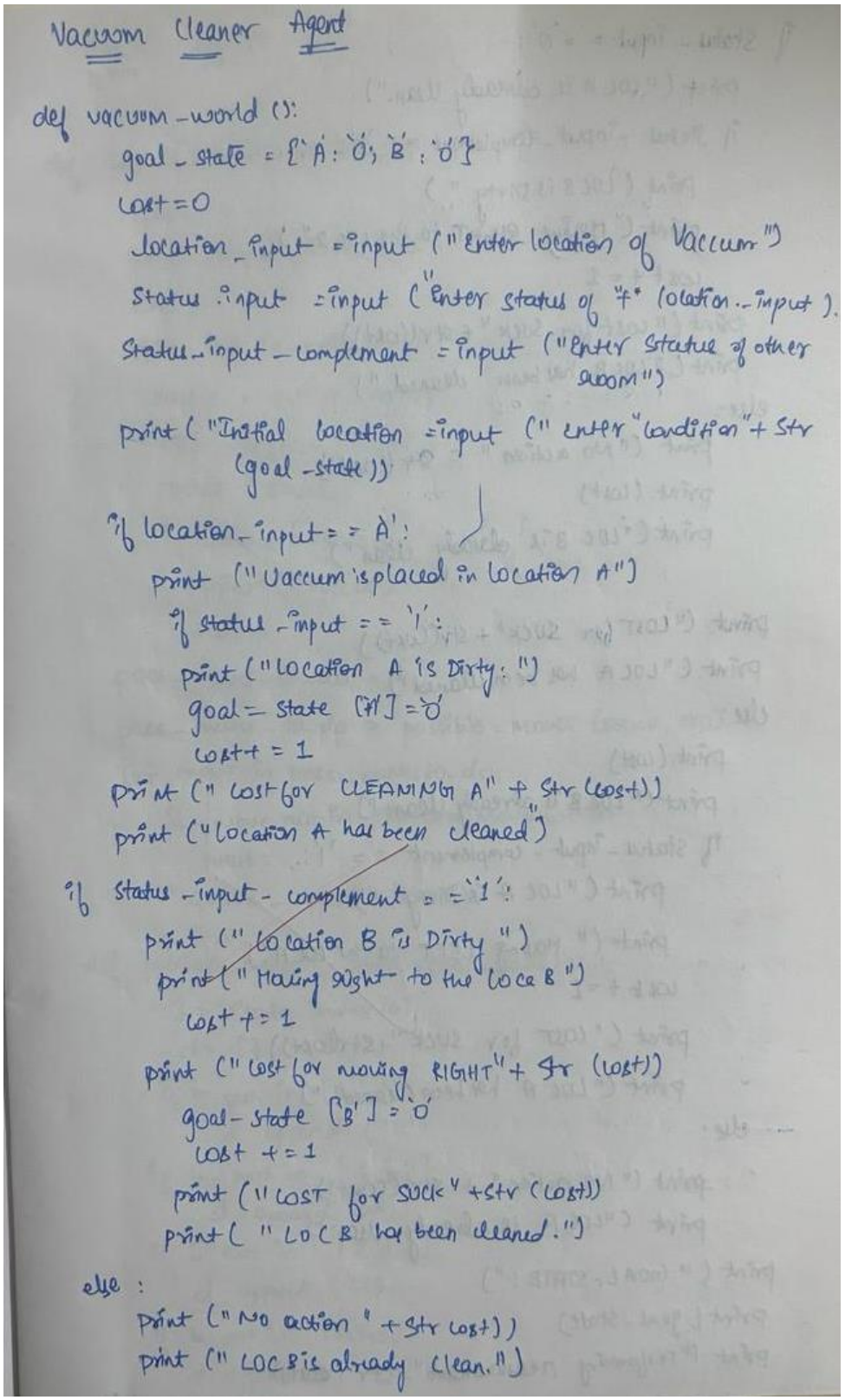
```
Example 1
Source:  [1, 2, 3, -1, 4, 5, 6, 7, 8]
Goal State:  [1, 2, 3, 4, 5, -1, 6, 7, 8]

1 2 3
  4 5
6 7 8


1 2 3
4   5
6 7 8


1 2 3
4 5
6 7 8

Success
Example 2
Source:  [1, 2, 3, -1, 4, 5, 6, 7, 8]
Goal State:  [1, 2, 3, 6, 4, 5, -1, 7, 8]

1 2 3
  4 5
6 7 8


1 2 3
6 4 5
  7 8

Success
```

```
Example 3
Source:  [1, 2, 3, 7, 4, 5, 6, -1, 8]
Goal State:  [1, 2, 3, 6, 4, 5, -1, 7, 8]

1 2 3
7 4 5
6   8


1 2 3
7 4 5
  6 8


1 2 3
  4 5
7 6 8


  2 3
1 4 5
7 6 8


1 2 3
4   5
7 6 8


1 2 3
4 6 5
7   8
```

```
1 2 3
  6 5
4 7 8


1 2 3
6   5
4 7 8


1 2 3
6 7 5
4   8


1 2 3
6 7 5
  4 8


1 2 3
  7 5
6 4 8


  2 3
1 7 5
6 4 8


1 2 3
7   5
6 4 8
```

```
7 1 3
4 6 5
  2 8


7 1 3
4 6 5
2   8


7 1 3
4   5
2 6 8


7 1 3
4 6 5
2 8


7 1 3
  4 5
2 6 8


7 1 3
2 4 5
  6 8

Fail
```

**5. Implement vacuum cleaner agent.**



Vacuum Cleaner Agent

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter location of Vaccum")
    status_input = input("Enter status of " + location_input)
    status_input_complement = input("Enter status of other
                                     room")
    print("Initial location condition" + str
          (goal_state))
    if location_input == 'A':
        print("Vaccum is placed in location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1
        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 Loc B")
        cost += 1
        print("cost for moving RIGHT" + str(cost))
        goal_state['B'] = '0'
        cost += 1
        print("COST for SUCK" + str(cost))
        print("LOC B has been cleaned.")
    else:
        print("No action" + str(cost))
        print("LOC B is already clean.")
```

```
if Status_input == '0':
    print ("LOC A is already clean.")
    if Status_input_complement == '1':
        print ("LOC B is Dirty.")
        print ("Moving RIGHT to the LOC B".)
        cost += 1
    print ("cost for SUCK" + str((cost))
    print ("LOC B has been cleaned.")
else:
    print ("No action " F str((cost))
    print (cost)
    print ("LOC B is already clean").

print ("COST for SUCK" + str(cost))
print ("LOC A has been cleaned")
else:
    print (cost)
    print ("LOC B is already clean:")
    if Status_input - complement == '1':
        print ("LOC A is Dirty.")
        print ("Moving LEFT to the LOC A".)
        cost += 1
        print ("COST for SUCK" + str((cost))
        print ("LOC A has been cleaned.")
    else:
        print ("No action" + str ((cost))
        print ("LOC A is already clean:")
print ("GOAL. STATE:")
print (goal-State)
print ("Performing measurement" + str (cost))
                                    vaccum_world ()
```

Output for Vaccum :-

Enter loc of Vaccum a
Enter status of a 1
Enter Status of other room 0
Intial location Condition {'A': '0', 'B': '0'}
Vaccum is placed in location B
LOCATION B is Dirty.
COST for Cleaning 1

Location B has been Cleaned
GOAL STATE:
{'A': '0', 'B': '0'}

**Implement vacuum cleaner agent.**

```
def clean(floor, row, col):
    i, j, m, n = row, col, len(floor), len(floor[0])
    goRight = goDown = True
    cleaned = [not any(f) for f in floor]
    while not all(cleaned):
        while any(floor[i]):
            print_floor(floor, i, j)
            if floor[i][j]:
                floor[i][j] = 0
                print_floor(floor, i, j)
            if not any(floor[i]):
                cleaned[i] = True
                break
            if j == n - 1:
                j -= 1
                goRight = False
            elif j == 0:
                j += 1
                goRight = True
            else:
                j += 1 if goRight else -1
        if all(cleaned):
            break
        if i == m - 1:
            i -= 1
            goDown = False
        elif i == 0:
            i += 1
```

```
            goDown = True
        else:
            i += 1 if goDown else -1
        if cleaned[i]:
            print_floor(floor, i, j)

def print_floor(floor, row, col): # row, col represent the current vacuum cleaner position
    for r in range(len(floor)):
        for c in range(len(floor[r])):
            if r == row and c == col:
                print(f" >{floor[r][c]}< ", end = '')
            else:
                print(f" {floor[r][c]} ", end = '')
        print(end = '\n')
    print(end = '\n')

# Test 1
floor = [[1, 0, 0, 0],
         [0, 1, 0, 1],
         [1, 0, 1, 1]]

print("Room Condition: ")
for row in floor:
    print(row)
print("\n")
clean(floor, 1, 2)
```

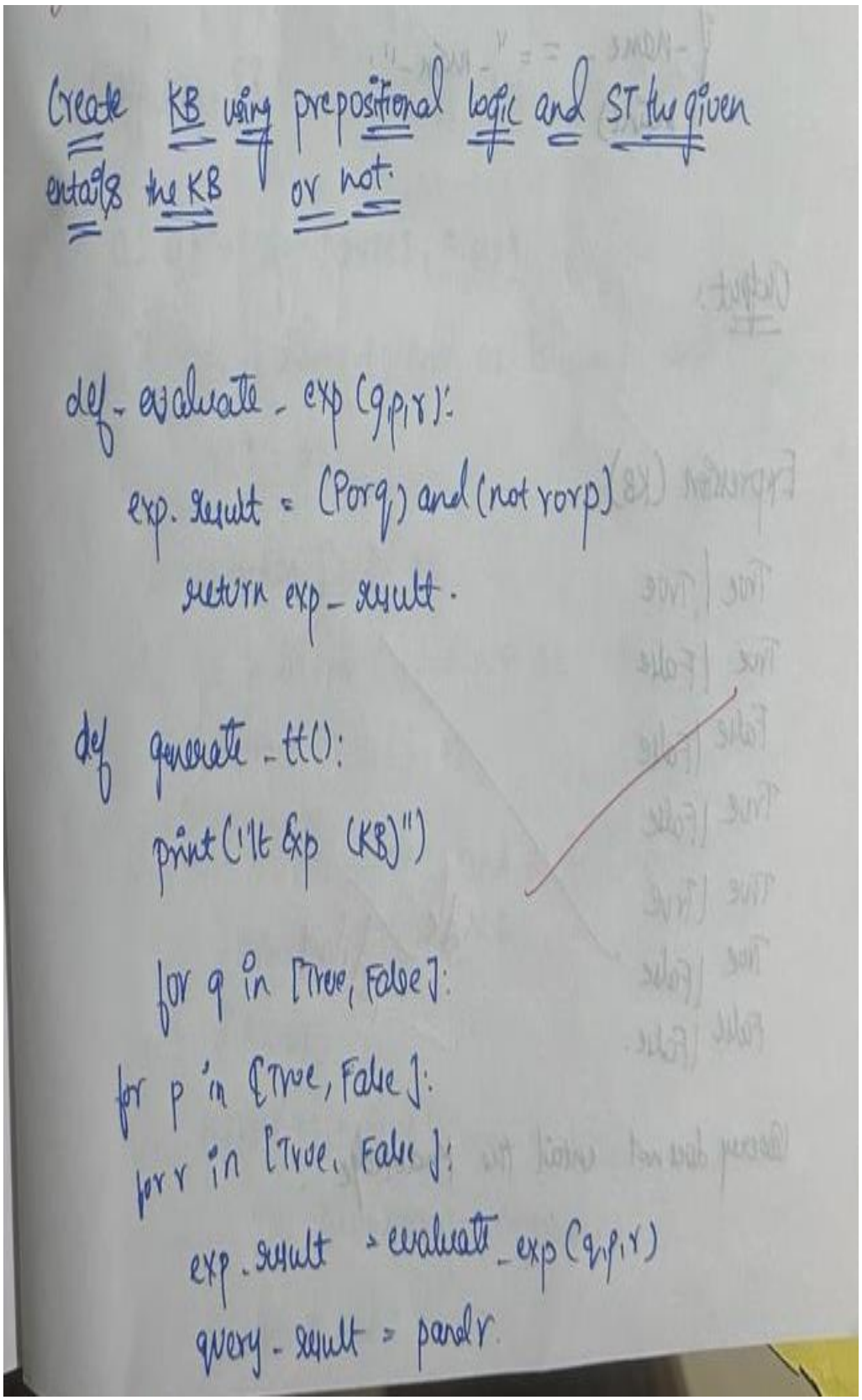
**OUTPUT:**

```
Room Condition:
[1, 0, 0, 0]
[0, 1, 0, 1]
[1, 0, 1, 1]


  1    0    0    0
  0    1   >0<   1
  1    0    1    1

  1    0    0    0
  0    1    0   >1<
  1    0    1    1

  1    0    0    0
  0    1    0   >0<
  1    0    1    1

  1    0    0    0
  0    1   >0<   0
  1    0    1    1

  1    0    0    0
  0   >1<   0    0
  1    0    1    1

  1    0    0    0
  0   >0<   0    0
  1    0    1    1

  1    0    0    0
  0    0    0    0
  1   >0<   1    1
```

```
 1    0    0    0
 0    0    0    0
>1<   0    1    1

 1    0    0    0
 0    0    0    0
>0<   0    1    1

 1    0    0    0
 0    0    0    0
 0   >0<   1    1

 1    0    0    0
 0    0    0    0
 0    0   >1<   1

 1    0    0    0
 0    0    0    0
 0    0   >0<   1

 1    0    0    0
 0    0    0    0
 0    0    0   >1<

 1    0    0    0
 0    0    0    0
 0    0    0   >0<

 1    0    0    0
 0    0    0   >0<
 0    0    0    0

 1    0    0   >0<
 0    0    0    0
 0    0    0    0
```

```
 1    0   >0<   0
 0    0    0    0
 0    0    0    0

 1   >0<   0    0
 0    0    0    0
 0    0    0    0

>1<   0    0    0
 0    0    0    0
 0    0    0    0

>0<   0    0    0
 0    0    0    0
 0    0    0    0
```

**6. Create a knowledge base using prepositional logic and show that the given query entails the knowledge base or not.**

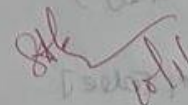


```
def query_entails_knowledge():
    for q in [True, False]:
    for p in [" ", False]:
        exp_result = evaluate_exp(q,p,r)
        query_result = p & r;
        return False.

return True
def main()
    generate_truth_table()
        print("In Query entails with knowledge"):

else
    if __name__ == "__main__":
    main()
```

Output:

Expression (KB)

True | True
True | False
False | False
True | False
True | True
True | False
False | False.



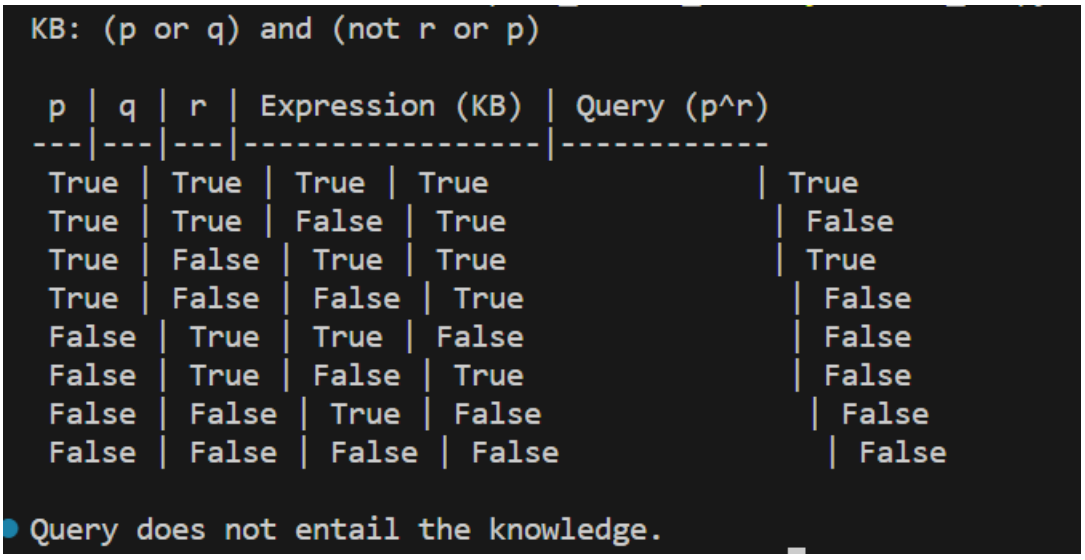
Query does not entail the knowledge.

**Create a knowledge base using prepositional logic and show that the given query entails the knowledge base or not.**

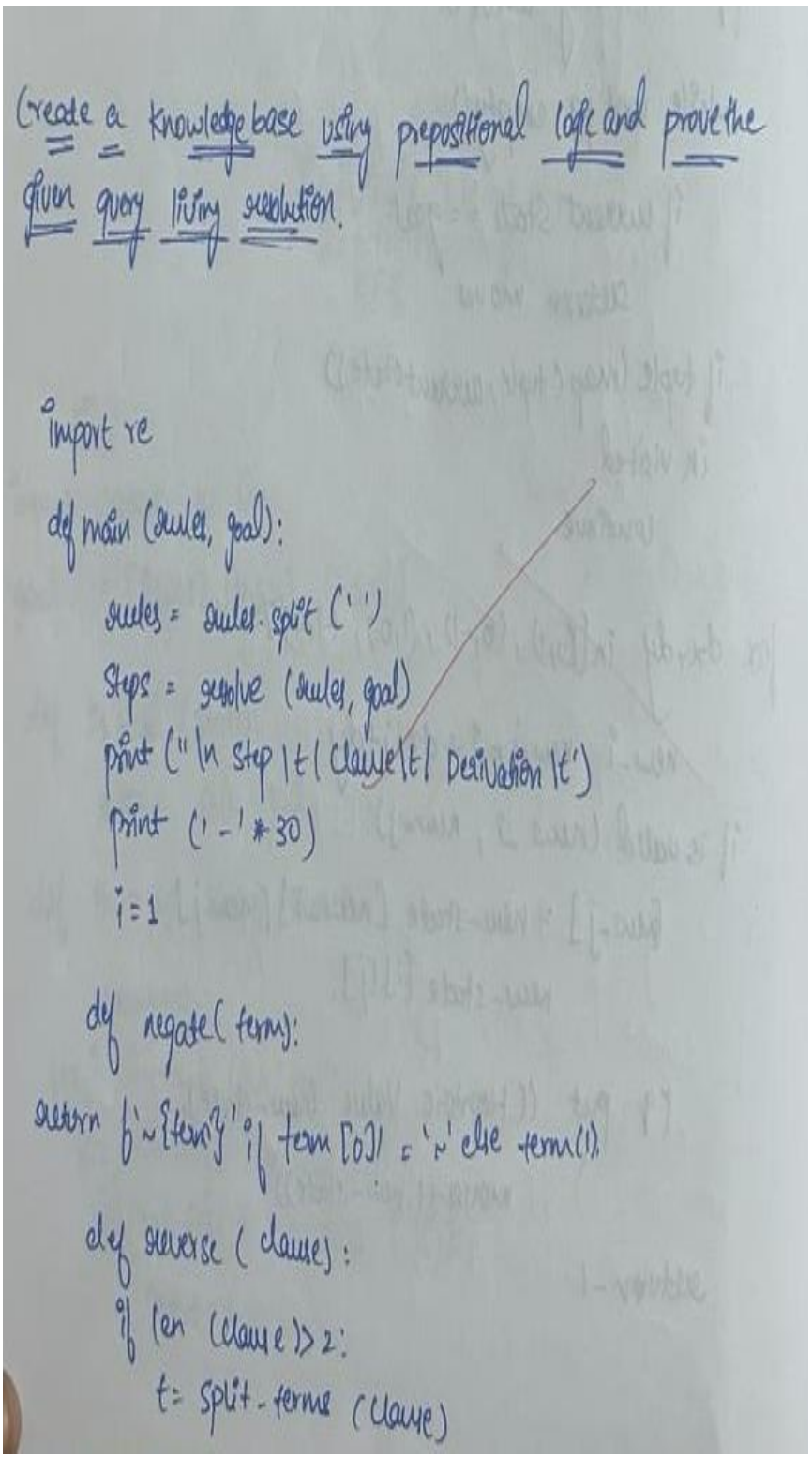
```
def evaluate_expression(p, q, r):
    expression_result = (p or q) and (not r or p)
    return expression_result

def generate_truth_table():
    print(" p | q | r | Expression (KB) | Query (p^r)")
    print("---|---|---|-----------------|------------")

    for p in [True, False]:
        for q in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_expression(p, q, r)
                query_result = p and r

                print(f" {p} | {q} | {r} | {expression_result}              | {query_result}")

def query_entails_knowledge():
    for p in [True, False]:
        for q in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_expression(p, q, r)
                query_result = p and r

                if expression_result and not query_result:
                    return False

    return True
```

```
def main():
    generate_truth_table()

    if query_entails_knowledge():
        print("\nQuery entails the knowledge.")
    else:
        print("\nQuery does not entail the knowledge.")

if __name__== "_main_":
    main()
```

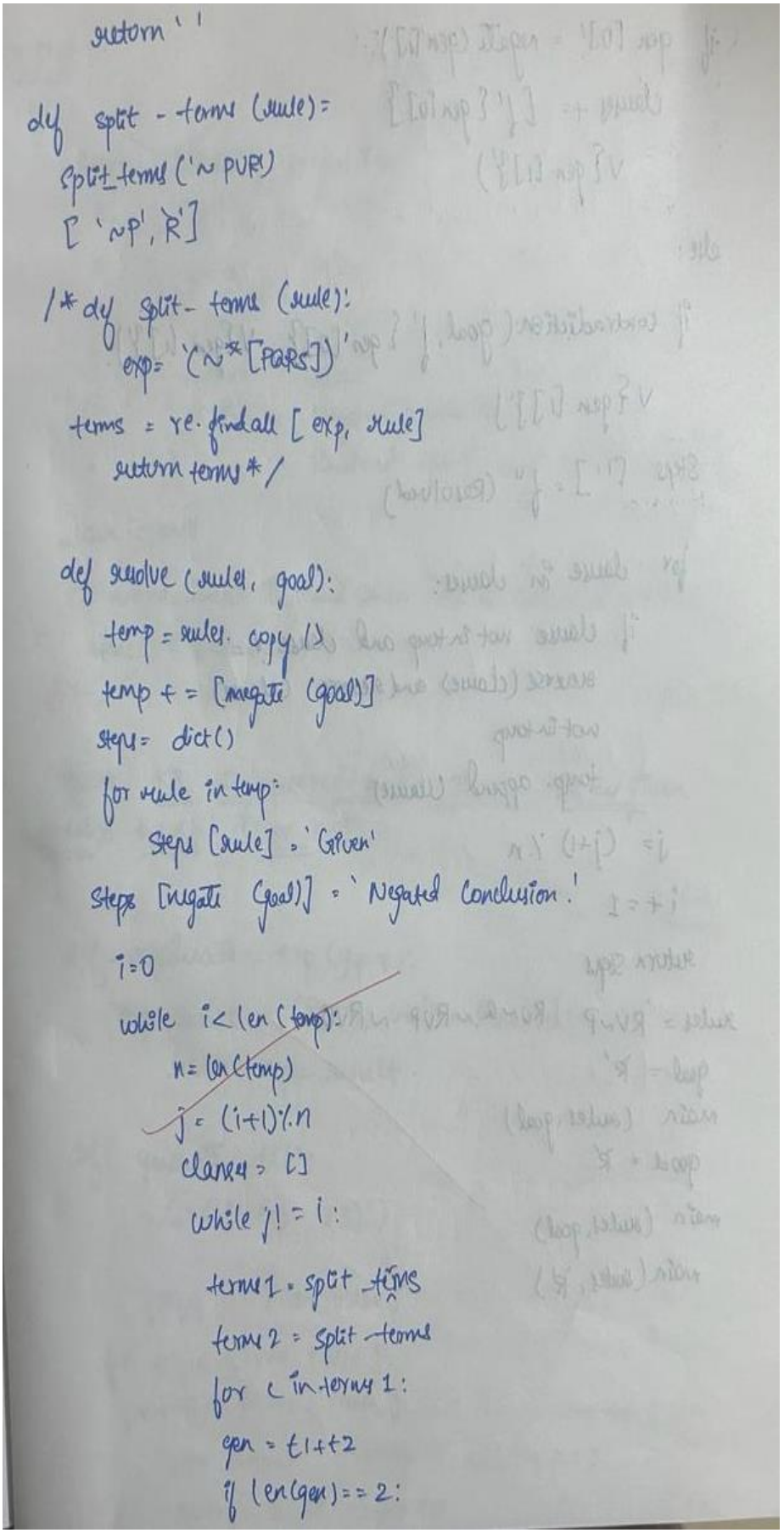
**OUTPUT:**



**7. Create a knowledge base using prepositional logic and prove the given query using resolution**



```
Create a knowledge base using propositional logic and prove the
given query using resolution.

import re
def main (rules, goal):
    rules = rules.split (',')
    steps = resolve (rules, goal)
    print ("\n Step \t| Clause \t| Derivation \t')
    print ('-' * 30)
    i=1

    def negate(term):
return f'~{term}' if term[0] != '~' else term[1]

    def reverse ( clause):
        if len (clause)>2:
            t= split_terms (clause)
```



```
    return ''

def split_terms(rule):
    split_terms('~PUR')
    ['~p', 'R']

/*def split_terms(rule):
    exp='(~*[PQRS])'
    terms = re.findall[exp, rule]
    return terms*/

def resolve(rules, goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given'
    steps[negate(goal)] = 'Negated Conclusion.'
    i=0
    while i<len(temp):
        n=len(temp)
        j=(i+1)%n
        clauses=[]
        while j!=i:
            terms1=split_terms
            terms2=split_terms
            for c in terms1:
            gen=t1+t2
            if(len(gen)==2:
```

```
if gen[0]! = negate(gen[1]):
    clauses += [f'{gen[0]}
        V{gen[1]}')

else:
    if contradiction(goal, f'{gen[0]}, V{gen[1]}'):
        V{gen[1]}')
    steps['1'] = f" (Resolved)

    for clause in clauses:
        if clause not in temp and clause[::-1] =
            reverse(clause) and reverse(clause)
            not in temp
            temp.append(clause)

    j = (j+1) % n
    i += 1
    return steps
rules = 'RV~P  RV~Q  ~RVP  ~RVQ
goal = 'R'
main(rules, goal)
goal = 'R'
main(rules, goal)
main(rules, 'R')
```

Output:-

| Step | Clause | Derivation |
|---|---|---|
| 1 | RVP | Given |
| 2 | RV~Q | Given |
| 3 | ~RVP | Given |
| 4 | ~RVQ | Given |
| 5 | ~R | Negated conclusion |
| 6 | | Resolved RVP and ~RVP to RVP, |

which is NULL

A contradiction is found when ~R is assumed as true.

Hence, R is true.

**Create a knowledge base using prepositional logic and prove the given query using resolution**

```
import re


def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}.\t| {step}\t| {steps[step]}\t')
        i += 1
def negate(term):
    return f'~{term}' if term[0] != '~' else term[1]


def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]}v{t[0]}'
    return ''
def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms


split_terms('~PvR')
def contradiction(goal, clause):
    contradictions = [ f'{goal}v{negate(goal)}', f'{negate(goal)}v{goal}']
    return clause in contradictions or reverse(clause) in contradictions
def resolve(rules, goal):
```

```
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given.'
    steps[negate(goal)] = 'Negated conclusion.'
    i = 0
    while i < len(temp):
        n = len(temp)
        j = (i + 1) % n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
                    t2 = [t for t in terms2 if t != negate(c)]
                    gen = t1 + t2
                    if len(gen) == 2:
                        if gen[0] != negate(gen[1]):
                            clauses += [f'{gen[0]}v{gen[1]}']
                        else:
                            if contradiction(goal,f'{gen[0]}v{gen[1]}'):
                                temp.append(f'{gen[0]}v{gen[1]}')
                                steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in
turn null. \
                                \nA contradiction is found when {negate(goal)} is assumed as true.
Hence, {goal} is true."
                                return steps
                    elif len(gen) == 1:
```

```
                clauses += [f'{gen[0]}']
            else:
                if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
                    temp.append(f'{terms1[0]}v{terms2[0]}')
                    steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                    \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                    return steps
        for clause in clauses:
            if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
                temp.append(clause)
                steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
        j = (j + 1) % n
    i += 1
  return steps
rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
print('Rules: ',rules)
print("Goal:  ",goal)
main(rules, goal)

rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR
goal = 'R'
print('Rules: ',rules)
print("Goal:  ",goal)
main(rules, goal)

rules = 'PvQ PvR ~PvR RvS Rv~Q ~Sv~Q' # (P=>Q)=>Q, (P=>P)=>R, (R=>S)=>~(S=>Q)
goal = 'R'
print('Rules: ',rules)
```

print("Goal: ",goal)

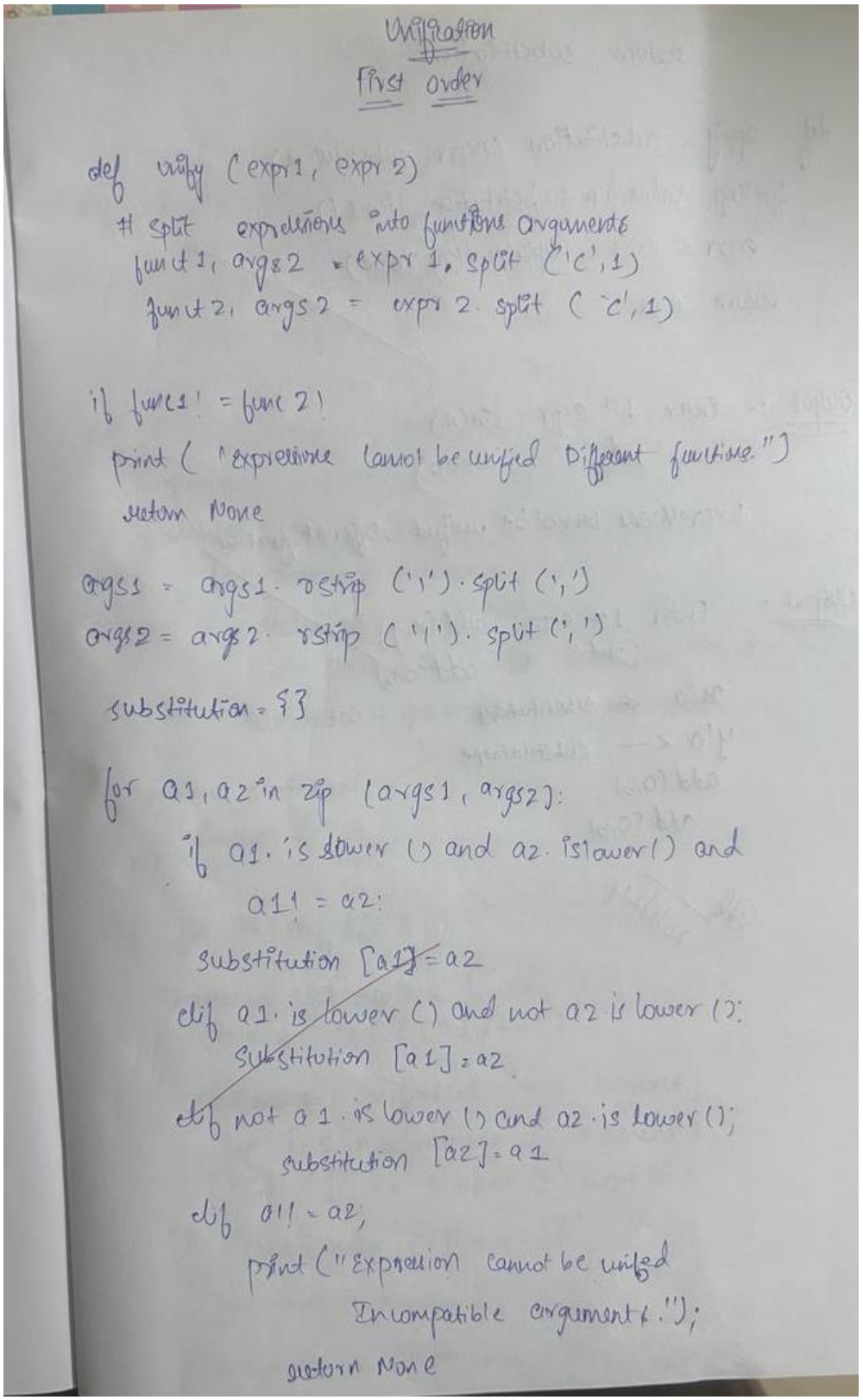
main(rules, goal)

**OUTPUT:**

```
Example 1
Rules:  Rv~P Rv~Q ~RvP ~RvQ
Goal:  R

Step    |Clause |Derivation
------------------------------
 1.     | Rv~P  | Given.
 2.     | Rv~Q  | Given.
 3.     | ~RvP  | Given.
 4.     | ~RvQ  | Given.
 5.     | ~R    | Negated conclusion.
 6.     |       | Resolved Rv~P and ~RvP to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.

Example 2
Rules:  PvQ ~PvR ~QvR
Goal:  R

Step    |Clause |Derivation
------------------------------
 1.     | PvQ   | Given.
 2.     | ~PvR  | Given.
 3.     | ~QvR  | Given.
 4.     | ~R    | Negated conclusion.
 5.     | QvR   | Resolved from PvQ and ~PvR.
 6.     | PvR   | Resolved from PvQ and ~QvR.
 7.     | ~P    | Resolved from ~PvR and ~R.
 8.     | ~Q    | Resolved from ~QvR and ~R.
 9.     | Q     | Resolved from ~R and QvR.
 10.    | P     | Resolved from ~R and PvR.
 11.    | R     | Resolved from QvR and ~Q.
 12.    |       | Resolved R and ~R to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

```
Example 3
Rules:  PvQ PvR ~PvR RvS Rv~Q ~Sv~Q
Goal:  R

Step    |Clause |Derivation
------------------------------
 1.     | PvQ   | Given.
 2.     | PvR   | Given.
 3.     | ~PvR  | Given.
 4.     | RvS   | Given.
 5.     | Rv~Q  | Given.
 6.     | ~Sv~Q | Given.
 7.     | ~R    | Negated conclusion.
 8.     | QvR   | Resolved from PvQ and ~PvR.
 9.     | Pv~S  | Resolved from PvQ and ~Sv~Q.
 10.    | P     | Resolved from PvR and ~R.
 11.    | ~P    | Resolved from ~PvR and ~R.
 12.    | Rv~S  | Resolved from ~PvR and Pv~S.
 13.    | R     | Resolved from ~PvR and P.
 14.    | S     | Resolved from RvS and ~R.
 15.    | ~Q    | Resolved from Rv~Q and ~R.
 16.    | Q     | Resolved from ~R and QvR.
 17.    | ~S    | Resolved from ~R and Rv~S.
 18.    |       | Resolved ~R and R to ~RvR, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

**8. Implement unification in first order logic**



Unification
First order

```
def unify (expr1, expr2)
  # split expressions into function arguments
  funct1, args2 = expr1, split ('(', 1)
  funct2, args2 = expr2. split ( '(', 1)

if func1 != func2)
  print ( "Expressions cannot be unified Different functions.")
  return None

args1 = args1. rstrip (')'). split (',')
args2 = args2. rstrip (')'). split (',')

substitution = {}

for a1, a2 in zip (args1, args2):
    if a1. islower () and a2. islower() and
        a1 != a2:
      substitution [a1] = a2
    elif a1. is lower () and not a2 is lower ():
      substitution [a1] = a2
    elif not a1. is lower () and a2. is lower ();
        substitution [a2] = a1
    elif a1 != a2;
        print ("Expression cannot be unified
              Incompatible arguments.");
        return None
```

```
    return substitution

def apply_substitution(expr, substitution):
    for key, value in substitution.items():
        expr = expr.replace(key, value)
    return expr
```

Output :- Enter 1st expr : sin(n)
" " 2nd " " : cos(a)

Expressions cannot be unified. Different functions

Output : Enter 1st expr : add(n,y)
" 2nd " " : add(a,b)

n/a ← substitutions
y/a ← substitutions
add(a,b)
add(a,b)

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**Implement unification in first order logic**

```
import re

def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
    expression = re.split("(?<!\(.),(?!.\))", expression)
    return expression

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)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    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:
            return False

    if isConstant(exp1):
```

```
    return [(exp1, exp2)]

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

if isVariable(exp1):
    if checkOccurs(exp1, exp2):
        return False
    else:
        return [(exp2, exp1)]

if isVariable(exp2):
    if checkOccurs(exp2, exp1):
        return False
    else:
        return [(exp1, exp2)]

if getInitialPredicate(exp1) != getInitialPredicate(exp2):
    print("Predicates do not match. Cannot be unified")
    return False

attributeCount1 = len(getAttributes(exp1))
attributeCount2 = len(getAttributes(exp2))
if attributeCount1 != attributeCount2:
    return False

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

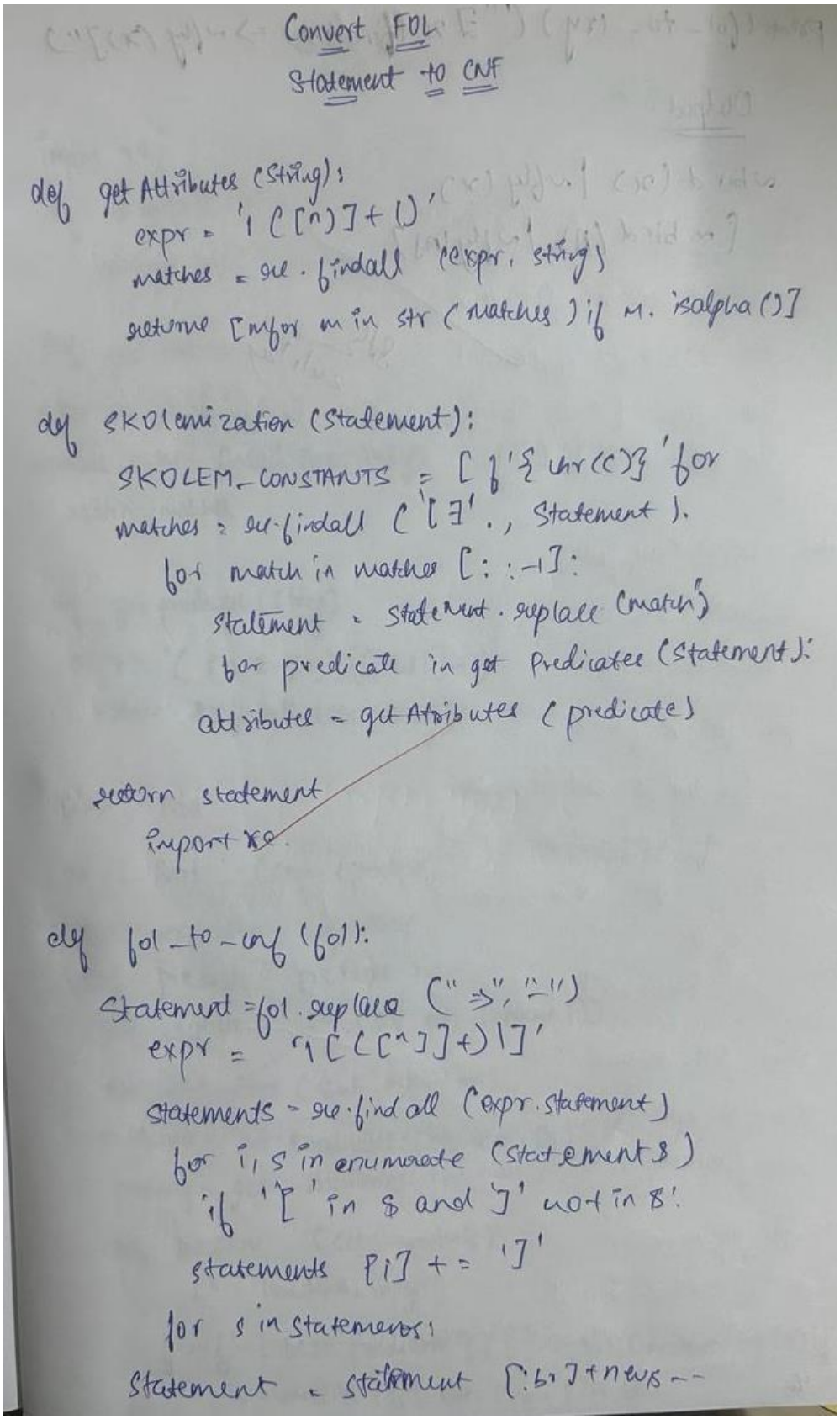
```
        return False
    if attributeCount1 == 1:
        return initialSubstitution

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

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

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

    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution

print("\nExample 1")
exp1 = "knows(f(x),y)"
exp2 = "knows(J,John)"
print("Expression 1: ",exp1)
print("Expression 2: ",exp2)

substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)

print("\nExample 2")
exp1 = "knows(John,x)"
```

```
exp2 = "knows(y,mother(y))"
print("Expression 1: ",exp1)
print("Expression 2: ",exp2)

substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)



print("\nExample 3")
exp1 = "Student(x)"
exp2 = "Teacher(Rose)"
print("Expression 1: ",exp1)
print("Expression 2: ",exp2)

substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

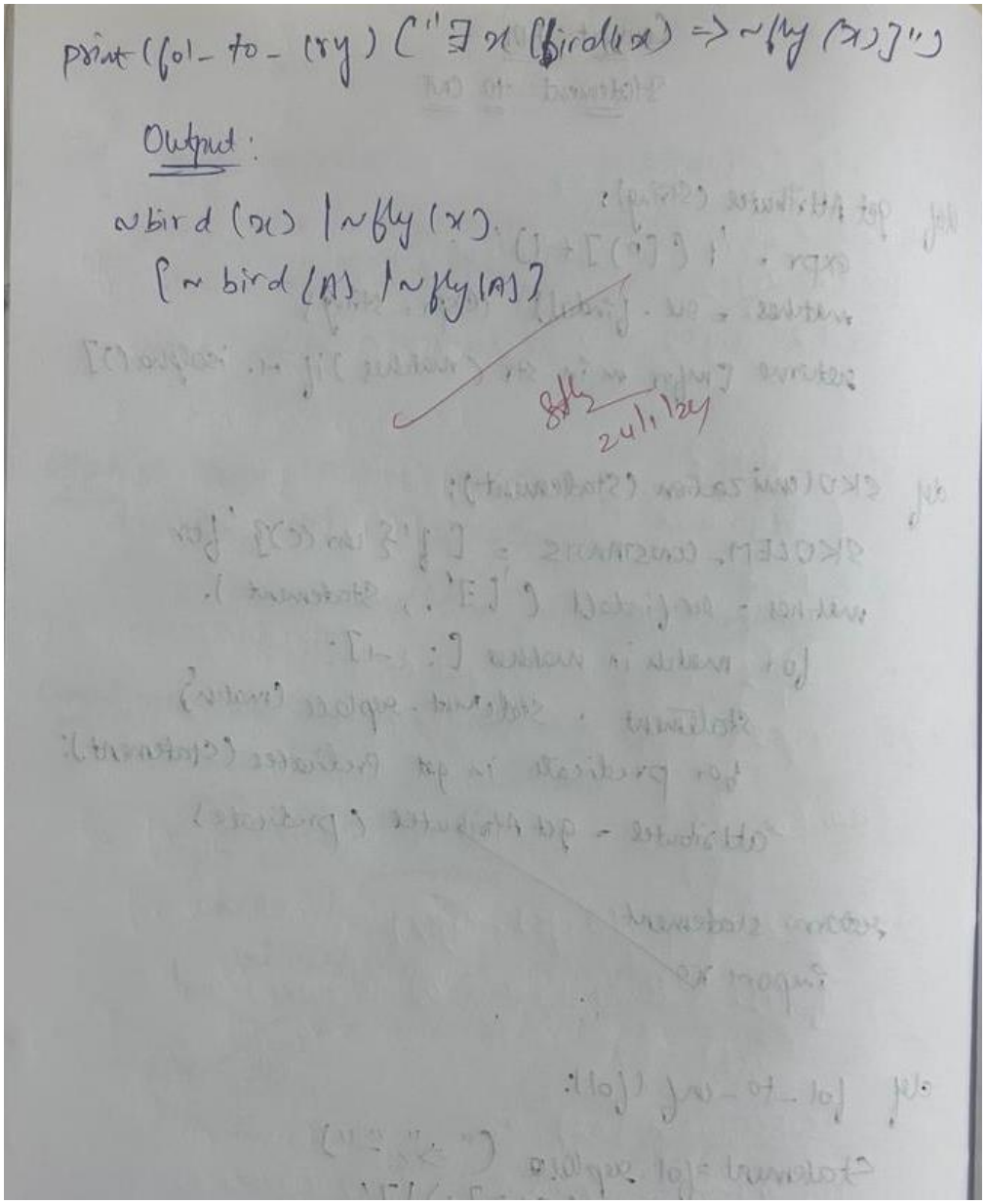
**OUTPUT:**

```
Example 1
Expression 1:  knows(f(x),y)
Expression 2:  knows(J,John)
Substitutions:
[('J', 'f(x)'), ('John', 'y')]

Example 2
Expression 1:  knows(John,x)
Expression 2:  knows(y,mother(y))
Substitutions:
[('John', 'y'), ('mother(y)', 'x')]

Example 3
Expression 1:  Student(x)
Expression 2:  Teacher(Rose)
Predicates do not match. Cannot be unified
Substitutions:
False
```

**9. Convert a given first order logic statement into Conjunctive Normal Form (CNF).**



```
Convert FOL
Statement to CNF

def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

def skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for
    matches = re.findall('[∃', statement).
        for match in matches[::-1]:
            statement = statement.replace(match)
            for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)

    return statement
    import re.

def fol_to_cnf(fol):
    statement = fol.replace("=>", "-")
    expr = '\[(\[^]]+)\]'
    statements = re.findall(expr, statement)
    for i, s in enumerate(statements)
        if '[' in s and ']' not in s:
            statements[i] += ']'
    for s in statements:
    statement = statement[:b1]+news--
```


print(fol_to_cnf("∃x(bird(x) => ~fly(x))"))
Output:
~bird(x) | ~fly(x).
[~bird(A) | ~fly(A)]

**Convert a given first order logic statement into Conjunctive Normal Form (CNF).**

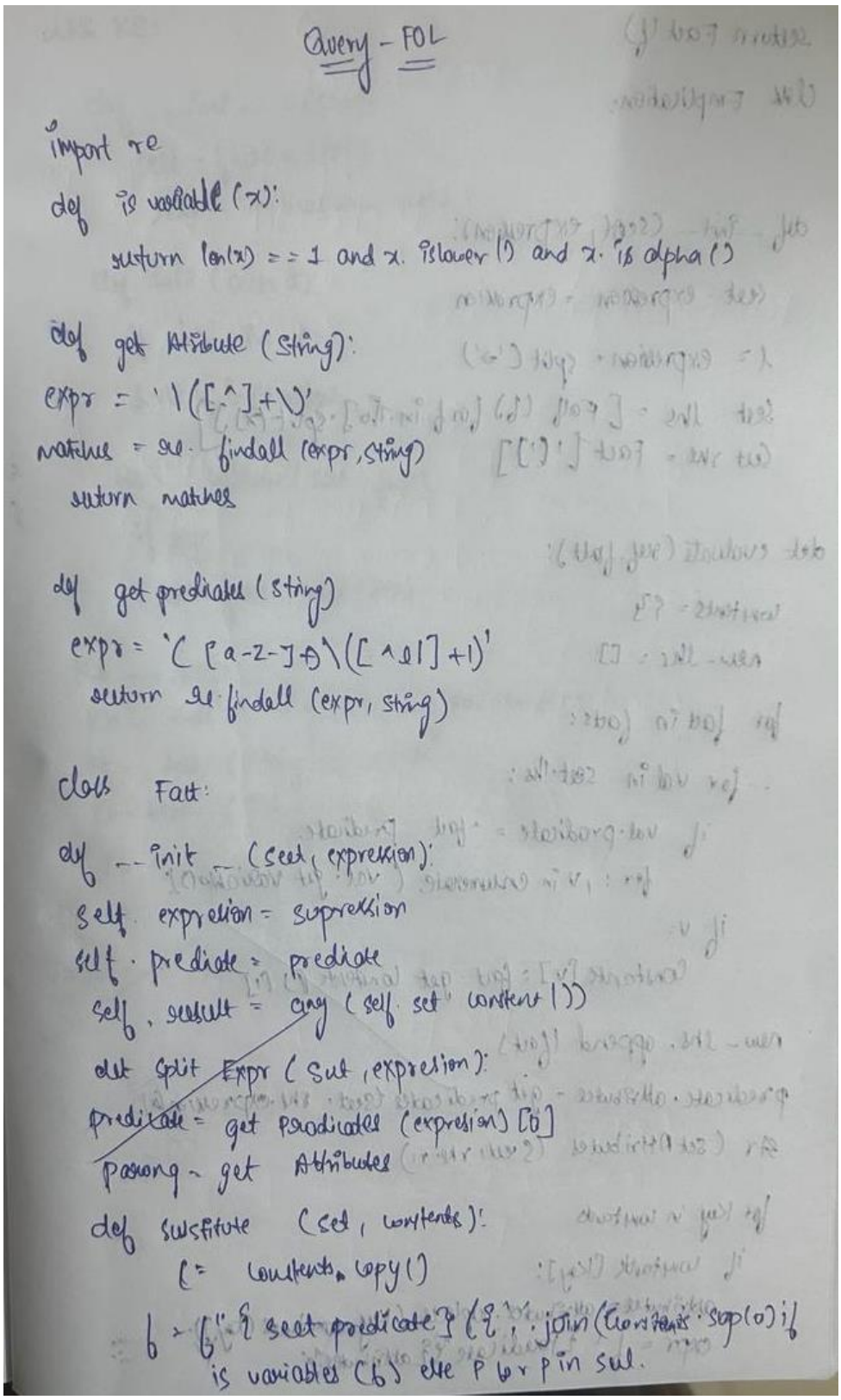
```
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

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

def Skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    matches = re.findall('[∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
    return statement
import re

def fol_to_cnf(fol):
    statement = fol.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
    for i, s in enumerate(statements):
        if '[' in s and ']' not in s:
            statements[i] += ']'
```

```
    for s in statements:
        statement = statement.replace(s, fol_to_cnf(s))
    while '-' in statement:
        i = statement.index('-')
        br = statement.index('[') if '[' in statement else 0
        new_statement = '~' + statement[br:i] + '|' + statement[i+1:]
        statement = statement[:br] + new_statement if br > 0 else new_statement
    return Skolemization(statement)

print(fol_to_cnf("bird(x)=>~fly(x)"))
print(fol_to_cnf("∃x[bird(x)=>~fly(x)]"))

print(Skolemization(fol_to_cnf("animal(y)<=>loves(x,y)")))
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]")))
print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))
```

**OUTPUT:**

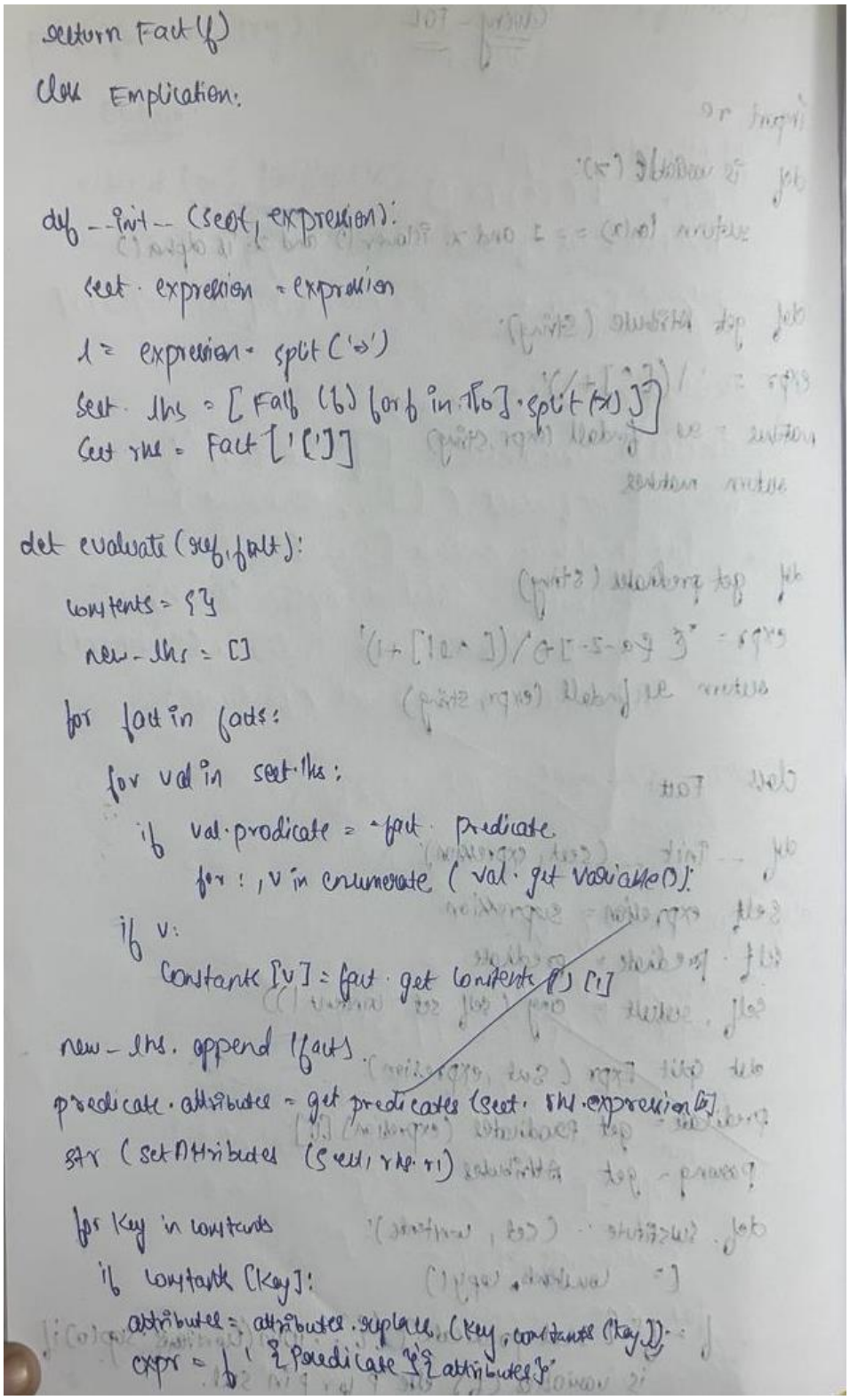
```
Example 1
FOL: bird(x)=>~fly(x)
CNF:  ~bird(x)|~fly(x)

Example 2
FOL: ∃x[bird(x)=>~fly(x)]
CNF:  [~bird(A)|~fly(A)]

Example 3
FOL: animal(y)<=>loves(x,y)
CNF:  ~animal(y)<|loves(x,y)

Example 4
FOL: ∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]
CNF:  ∀x~[∀y[~animal(y)|loves(x,y)]]|[[loves(A,x)]]

Example 5
FOL: [american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)
CNF:  ~[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]|criminal(x)
```

**10. Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.**

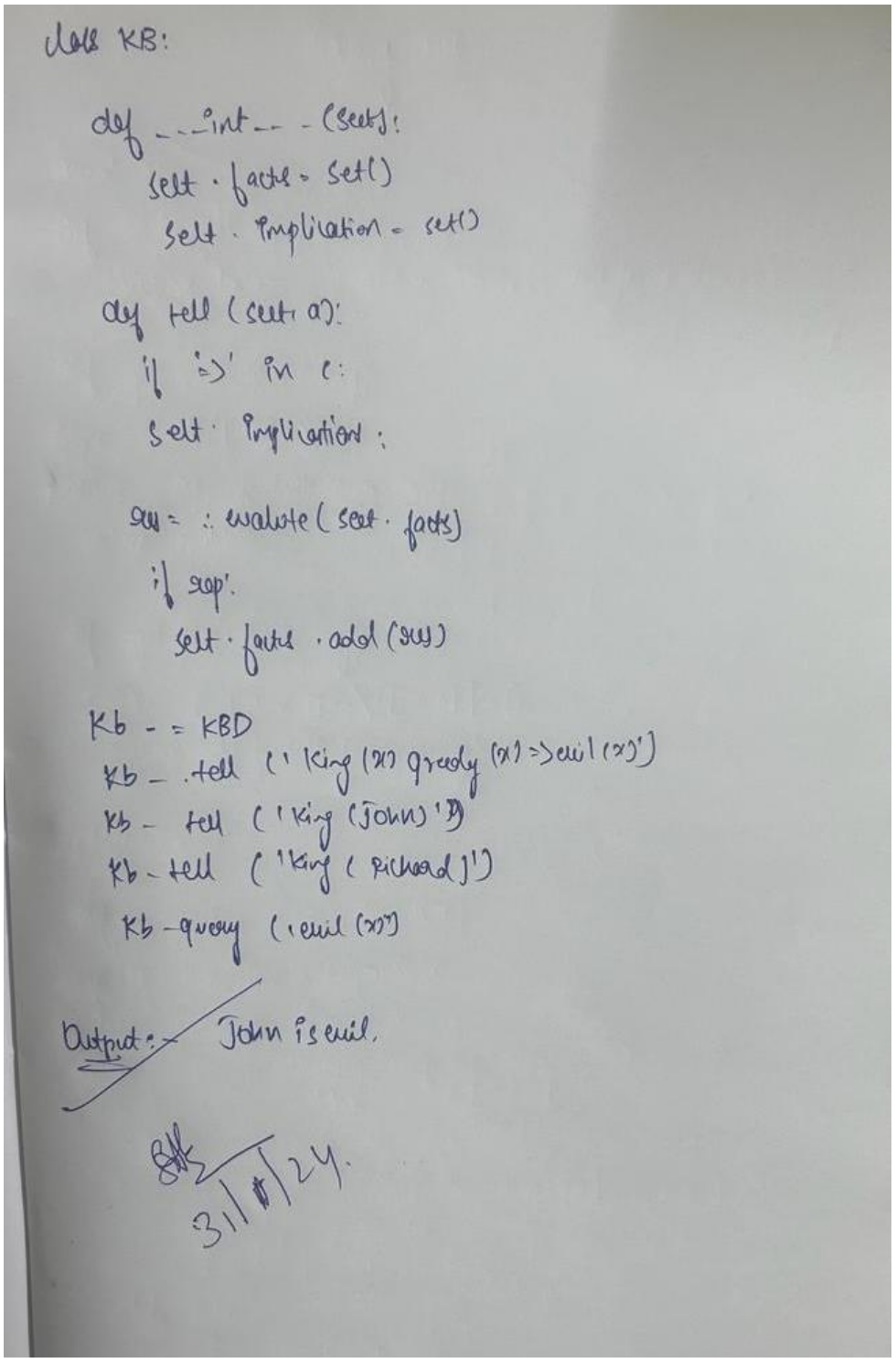


Query - FOL

```
import re
def is_variable(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
 self.predicate = predicate
 self.result = any(self.getContent())

def splitExpr(self, expression):
predicate = getpredicates(expression)[0]
params = getAttributes
def substitute(self, constants):
    c = constants.copy()
f = f"{self.predicate}({','.join(constants.pop(0) if
    is_variable(p) else p for p in self.
```



```
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.getContents()[i]

    new_lhs.append(fact)
    predicate, attributes = getPredicates(self.rhs.expression)
    str(setAttributes(self.rhs.r))

    for key in constants
        if constants[key]:
            attributes = attributes.replace(key, constants[key])
            expr = '{}({})'.format(predicate, attributes)
```



```
class KB:

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

    def tell(self, e):
        if '=>' in e:
            self.implication.add(e)
        else:
            self.facts.add(e)

    def query(self, e):
        print("Query:", e)
        for fact in self.facts:
            if fact == e:
                print("Found fact:", fact)
                return True
        for implication in self.implication:
            left, right = implication.split('=>')
            if right.strip() == e:
                print("Found implication:", implication)
                return True
        print("Not found")
        return False

kb = KB()
kb.tell('King(x) Greedy(x) => Evil(x)')
kb.tell('King(John)')
kb.tell('King(Richard)')
kb.query('Evil(x)')
```

Output:- John is evil.

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**Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.**

```
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 query(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}')

kb = KB()
kb.tell('missile(x)=>weapon(x)')
kb.tell('missile(M1)')
kb.tell('enemy(x,America)=>hostile(x)')
kb.tell('american(West)')
kb.tell('enemy(Nono,America)')
kb.tell('owns(Nono,M1)')
kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
kb.query('criminal(x)')
kb.display()

kb_ = KB()
kb_.tell('king(x)&greedy(x)=>evil(x)')
kb_.tell('king(John)')
kb_.tell('greedy(John)')
kb_.tell('king(Richard)')
kb_.query('evil(x)')
```

**OUTPUT:**

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

Example 2
Querying evil(x):
        1. evil(John)
```