B.M.S. COLLEGE OF ENGINEERING
BENGALURU Autonomous Institute, Affiliated to VTU

Lab Record

Artificial Intelligence

(22CS5PCAIN)

Bachelor of Technology
in
Computer Science and Engineering

Submitted by:

SUHAS
1BM21CS223

Department of Computer Science and
Engineering B.M.S. College of Engineering
Bull Temple Road, Basavanagudi, Bangalore 560 019

B.M.S. COLLEGE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

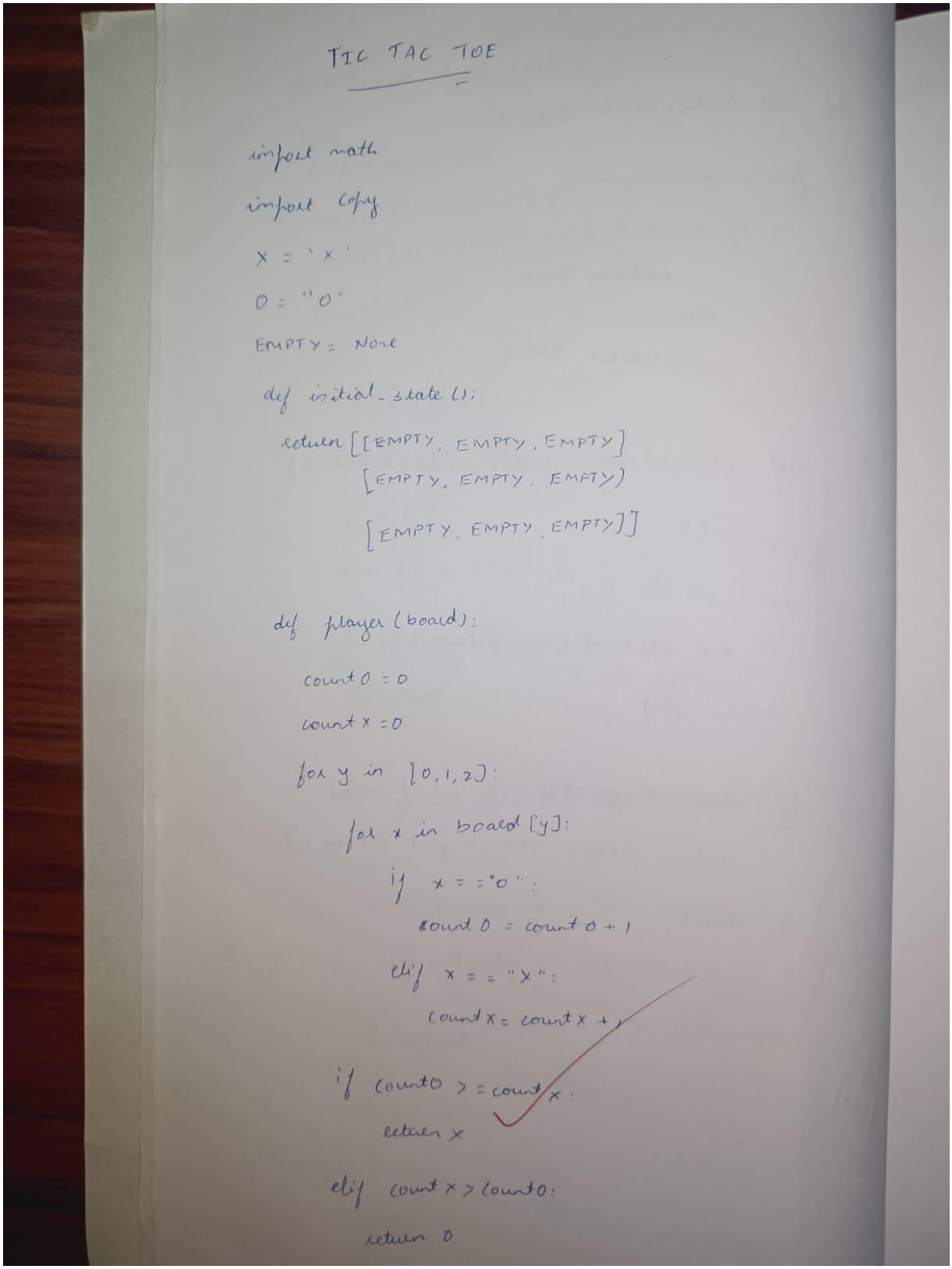
CERTIFICATE

This is to certify that the Artificial Intelligence (22CS5PCAIN) laboratory has been carried out by Suhas(1BM21CS223) during the 5th Semester September-January 2021.

Signature of the Faculty In charge:
Dr. Pallavi G B
Assistant Professor
Department of Computer Science and Engineering
B.M.S. College of Engineering, Bangalore

Table of Contents

1.Tic Tac Toe



TIC TAC TOE

```
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
```

z

```
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][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] == 0 or board[
    == board[1][1] == 0 or board[2][0] == board[2][1] ==
                                    board[2][2] == 0):
    return 0
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:
```

```
    if not 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
```

False

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

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("\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(f"\n The winner is: {winner(game_board)}")
else
    print("\n It's a tie!")
```

Output:

Initial board

```
[ _ _ _ ]
[ _ _ _ ]
[ _ _ _ ]
```

The game goes as below:

```
X _ _        X _ _        X _ _
_ _ _   ->   _ O _   ->   _ O _
_ _ _        _ _ _        _ _ _
```

(Person) (AI) (Person)

```
X _ _        X _ _        X _ O
X O _   ->   X O _   ->   X O _
O _ _        O X _        O X _
```

(AI) (Person) (AI)

AI WINS!!

20/12/23

Implement Tic-Tac-Toe Game

Objective: The objective of tic-tac-toe is that players have to position their marks so that they make a continuous line of three cells horizontally, vertically or diagonally**.**

Code:

```
board = [' ' for x in range(10)]
def insertLetter(letter, pos):
    board[pos] = letter


def spaceIsFree(pos):
return board[pos] == ' '



def printBoard(board):
    print(' | |') print(' ' + board[1] + ' | ' + board[2] + ' | '
    + board[3]) print(' | |')
    print('_____')
    print(' | |') print(' ' + board[4] + ' | ' + board[5] + ' | '
    + board[6]) print(' | |')
    print('_____')
    print(' | |') print(' ' + board[7] + ' | ' + board[8] + ' | '
    + board[9]) print(' | |')


def isWinner(bo, le):
    return (bo[7] == le and bo[8] == le and bo[9] == le) or (bo[4] == le and bo[5]
== le and bo[6] == le) or ( bo[1] == le and bo[2] == le and bo[3] == le) or
            (bo[1] == le and bo[4]
```

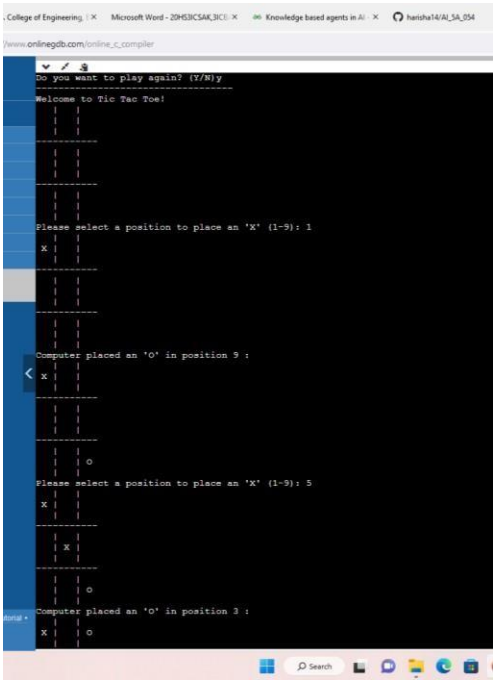
```
== le and bo[7] == le) or ( bo[2] == le and bo[5] == le and bo[8] == le) or (
                bo[3] == le and bo[6] == le and bo[9] == le) or ( bo[1] == le
                and bo[5] == le and bo[9] == le) or (bo[3] == le and
bo[5] == le and bo[7] == le)


def playerMove():
   run = True while
   run:
      move = input('Please select a position to place an \'X\' (1-9): ')
      try:
         move = int(move) if move
         > 0 and move < 10:
            if     spaceIsFree(move):
               run         =         False
               insertLetter('X', move)
            else: print('Sorry, this space is
               occupied!')
         else: print('Please type a number within the
            range!')
      except:
         print('Please type a number!')


def compMove():
   possibleMoves = [x for x, letter in enumerate(board) if letter == ' ' and x != 0]
   move = 0

   for let in ['O', 'X']:
```

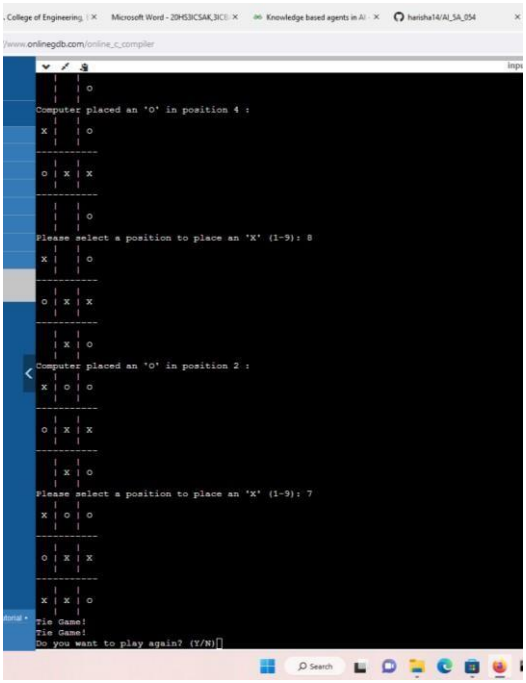
```
        for i in possibleMoves:
            boardCopy = board[:]
            boardCopy[i] = let if
            isWinner(boardCopy, let):
                move = i
                return move

    cornersOpen = [] for i
    in possibleMoves: if i
    in [1, 3, 7, 9]:
            cornersOpen.append(i)

    if len(cornersOpen) > 0:
        move = selectRandom(cornersOpen)
        return move
if 5 in possibleMoves:
        move = 5
        return move
        edgesOpen = []
        for i in
        possibleMoves:
        if i in [2, 4, 6,
        8]:
            edgesOpen.append(i)

    if len(edgesOpen) > 0: move =
        selectRandom(edgesOpen)

    return move
```

```
def selectRandom(li):
import random
   ln = len(li) r =
   random.randrange(0, ln)
   return li[r]



def isBoardFull(board):
   if board.count(' ') > 1:
      return False
   else:
      return True


def main():
   print('Welcome to Tic Tac Toe!') printBoard(board)
   while not (isBoardFull(board)):
      if not (isWinner(board, 'O')):
         playerMove()
         printBoard(board)
      else: print('Sorry, O\'s won this
         time!') break
if not (isWinner(board, 'X')):
      move = compMove() if
      move == 0:
            print('Tie Game!')
         else:
            insertLetter('O', move) print('Computer placed an
            \'O\' in position', move, ':') printBoard(board)
```

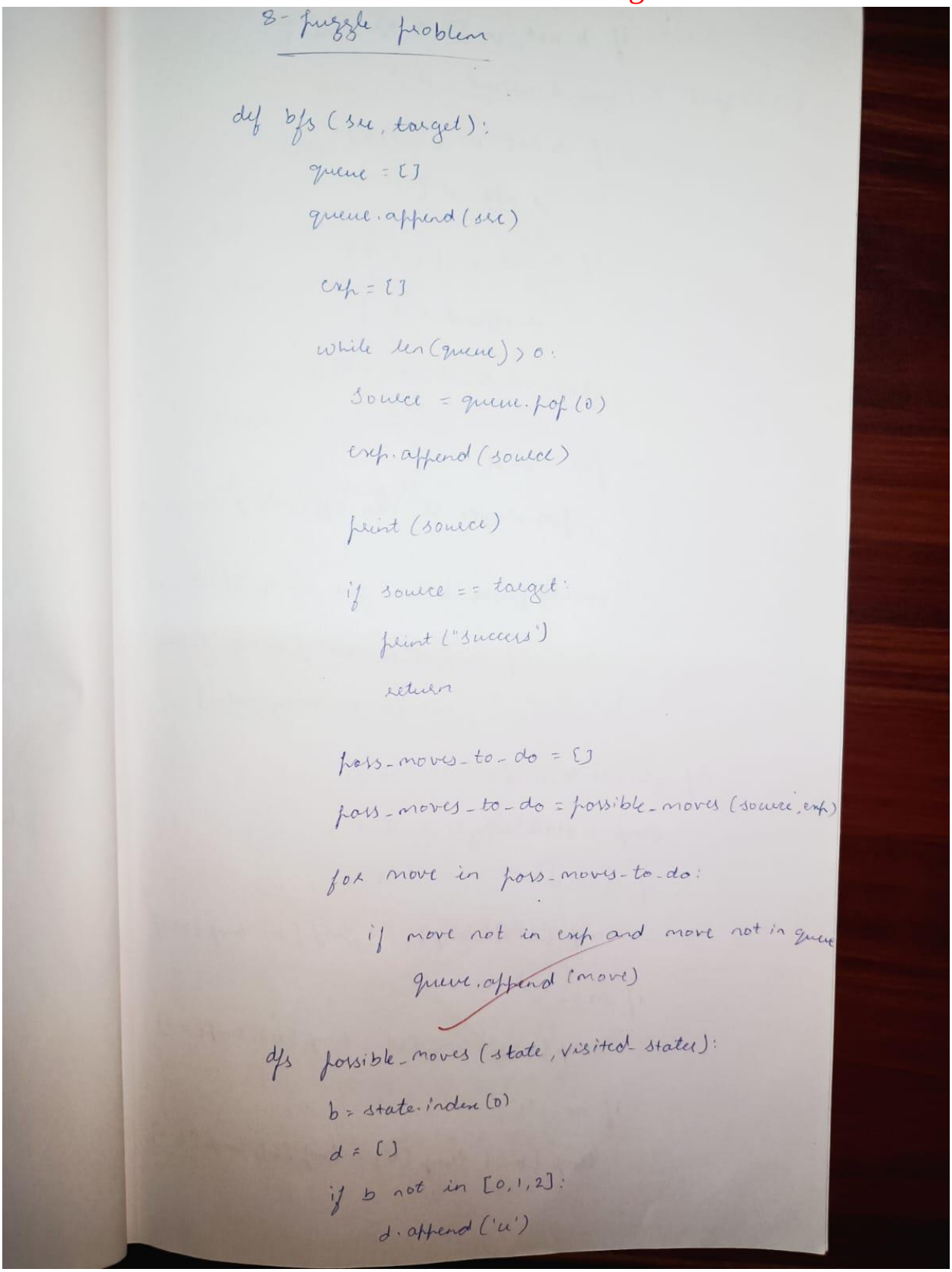
```
        else: print('X\'s won this time! Good
            Job!') break

if     isBoardFull(board):
    print('Tie Game!')



while True:
    answer = input('Do you want to play again? (Y/N)') if
    answer.lower() == 'y' or answer.lower == 'yes': board
    = [' ' for x in range(10)]
        print('_____')
        main()
    else:
        break;
```

Output:





2. 8 Puzzle Breadth First Search Algorithm



8- 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_can = []
        for i in d:
            pos_moves_it_can.append(gen(state,i
        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 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

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

target = [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, 0, 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]

Solve 8 puzzle problem.

Objective: The objective of 8-puzzle problem is to reach the end state from the start state by considering all possible movements of the tiles without any heuristic.

Code:

```
import numpy as np import os class Node: def _init
_(self, node_no, data, parent, act,
cost):
        self.data = data
        self.parent = parent
        self.act = act
        self.node_no = node_no
        self.cost = cost
def get_initial():
    print("Please enter number from 0-8, no number
should be repeated or be out of this range")
    initial_state = np.zeros(9) for i in
    range(9):
        states = int(input("Enter the " + str(i + 1)
+ " number: ")) if states < 0 or
        states > 8:
            print("Please only enter states which are
[0-8], run code again") exit(0)
        else:
            initial_state[i] = np.array(states)
    return np.reshape(initial_state, (3, 3))
def find_index(puzzle):
    i, j = np.where(puzzle == 0)
i = int(i) j = int(j) return i,
j def move_left(data):
    i, j = find_index(data)
    if j == 0: return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i, j - 1]
        temp_arr[i, j] = temp
        temp_arr[i, j - 1] = 0
        return temp_arr
```

```
def move_right(data): i, j
    = find_index(data) if j
    == 2: return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i, j + 1]
        temp_arr[i, j] = temp
        temp_arr[i, j + 1] = 0
        return temp_arr
def move_up(data): i, j =
    find_index(data) if i
    == 0: return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i - 1, j]
        temp_arr[i, j] = temp
        temp_arr[i - 1, j] = 0
        return temp_arr
def move_down(data): i, j =
    find_index(data) if i
    == 2: return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i + 1, j]
        temp_arr[i, j] = temp
        temp_arr[i + 1, j] = 0
        return temp_arr
def move_tile(action, data):
    if action == 'up':
        return move_up(data)
    if action == 'down':
        return move_down(data)
    if action == 'left':
        return move_left(data)
    if action == 'right':
        return move_right(data)
    else:
        return None
def print_states(list_final): # To print the final
states on the console print("printing final
solution") for l in list_final:
```

```
        print("Move : " + str(l.act) + "\n" + "Result
: " + "\n" + str(l.data) + "\t" + "node number:" +
str(l.node_no))


def write_path(path_formed): # To write the final
path      in      the      text      file      if
os.path.exists("Path_file.txt"):
        os.remove("Path_file.txt")
 f = open("Path_file.txt", "a")
    for node in path_formed:
        if node.parent is not None:
            f.write(str(node.node_no) + "\t" +
str(node.parent.node_no) + "\t" + str(node.cost) +
"\n")
    f.close()
def write_node_explored(explored): # To write all
the   nodes   explored   by   the   program   if
os.path.exists("Nodes.txt"):
        os.remove("Nodes.txt")
 f = open("Nodes.txt", "a")
    for element in explored:
        f.write('[') for i in
        range(len(element)):
            for j in range(len(element)):
                f.write(str(element[j][i]) + " ")
        f.write(']')
        f.write("\n")
    f.close()
def write_node_info(visited): # To write all the
info about the nodes explored by the program if
os.path.exists("Node_info.txt"):
        os.remove("Node_info.txt")
 f = open("Node_info.txt", "a") for
    n in visited:
        if n.parent is not None:
            f.write(str(n.node_no) + "\t" +
str(n.parent.node_no) + "\t" + str(n.cost) + "\n")
    f.close()
def path(node): # To find the path from the goal
node to the starting node p = [] # Empty list
```

```
p.append(node) parent_node = node.parent while
parent_node is not None:
        p.append(parent_node)
        parent_node = parent_node.parent
    return list(reversed(p))
def path(node): # To find the path from the goal
node to the starting node p = [] # Empty list
p.append(node) parent_node = node.parent while
parent_node is not None:
        p.append(parent_node)
        parent_node = parent_node.parent
    return list(reversed(p))
def path(node): # To find the path from the goal
node to the starting node p = [] # Empty list
    p.append(node)  parent_node  =
    node.parent  while  parent_node
    is not None:
        p.append(parent_node)
        parent_node = parent_node.parent
    return list(reversed(p))
def check_correct_input(l):
    array = np.reshape(l, 9)
    for i in range(9):
    counter_appear = 0 f =
    array[i] for j in
    range(9):
            if f == array[j]:
                counter_appear += 1
        if counter_appear >= 2:
            print("invalid input, same number entered
2 times") exit(0)
def check_solvable(g): arr
    =   np.reshape(g,   9)
    counter_states = 0 for
    i in range(9):
        if not arr[i] == 0:
            check_elem = arr[i] for
            x in range(i + 1, 9):
                if check_elem < arr[x] or arr[x] ==
0: continue
                else:
```

```
                    counter_states += 1
    if counter_states % 2 == 0:
        print("The puzzle is solvable, generating
path") else: print("The puzzle is insolvable,
    still
creating nodes") k =

get_initial()

check_correct_input(k

) check_solvable(k)

 root = Node(0, k, None, None,
0)
# BFS implementation call
goal, s, v = exploring_nodes(root)
 if goal is None and s is None and v is
None:
    print("Goal State could not be reached, Sorry")
else:
    # Print and write the final output
    print_states(path(goal))
    write_path(path(goal))
    write_node_explored(s)
    write_node_info(v)
```

Output:

```
Please enter number from 0-8, no number should be repeated or be out of this range
Enter the 1 number: 1
Enter the 2 number: 3
Enter the 3 number: 2
Enter the 4 number: 5
Enter the 5 number: 4
Enter the 6 number: 6
Enter the 7 number: 0
Enter the 8 number: 7
Enter the 9 number: 8
The puzzle is solvable, generating path
Exploring Nodes
Goal_reached
printing final solution
Move : None
Result :
[[1. 3. 2.]
 [5. 4. 6.]
 [0. 7. 8.]]    node number:0
Move : up
Result :
[[1. 3. 2.]
 [0. 4. 6.]
 [5. 7. 8.]]    node number:1
Move : right
Result :
[[1. 3. 2.]
 [4. 0. 6.]
 [5. 7. 8.]]    node number:5
```

3. 8 Puzzle Iterative Deepening Search Algorithm

8- Puzzle using deep iterative search

```
def print_state(state):
    for i in range(0, 9, 3):
        print(state[i:i+3])
    print()

def find_blank(state):
    return state.index(-1)

def is_goal(state, target):
    return state == target

def actions(state):
    blank_index = find_blank(state)
    possible_actions = []
    if if blank_index not in [0,1,2]:
        possible_actions.append(-3)
    if blank_index not in [6,7,8]:
        possible_actions.append(3)
    if blank_index not in [0,3,6]:
        possible_actions.append(-1)
    if blank_index not in [2,5,8]:
        possible_actions.append(1)
```

search

```
    return possible_actions

def apply_action(state, action):
    blank_index = find_blank(state)
    new_state = state.copy()
    new_state[blank_index], new_state[blank_index
        + action] = new_state[blank_index + action],
                    new_state[blank, index]
    return new_state

def depth_limited_dfs(src, target, depth_limit,
                      path=[]):
    if depth_limit < 0:
        return None
    if src == target:
        return path + [src]

    for action in actions(src):
        new_state = apply_action(src, action)
        result = depth_limited_dfs(new_state,
                 target, depth_limit - 1, path + [src])
        if result:
            return result

    return false
```

```
def iddfs(src, target, max_depth):
    for depth_limit in range(max_depth+1)
    result = depth_limited_dfs(src, target,
                               depth_lim
    if result:
        return result
    return false
```

Output:-

src 1 = [1, 2, 3, -1, 4, 5, 6, 7, 8]

target 1 = [1, 2, 3, 4, 5, -1, 6, 7, 8]

depth 1 = 1

False ~~print(iddfs(src1, target1, depth1))~~

src 2 = [3, 5, 2, 8, 7, 6, 4, 1, -1]

target 2 = [-1, 3, 7, 8, 1, 5, 4, 6, 2]

depth 2 = 1

False

src 3 = [1, 2, 3, -1, 4, 5, 6, 7, 8]

target 3 = [1, 2, 8, 6, 4, 5, -1, 7, 8]

depth 3 = 1

True

Implement Iterative deepening search algorithm.

Objective: IDDFS combines depth first search's space efficiency and breadth first search's completeness. It improves depth definition, heuristic and score of searching nodes so as to improve efficiency.

Code:

```
import copy
inp=[[1,2,3],[4,-1,5],[6,7,8]]
out=[[1,2,3],[6,4,5],[-1,7,8]]
def move(temp, movement):
 if movement=="up":
  for i in range(3):
   for j in range(3): if(temp[i][j]==-
    1):
    if i!=0:
      temp[i][j]=temp[i-1][j] temp[i-1][j]=-
      1
     return temp
 if movement=="down":
  for i in range(3):
   for j in range(3): if(temp[i][j]==-
    1):
    if i!=2:
      temp[i][j]=temp[i+1][j] temp[i+1][j]=-
      1
     return temp
 if movement=="left":
  for i in range(3):
   for j in range(3): if(temp[i][j]==-
    1):
    if j!=0:
```

```
            temp[i][j]=temp[i][j-
          1] temp[i][j-1]=-1
          return temp
  if movement=="right":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
          if j!=2:
            temp[i][j]=temp[i][j+1] temp[i][j+1]=-
            1
          return temp
def ids(): global inp global out
  global flag for limit in
  range(100): print('LIMIT ->
  '+str(limit)) stack=[]
  inpx=[inp,"none"]
  stack.append(inpx) level=0
  while(True): if
  len(stack)==0: break
      puzzle=stack.pop(0) if level<=limit:
      print(str(puzzle[1])+" --> "+str(puzzle[0]))
      if(puzzle[0]==out): print("Found")
      print('Path cost='+str(level)) flag=True
      return
        else:
          level=level+1
          if(puzzle[1]!="down"):
          temp=copy.deepcopy(puzzle[0]
          ) up=move(temp, "up")
          if(up!=puzzle[0]):
          upx=[up,"up"] stack.insert(0,
          upx) if(puzzle[1]!="right"):
            temp=copy.deepcopy(puzzle[0])
            left=move(temp, "left")
            if(left!=puzzle[0]):
            leftx=[left,"left"]
              stack.insert(0, leftx)
          if(puzzle[1]!="up"):
          temp=copy.deepcopy(puzzle[0])
          down=move(temp, "down")
```

```
            if(down!=puzzle[0]):
            downx=[down,"down"] stack.insert(0,
            downx)
            if(puzzle[1]!="left"):
              temp=copy.deepcopy(puzzle[0])
            right=move(temp, "right")
              if(right!=puzzle[0]):
              rightx=[right,"right"]
              stack.insert(0, rightx)
 print('~~~~~~~~~~~~~ IDS
~~~~~~~~~~~~~') ids()
 import                    copy
 inp=[[1,2,3],[4,-1,5],[6,7,8]]
 out=[[1,2,3],[6,4,5],[-1,7,8]]
 def move(temp, movement):
 if movement=="up": for i in
 range(3):
      for j in range(3): if(temp[i][j]==-
        1):
        if i!=0:
           temp[i][j]=temp[i-1][j] temp[i-
           1][j]=-1
         return temp
  if movement=="down":
    for i in range(3):
     for j in range(3):
      if(temp[i][j]==-1):
      if i!=2:
         temp[i][j]=temp[i+1][j]
         temp[i+1][j]=-1
       return temp
  if movement=="left":
    for i in range(3): for
    j in range(3):
    if(temp[i][j]==-1): if
    j!=0:
          temp[i][j]=temp[i][j-1]
          temp[i][j-1]=-1
        return temp
  if
    movement=="right":
    for i in range(3): for j
    in range(3):
    if(temp[i][j]==-1):
```

```
        if j!=2:
          temp[i][j]=temp[i][j+1]
          temp[i][j+1]=-1
        return temp
def ids(): global inp global out
 global flag for limit in
 range(100): print('LIMIT ->
 '+str(limit)) stack=[]
 inpx=[inp,"none"]
 stack.append(inpx) level=0
 while(True): if
 len(stack)==0: break
    puzzle=stack.pop(0) if level<=limit:
    print(str(puzzle[1])+" --> "+str(puzzle[0]))
    if(puzzle[0]==out): print("Found")
    print('Path cost='+str(level)) flag=True
    return
     else:
      level=level+1
      if(puzzle[1]!="down"):
      temp=copy.deepcopy(puzzle[0])
      up=move(temp, "up")
      if(up!=puzzle[0]): upx=[up,"up"]
      stack.insert(0, upx)
      if(puzzle[1]!="right"):
        temp=copy.deepcopy(puzzle[0])
        left=move(temp, "left")
        if(left!=puzzle[0]):
        leftx=[left,"left"] stack.insert(0,
        leftx)
      if(puzzle[1]!="up"):
      temp=copy.deepcopy(puzzle[0])
      down=move(temp, "down")
      if(down!=puzzle[0]):
      downx=[down,"down"]
      stack.insert(0, downx)
      if(puzzle[1]!="left"):
        temp=copy.deepcopy(puzzle[0])
      right=move(temp, "right")
        if(right!=puzzle[0]):
        rightx=[right,"right"]
       stack.insert(0, rightx)
print('~~~~~~~~~~~~ IDS ~~~~~~~~~~~~')
ids()
```

Output:

```
#Test 1
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]

depth = 1
iddfs(src, target, depth)
```

```
False
```

```
#Test 2
src = [3,5,2,8,7,6,4,1,-1]
target = [-1,3,7,8,1,5,4,6,2]

depth = 1
iddfs(src, target, depth)
```

```
False
```

```
# Test 2
src = [1,2,3,-1,4,5,6,7,8]
target=[1,2,3,6,4,5,-1,7,8]

depth = 1
iddfs(src, target, depth)
```

```
src = [1, 2, 3, 4, 5, 6, 7, 8, -1]
target = [-1, 1, 2, 3, 4, 5, 6, 7, 8]

for i in range(1, 100):
    val = iddfs(src,target,i)
    print(i, val)
    if val == True:
        break
```

```
1 False
2 False
3 False
4 False
5 False
6 False
7 False
8 False
9 False
10 False
11 False
12 False
13 False
14 False
15 False
16 False
17 False
18 False
19 False
20 False
21 False
22 False
23 False
24 False
```

Lab Program 4

A* algorithm

```
import heapq

class Node:

    def __init__(self, data, level, fval):
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        x, y = self.find(self.data, '_')
        val_list = [[x, y-1], [x, y+1], [x-1, y], [x+1, y]]
        children = []
        for i in val_list:
            child = self.shuffle(self.data, x, y, i[0], i[1])
            if child is not None:
                child_node = Node(child, self.level+1, 0)
                children.append(child_node)
        return children

    def shuffle(self, puz, x1, y1, x2, y2):
        if x2 >= 0 and x2 < len(self.data) and y2 >= 0
                    and y2 < len(self.data):
            temp_puz = self.copy(puz)
            temp = temp_puz[x2][y2]
            temp_puz[x2][y2] = temp_puz[x1][y1]
```

```
        temp_puz[x1][y1] = temp
        return temp_puz

    else:
        return None

def copy(self, root):
    temp = []
    for i in root:
        t = []
        for j in i:
            t.append(j)
        temp.append(t)
    return temp

def find(self, puz, x):
    for i in range(0, len(self.data)):
        for j in range(0, len(self.data)):
            if puz[i][j] == x:
                return i,j

class Puzzle:
    def __init__(self, size):
        self.n = size
        self.open = []
        self.closed = []
    def f(self, start, goal):
        return self.h(start.data, goal) + start.level
```

```
def h(self, start, goal):
    temp = 0
    for i in range(0, self.n):
        for j in range(0, self.n):
            if start[i][j] != goal[i][j] and
                start[i][j] != '_':
                temp += 1
    return temp

def process(self, start_data, goal_data):
    start = Node(start_data, 0, 0)
    start.fval = self.f(start, goal_data)
    self.open.append(start)
    print("\n\n")
    while True:
        cur = self.open[0]
        print("  ")
        print(" | ")
        print(" | ")
        print(" \\|/ \n")
        for i in cur.data:
            for j in i:
                print(j, end=" ")
            print("")
```

```
if self.h(cur.data, goal_data) == 0:
    break
for i in cur.generate_child():
    i.fval = self.f(i, goal_data)
    self.open.append(i)
self.closed.append(cur)
del self.open[0]
self.open.sort(key= lambda x: x.fval, reverse=
```

```
start_state = [['1','2','3'],['_','4','6'],['7','5','8
goal_state = [['1','2','3'],['4','5','6'],['7','8','_']]
```

```
puz = Puzzle(3)
puz.process(start_state, goal_state)
```

output

```
1 2 3        1 2 3        1 2 3
_ 4 6  ->    4 _ 6  ->    4 5 6
7 5 8        7 5 8        7 _ 8

->  1 2 3
    4 5 6
    7 8 _
```

22/12/23

Implement A* search algorithm.

Objective: The a* algorithm takes into account both the cost to go to goal from present state as well the cost already taken to reach the present state. In 8 puzzle problem, both depth and number of misplaced tiles are considered to take decision about the next state that has to be visited.

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:

```
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
```

Lab Program 5

Vaccum Cleaner

```
def vaccum-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 location B")
                cost += 1
                print("cost for moving RIGHT" + str(cost))
```

```
        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 ("Vaccum 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))

vaccum_world()
```

Output:-

```
Enter location of vaccum : A
Enter status of A : 1
Enter status of other room : 0
Initial status : {'A': '0', 'B': '0'
Vaccum is placed in Locatin A
Location A is dirty
Cost for cleaning A : 1
Location A haven cleaned
No action
Location B is already clean
GOAL State : {'A': '0', 'B': '0'
```

Implement vacuum cleaner agent.

Objective: The objective of the vacuum cleaner agent is to clean the whole of two rooms by performing any of the actions – move right, move left or suck. Vacuum cleaner agent is a goal based agent.

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:

```
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
```

Lab Program 6

20/11/23

Propositional logic:

- given query entails the knowledge base or not

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

def generate_truth_table():
    print("Enter rule = (~q v ~p v r) ^ (~q ^ p) ^ q |")
    print("Query = r")
    print("| ----- truth table reference ----- |")
    print("Expression_result    Query_result")
    for q in [True, False]:
        for p in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_expression(q,p,r)
                query_result = r
                print(f" {q} | {p} | {r} | {expression_result}
                    | {query_result}")

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

```
        if expression_result and not query_result:
            return False

    return True

def main():
    generate_truth_table()
    if query_entails_knowledge():
        print("\n Query entails the knowledge")
    else:
        print("\n Query does not entail the
                                    knowledge")

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

Output:

① Enter rule = (~p v ~r v s) ^ (~p ^ r) ^ p

Query = s.

| ---- truth table reference ---- |

False	True
False	False
False	True
False	False
False	True
False	False
False	True
False	False

Enter rule : $(p \vee q) \wedge (\neg r \vee p)$

query : $p \wedge r$

|---------- Truth table inference ----------|

True	True
True	False

The knowledge base does not entail query.

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

Objective: The objective of this program is to see if the given query entails a knowledge base. A query is said to entail a knowledge base if the query is true for all the models where knowledge base is true.

Code:

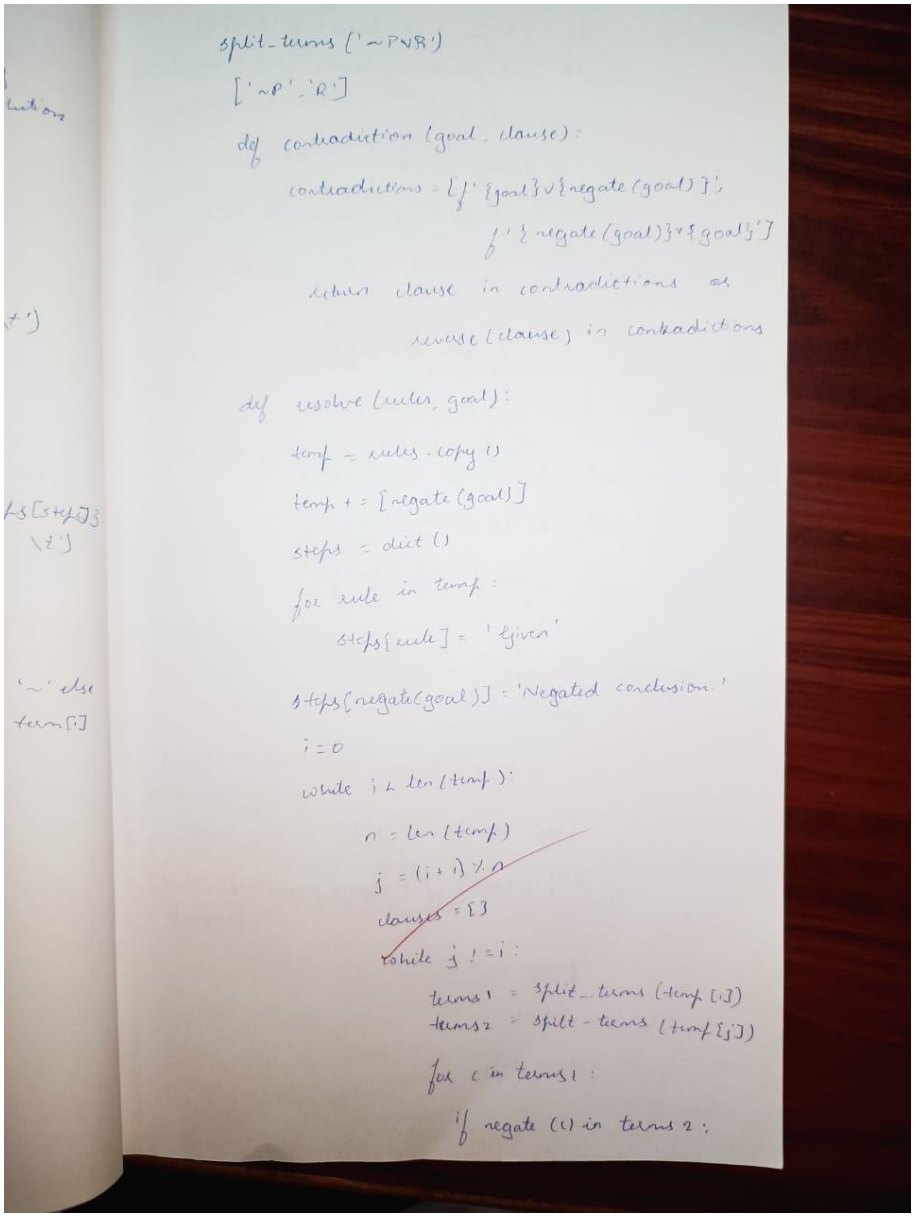
```
combinations=[(True,True,
True),(True,True,False),(True,False,True),(True,False, False),(False,True,
True),(False,True, False),(False, False,True),(False,False, False)]
variable={'p':0,'q':1, 'r':2} kb=" q=" priority={'~':3,'v':1,'^':2} def
input_rules(): global kb, q kb = (input("Enter rule: ")) 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 == '^':
```

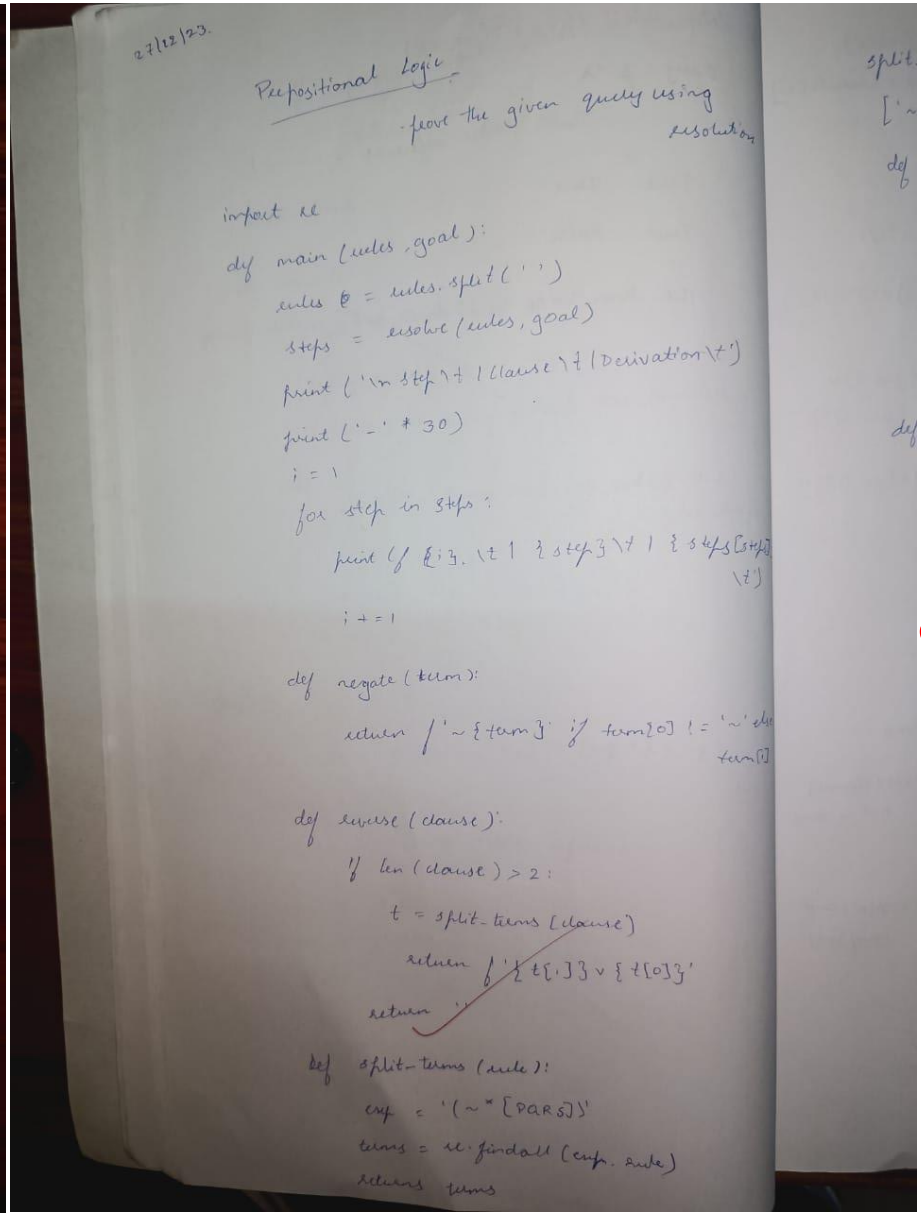
```
        return val2 and val1
    return val2 or val1 #Test 1
input_rules() ans = entailment() if ans:
print("Knowledge Base entails query")
else:
    print("Knowledge Base does not entail query")
#Test 2 input_rules() ans = entailment() if
ans:  print("Knowledge  Base  entails
query")
else:
    print("Knowledge 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
```



```
split_terms ('~PVR')
['~P', 'R']

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:
```



27/12/23.

Propositional Logic

- 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
```

Lab Program 7

Output :-

step	clause	Derivation
1		RvP	Given
2		R v ~P	Given
3		~R v P	Given
4		~R v ~P	Given
5		~R	Negated conclusion.
6			Resolved RvP and ~RvP to RvR, which is in turn null.

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

Sneha
27/12/23

```
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]}')
elif len(gen) == 1:
    clauses += [f'{gen[0]}']
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
```

Create a knowledgebase using prepositional logic and prove the given query using resolution

Objective: The resolution takes two clauses and produces a new clause which includes all the literals except the two complementary literals if exists. The knowledge base is conjuncted with the not of the give query and then resolution is applied.

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:

```
#Test1
TELL(['implies', 'p', 'q'])
TELL(['implies', 'r', 's'])
ASK(['implies',['or','p','r'], ['or', 'q', 's']])
```

```
True
```

```
CLEAR()
```

```
#Test2
TELL('p')
TELL(['implies',['and','p','q'],'r'])
TELL(['implies',['or','s','t'],'q'])
TELL('t')
ASK('r')
```

```
True
```

```
CLEAR()
```

```
#Test3
TELL('a')
TELL('b')
TELL('c')
TELL('d')
ASK(['or', 'a', 'b', 'c', 'd'])
```

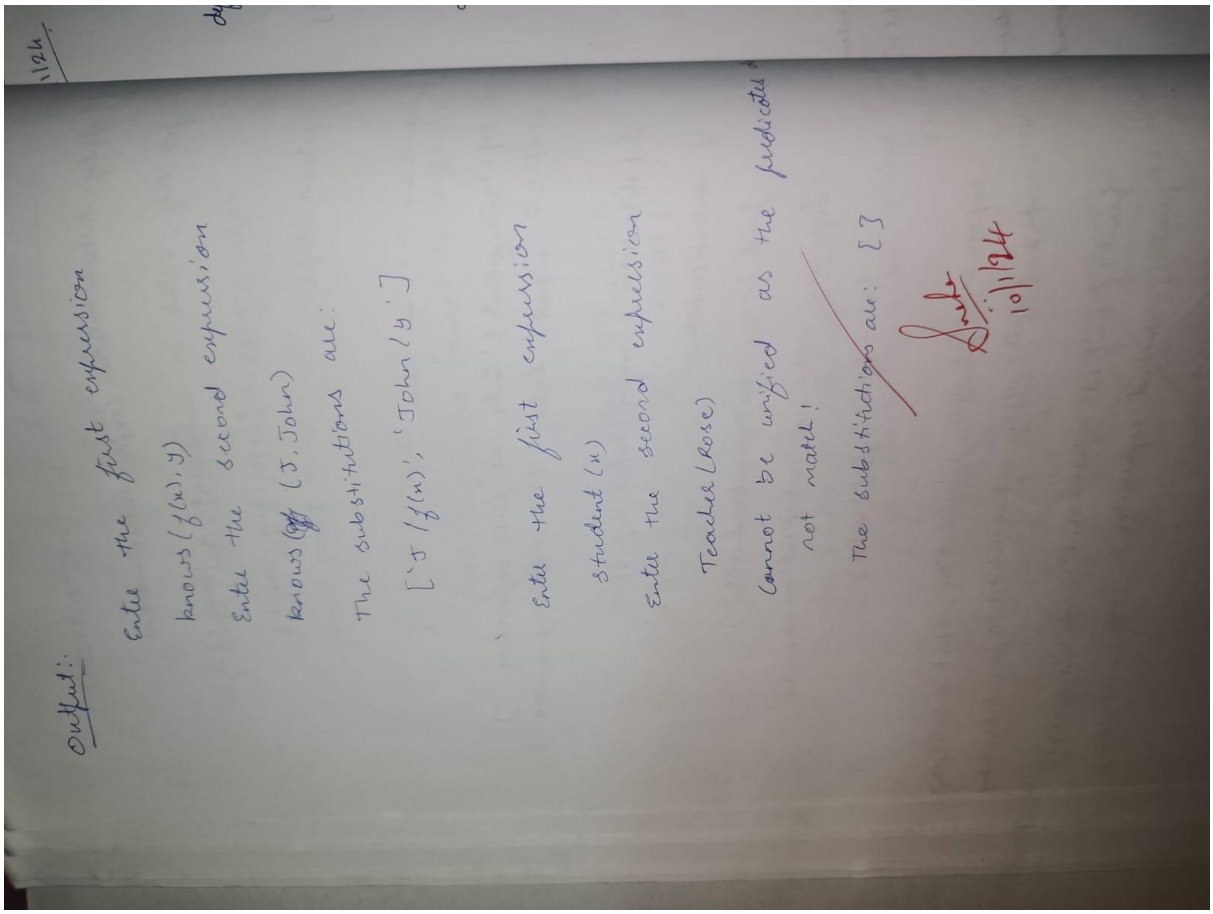
Lab Program 8

```
    return substitution

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

if __name__ == "__main__":
    expr1 = input("Enter the first expression: ")
    expr2 = input("Enter the second expression: ")

    substitution = unify(expr1, expr2)

    if substitution:
        print("The substitutions are:")
        for key, value in substitution.items():
            print(f'{key} / {value}')

        expr1_result = apply_substitution(expr1, substitution)
        expr2_result = apply_substitution(expr2, substitution)

        print(f'Unified expression 1: {expr1_result}')
        print(f'Unified expression 2: {expr2_result}')
```

10/1/23

UNIFIATION IN FIRST ORDER LOGIC

```
def unify(expr1, expr2):
    func1, args1 = expr1.split('(', 1)
    func2, 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.islower() and not a2.islower():
            substitution[a1] = a2
        elif not a1.islower() and a2.islower():
            substitution[a2] = a1
        elif a1 != a2:
            print("Expressions cannot be unified
                  Incompatible arguments")
```



Implement unification in first order logic

Objective: Unification can find substitutions that make different logical expressions identical. Unify takes two sentences and make a unifier for the two if a unification exist.

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:

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

Lab Program 9

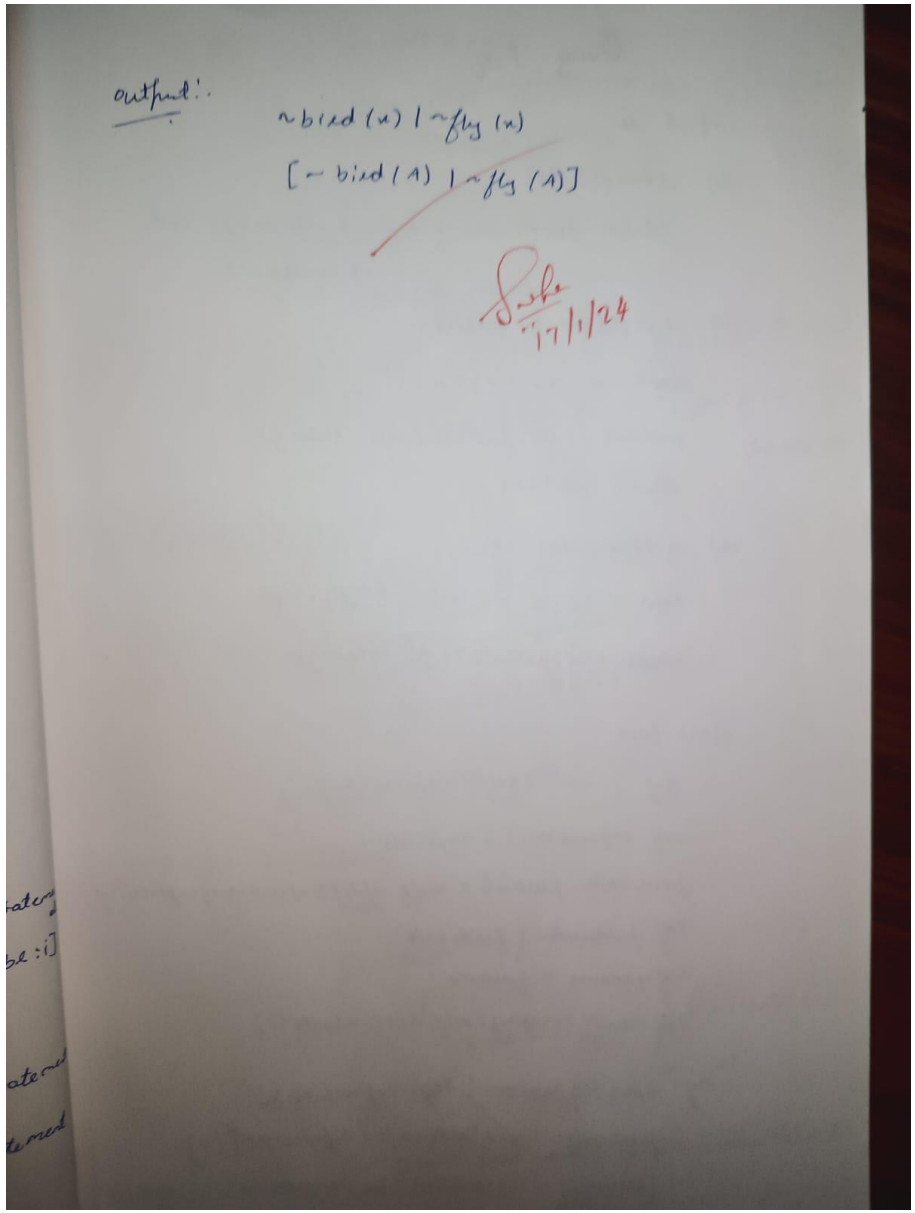
```
import re

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 stat
        new_statement = '~' + statement[br
                + '|' + statement[i+1:]
        statement = statement[:br] + new_state
                if br>0 else new_statem
    return skolemization(statement)

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

output

17/1/24

CONVERSION OF FIRST ORDER LOGIC TO 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))
```


output:
~bird(x) | ~fly(x)
[~bird(A) | ~fly(A)]
17/1/24

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

Objective: FOL logic is converted to CNF makes implementing resolution theorem easier.

Code:

```
import re
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 DeMorgan(sentence):
    string = ''.join(list(sentence).copy()) string =
    string.replace('~~','') flag = '[' in string string =
    string.replace('~[','') string = string.strip(']') for
    predicate in getPredicates(string): string =
    string.replace(predicate, f'~{predicate}')
    s = list(string) for i, c in
    enumerate(string):
        if c == 'V':
            s[i] = '^'
        elif c == '^':
            s[i] = 'V'
    string = ''.join(s) string =
    string.replace('~~','') return
    f'[{string}]' if flag else string def
    Skolemization(sentence):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    statement = ''.join(list(sentence).copy())
```

```
    matches = re.findall('[∀∃].', statement) for
    match in matches[::-1]: statement =
    statement.replace(match, '') statements =
    re.findall('\[\[^]]+\]]', statement) for s in statements:
    statement = statement.replace(s, s[1:-1])
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate) if
            ''.join(attributes).islower():
                statement =
statement.replace(match[1],SKOLEM_CONSTANTS.pop(0)
            ) else: aL = [a for a in attributes if a.islower()] aU = [a
            for a in attributes if not a.islower()][0]
                statement = statement.replace(aU,
f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if len(aL) else match[1]})')
    return statement

def fol_to_cnf(fol):
statement = fol.replace("<=>", "_")
    while '_' in statement: i =
    statement.index('_')
        new_statement = '[' + statement[:i] + '=>' + statement[i+1:] + ']^['+
statement[i+1:] + '=>' + statement[:i] + ']'
        statement = new_statement
    statement = statement.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] + 'V' + statement[i+1:] statement = statement[:br] +
     new_statement if br > 0 else new_statement while '~∀' in statement:
     i = statement.index('~∀')
        statement = list(statement)
```

```
                statement[i], statement[i+1], statement[i+2] = '∃',
statement[i+2], '~'
    statement = ''.join(statement) while
  '~∃' in statement: i =
  statement.index('~∃')
    s = list(statement)
      s[i], s[i+1], s[i+2] = '∀', s[i+2], '~' statement =
    ''.join(s)
  statement = statement.replace('~[∀','[~∀')
  statement = statement.replace('~[∃','[~∃') expr =
  '(~[∀V∃].)'
 statements = re.findall(expr, statement) for
 s in statements:
    statement = statement.replace(s, fol_to_cnf(s))
 expr = '~\[[^]]+\]' statements =
 re.findall(expr, statement) for s in
 statements:
    statement = statement.replace(s, DeMorgan(s))
 return statement

def main(): print("Enter FOL:") fol = input()
  print("The CNF form of the given FOL is:
  ") print(Skolemization(fol_to_cnf(fol)))
main()
```

Output:

```
main()

Enter FOL:
∀x food(x) => likes(John, x)
The CNF form of the given FOL is:
~ food(A) V likes(John, A)
```

```
main()

Enter FOL:
∀x[∃z[loves(x,z)]]
The CNF form of the given FOL is:
[loves(x,B(x))]
```

```
def get constants (self):
    return [None if is Vaiable (c) else c for c in
                self.params]

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

```
class implications:
    def __init__(self, expression):
        self.expression = expression
        self.lhs = Fact(lhs[i])

    def evaluate (self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            if v:
                constant[v] = fact.get(constants[i]
                new_lhs.append(fact)
        return fact(exp) if less(new_lhs) and
            all([f.get result() for f in
            new_lhs]) else None.
```

Query FOL

```
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-zA-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 = getPredicate(expression)[0]
        params = getAttributes(expression)[0].split(',')
        return [predicate, params]
```

Lab Program 10

Output :-

All facts :

P_1 = king (John)

P_1' = king (x)

P_2' = greedy (x)

P_2 = greedy (y)

P_3 = (x | John, y | John)

q = evil (x)

⇒ evil (John)

31/1/24

```
class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()

    def (self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.self.facts.add(Fact(e))

        if res:
            self.facts.add(res)

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

kb = KBC()
kb = tell('king(x) and greedy(x) => ev
kb.tell('king(John)')
kb.full('greedy(John)')
kb.full('king(Richard)')
kb.query
```

Output :-

All fac

P_1 =

P_1'

P_2'

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

Objective: A forward-chaining algorithm will begin with facts that are known. It will proceed to trigger all the inference rules whose premises are satisfied and then add the new data derived from them to the known facts, repeating the process till the goal is achieved or the problem is solved.

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("Ente
        r the
        number of
        FOL
        expressions
        present in
        KB:") n =
        int(input())
        print("Ente
        r the
        expressions
        :") for i in
        range(n):
        fact =
        input()
        kb.tell(fact)
```

```
print("Enter the query:")
query = input() kb.ask(query)
kb.display()
```

Output:

```
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)
```