VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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

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

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Prajwal P (1BM22CS200),** who is a bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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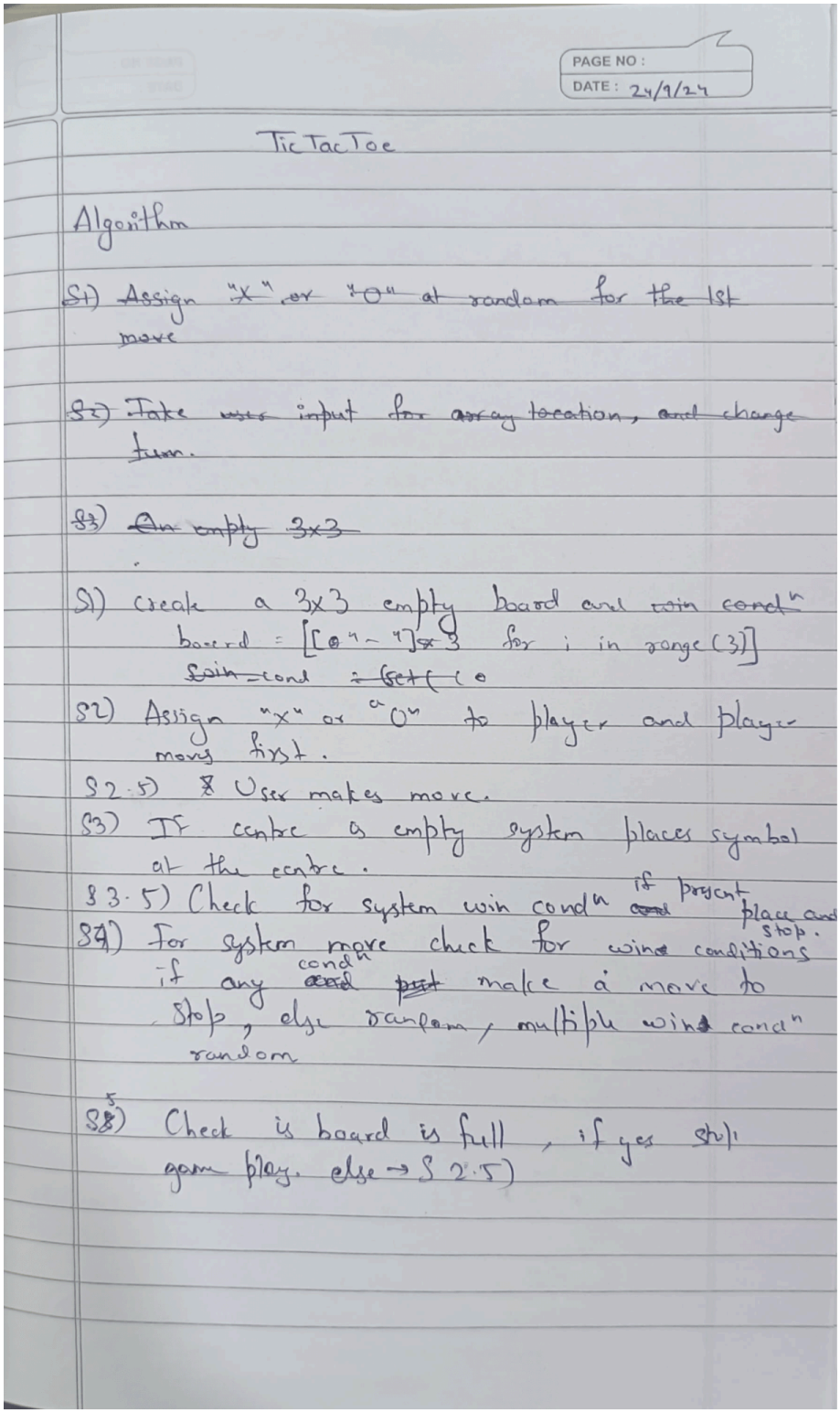
Index

Github Link:
AI Lab Github Link

Implement Tic-Tac-Toe Game.

Algorithm:



PAGE NO :
DATE : 24/9/24

TicTacToe

Algorithm

S1) ~~Assign "X" or "O" at random for the 1st move~~

~~S2) Take user input for array location, and change turn.~~

~~S3) On empty 3x3~~

S1) Create a 3x3 empty board and ~~win cond^n~~
board = [[" " for _ in range(3)] for _ in range(3)]
~~win_cond = {}~~

S2) Assign "X" or "O" to player and player moves first.

S2.5) User makes move.

S3) If centre is empty system places symbol at the centre.

S3.5) Check for system win cond^n ~~cond~~ if present place and stop.

S4) For system move check for wins conditions if any cond^n ~~cond~~ ~~print~~ make a move to stop, else random, multiple win cond^n random

S5) Check is board is full, if yes stop game play. else → S2.5)

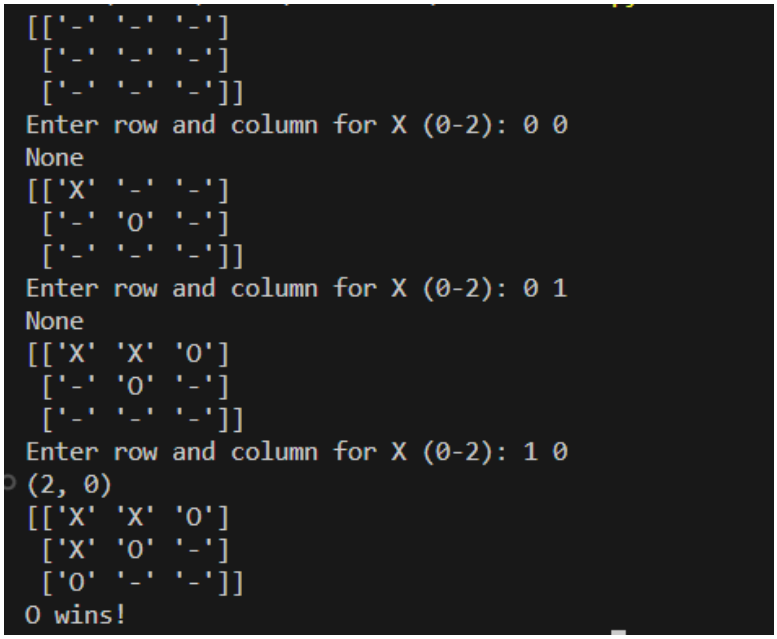
Code:

```
import random
import numpy as np

board = [["-"] * 3 for _ in range(3)]

def check_win():
    for i in range(3):
        if board[i][0] == board[i][1] == board[i][2] != "-":
            return True
        if board[0][i] == board[1][i] == board[2][i] != "-":
            return True

    if board[0][0] == board[1][1] == board[2][2] != "-":
        return True
    if board[0][2] == board[1][1] == board[2][0] != "-":
        return True

    return False

def full():
    return all(cell != "-" for row in board for cell in row)

def can_win(m):
    for i in range(3):
        row = board[i]
        if row.count(m) == 2 and row.count("-") == 1:
```

```
            return (i, row.index("-"))

    for i in range(3):
        col = [board[j][i] for j in range(3)]
        if col.count(m) == 2 and col.count("-") == 1:
            return (col.index("-"), i)

    diag1 = [board[i][i] for i in range(3)]
    if diag1.count(m) == 2 and diag1.count("-") == 1:
        return (diag1.index("-"), diag1.index("-"))

    diag2 = [board[i][2 - i] for i in range(3)]
    if diag2.count(m) == 2 and diag2.count("-") == 1:
        return (diag2.index("-"), 2 - diag2.index("-"))

    return None

def display():
    print(np.array(board))

while True:
    display()
    u = tuple(map(int, input("Enter row and column for X (0-2): ").strip().split()))
    if board[u[0]][u[1]] != "-":
        print("Invalid move, try again.")
        continue
```

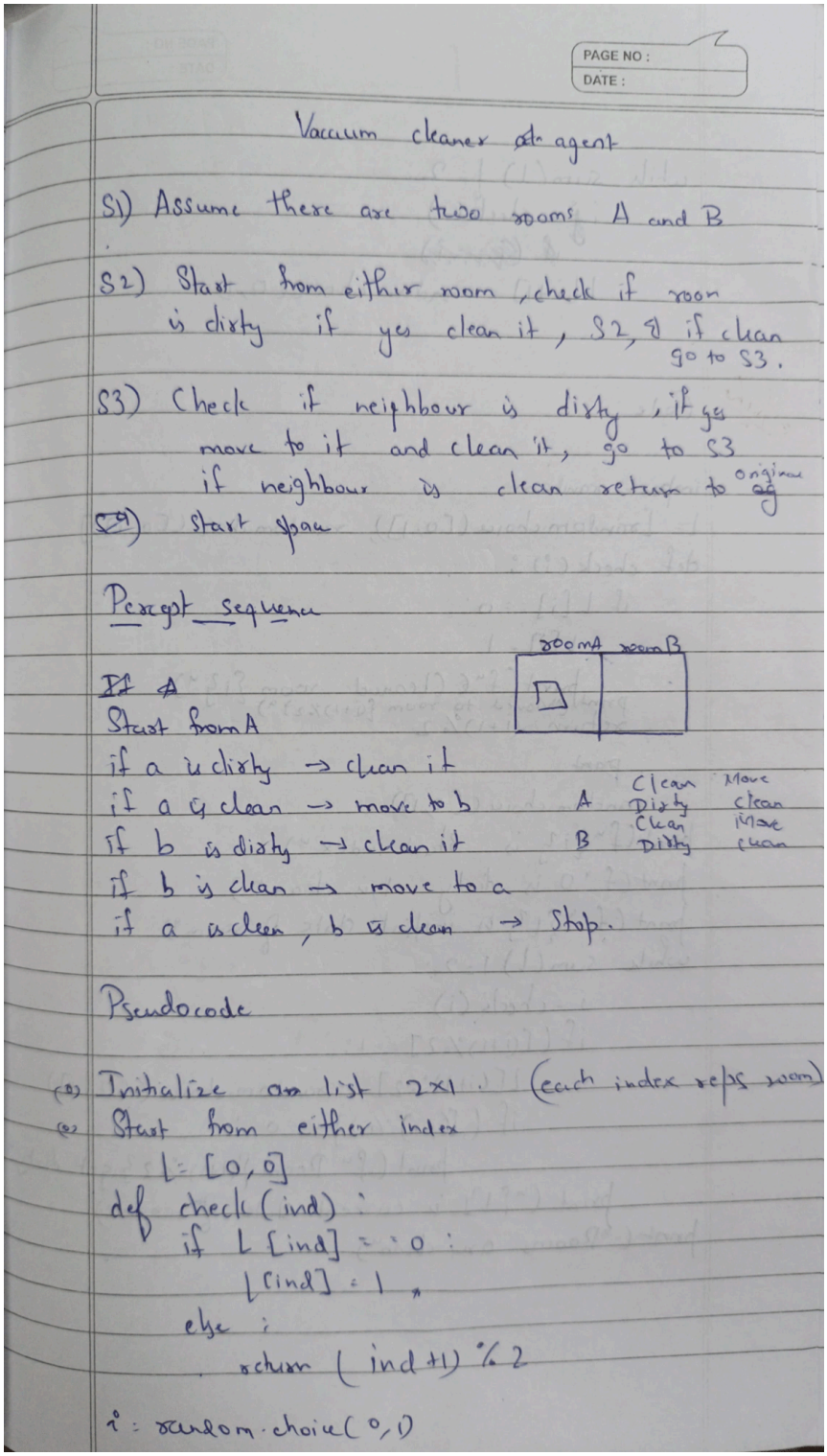
```
board[u[0]][u[1]] = "X"

if check_win():
    display()
    print("X wins!")
    break

if full():
    display()
    print("It's a tie!")
    break

move = can_win("O")
print(move)
if move is None:
    move = can_win("X")
    if move is None:
        empty = [(i, j) for i in range(3) for j in range(3) if board[i][j] == "-"]
        move = random.choice(empty)
if board[1][1]=="-":
    move=(1 ,1)
board[move[0]][move[1]] = "O"

if check_win():
    display()
    print("O wins!")
    break
```

Output:


[['-' '-' '-']
['-' '-' '-']
['-' '-' '-']]
Enter row and column for X (0-2): 0 0
None
[['X' '-' '-']
['-' 'O' '-']
['-' '-' '-']]
Enter row and column for X (0-2): 0 1
None
[['X' 'X' 'O']
['-' 'O' '-']
['-' '-' '-']]
Enter row and column for X (0-2): 1 0
(2, 0)
[['X' 'X' 'O']
['X' 'O' '-']
['O' '-' '-']]
O wins!

Implement Vacuum Cleaner Agent.

Algorithm:



PAGE NO :
DATE :

Vacuum cleaner agent

S1) Assume there are two rooms A and B

S2) Start from either room, check if room is dirty if yes clean it, S2, if clean go to S3.

S3) Check if neighbour is dirty, if yes move to it and clean it, go to S3 if neighbour is clean return to original

S4) Stop

Percept sequence

Start from A
if a is dirty → clean it
if a is clean → move to b
if b is dirty → clean it
if b is clean → move to a
if a is clean, b is clean → Stop.

	Clean	Move
A	Dirty	clean
	Clean	Move
B	Dirty	clean

Pseudocode

```
Initialize as list 2x1. (each index refs room)
Start from either index
    L = [0, 0]
def check(ind):
    if L[ind] == 0:
        L[ind] = 1
    else:
        return (ind+1) % 2
i = random.choice(0,1)
```

PAGE NO :
DATE :

```
while sum(l) != 2:
    i = check(i)
    l[i+1] = random.choice(0,1)
```

Code:

```
import random
l = [random.choice([0,1]), random.choice([0,1])]
def check(i):
    if l[i] == 0:
        l[i] = 1
        print(f"{Cleaned room {i}")
print("Moved to room {(i+1)%2}")
return (i+1)%2
print
i = random.choice([0,1])
print(f"{i} is start index")
print(f"0 is dirty 1 is clean")
print(f"{l} is initial state of room")
while sum(l) != 2:
    i = check(i)
    if [(i+1)%2] == 1:
        l[(i+1)%2] = random.choice([0,1])
        if [(i+1)%2] == 0:
            print(f"Room {(i+1)%2} got dirty")
    print("{l} is current state of room")
print("Rooms are clean")
```

Code:

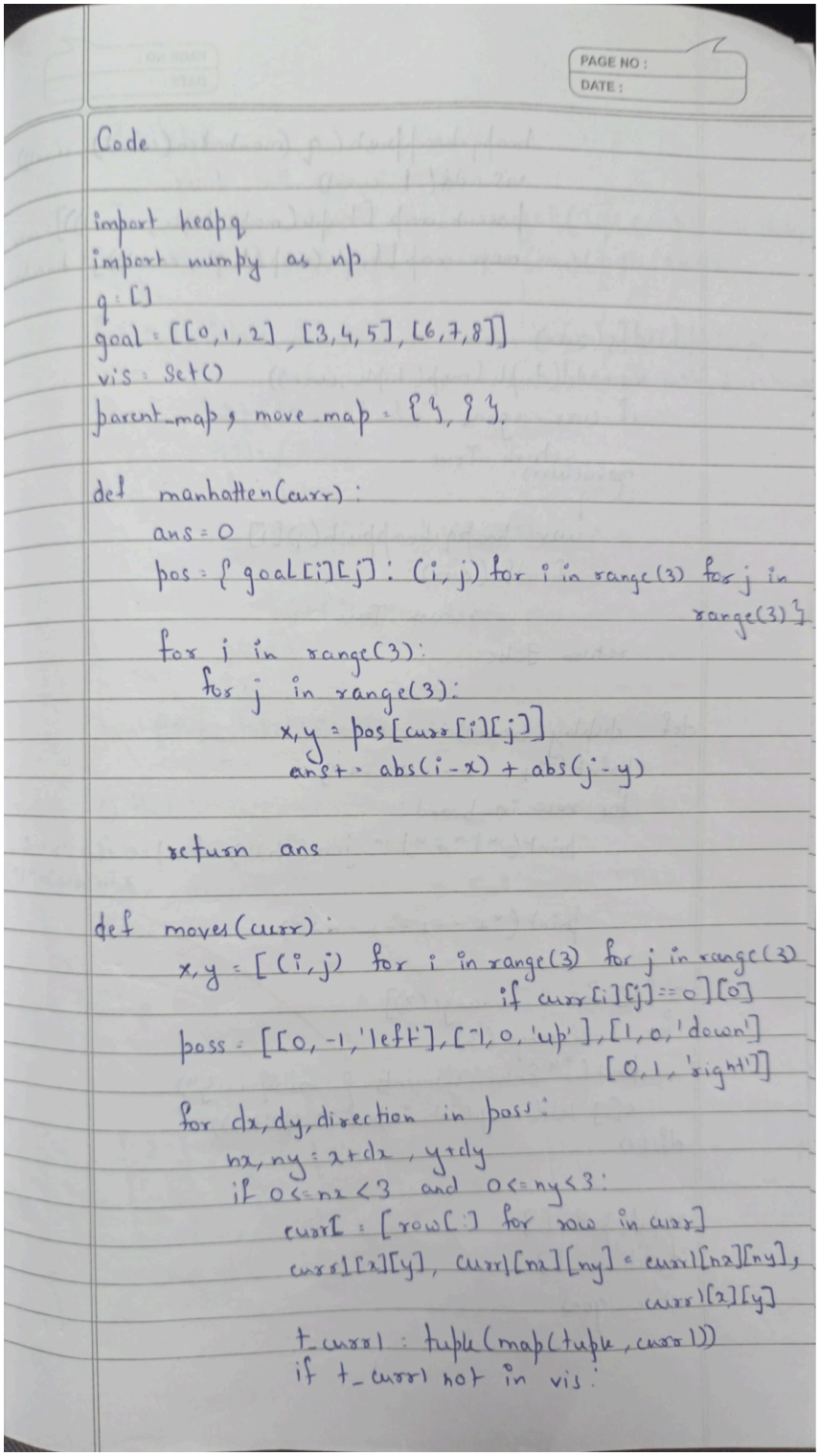
```
import random
l=[random.choice([0,1]),random.choice([0,1])]
def check(i):
    if l[i]==0:
        l[i]=1
        print(f"Cleaned Room {i}")
    print(f"Moved to Room {(i+1)%2}")
    return (i+1)%2
i=random.choice([0,1])

print(f"{i} is the start index")
print("0 is dirty and 1 is clean")
print(f"{l} is the initial state of room")

while sum(l)!=2:
    i=check(i)
    if l[(i+1)%2]==1:
        l[(i+1)%2]=random.choice([0,1])
        if l[(i+1)%2]==0:
            print(f"Room {(i+1)%2} got dirty")
    print(f"{l} is current state of rooms")
print("Rooms are clean")
```

Output:

```
1 is the start index
0 is dirty and 1 is clean
[0, 0] is the initial state of room
Cleaned Room 1
Moved to Room 0
Room 1 got dirty
[0, 0] is current state of rooms
Cleaned Room 0
Moved to Room 1
Room 0 got dirty
[0, 0] is current state of rooms
Cleaned Room 1
Moved to Room 0
Room 1 got dirty
[0, 0] is current state of rooms
Cleaned Room 0
Moved to Room 1
Room 0 got dirty
[0, 0] is current state of rooms
Cleaned Room 1
Moved to Room 0
[0, 1] is current state of rooms
Cleaned Room 0
Moved to Room 1
Room 0 got dirty
[0, 1] is current state of rooms
Moved to Room 0
Room 1 got dirty
[0, 0] is current state of rooms
Cleaned Room 0
Moved to Room 1
[1, 0] is current state of rooms
Cleaned Room 1
Moved to Room 0
[1, 1] is current state of rooms
Rooms are clean
```

Implement 8 puzzle problems using Depth First Search (DFS).

Algorithm:



Code

```
import heapq
import numpy as np
q = []
goal = [[0,1,2],[3,4,5],[6,7,8]]
vis = set()
parent_map, move_map = {}, {}

def manhatten(curr):
    ans = 0
    pos = {goal[i][j]: (i,j) for i in range(3) for j in
                                                range(3)}

    for i in range(3):
        for j in range(3):
            x,y = pos[curr[i][j]]
            ans += abs(i-x) + abs(j-y)

    return ans

def moves(curr):
    x,y = [(i,j) for i in range(3) for j in range(3)
                                    if curr[i][j]==0][0]
    poss = [[0,-1,'left'],[-1,0,'up'],[1,0,'down']
                                    [0,1,'right']]

    for dx,dy,direction in poss:
        nx,ny = x+dx, y+dy
        if 0<=nx<3 and 0<=ny<3:
            currL = [row[:] for row in curr]
            currL[x][y], currL[nx][ny] = currL[nx][ny],
                                        currL[x][y]

            t_currL = tuple(map(tuple,currL))
            if t_currL not in vis:
```

PAGE NO :
DATE :

```
while state:
    result_path.append(state)
    directions.append(move_maps.get(tuple(map(tuple,state))))
    state = parent_map.get(tuple(map(tuple,state)))

for ind, (state, direction) in enumerate(reversed(list(zip(
                                        result_path, directions)))):
    print(f"Step {ind}:")
    display(state)
    if ind == 0:
        print("Initial State")
    if direction:
        print(f"Move empty space {direction}")
    print()

print(f"Steps taken: {len(result_path)-1}")
```

Output :-

```
Enter elements of row 1: 3 7 6
Enter elements of row 2: 4 5 8
Enter elements of row 3: 2 0 1

Step 0:
+---+---+---+
| 3 | 7 | 6 |
+---+---+---+
| 2 | 4 | 8 |
+---+---+---+
| 2 |   | 1 |
+---+---+---+
Initial State
```

Code:

```
import heapq
import numpy as np


goal = [[0,1,2], [3,4,5], [6,7,8]]
vis = set()
q = []
parent_map = {}
move_map = {}


def manhattan(curr):
    ans = 0
    pos = {goal[i][j]: (i, j) for i in range(3) for j in range(3)}
    for i in range(3):
        for j in range(3):
            x, y = pos[curr[i][j]]
            ans += abs(i - x) + abs(j - y)
    return ans


def moves(curr):
    x, y = [(i, j) for i in range(3) for j in range(3) if curr[i][j] == 0][0]
    poss = [[0, -1, 'left'], [-1, 0, 'up'], [1, 0, 'down'], [0, 1, 'right']]
    for dx, dy, direction in poss:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            curr1 = [row[:] for row in curr]
```

```
            curr1[x][y], curr1[nx][ny] = curr1[nx][ny], curr1[x][y]
            tuple_curr1 = tuple(map(tuple, curr1))
            if tuple_curr1 not in vis:
                heapq.heappush(q, (manhattan(curr1), curr1))
                vis.add(tuple_curr1)
                parent_map[tuple(map(tuple, curr1))] = curr
                move_map[tuple(map(tuple, curr1))] = direction

def dfs(curr):
    vis.add(tuple(map(tuple, curr)))
    if curr == goal:
        return True
    moves(curr)
    if q:
        curr = heapq.heappop(q)[1]
        if dfs(curr):
            return True
    return False

def display_board(board):
    print("+---+---+---+")
    for row in board:
        print("| " + " | ".join(str(x) if x != 0 else ' ' for x in row) + " |")
        print("+---+---+---+")

c =[[] for i in range(3)]
for i in range(3):
```

```
  print(f"Enter elements of row {i+1}")
  c[i]=list(map(int,input().split()))
dfs(c)

result_path = []
directions = []
state = goal
while state:
    result_path.append(state)
    directions.append(move_map.get(tuple(map(tuple, state)), None))
    state = parent_map.get(tuple(map(tuple, state)))

for ind, (state, direction) in enumerate(reversed(list(zip(result_path, directions)))):
    print(f"Step {ind}:")
    display_board(state)
    if ind==0:
      print("Initial state")
    if direction:
        print(f" Move empty space {direction}")
    print()

print(f"Steps taken: {len(result_path) - 1}")
```

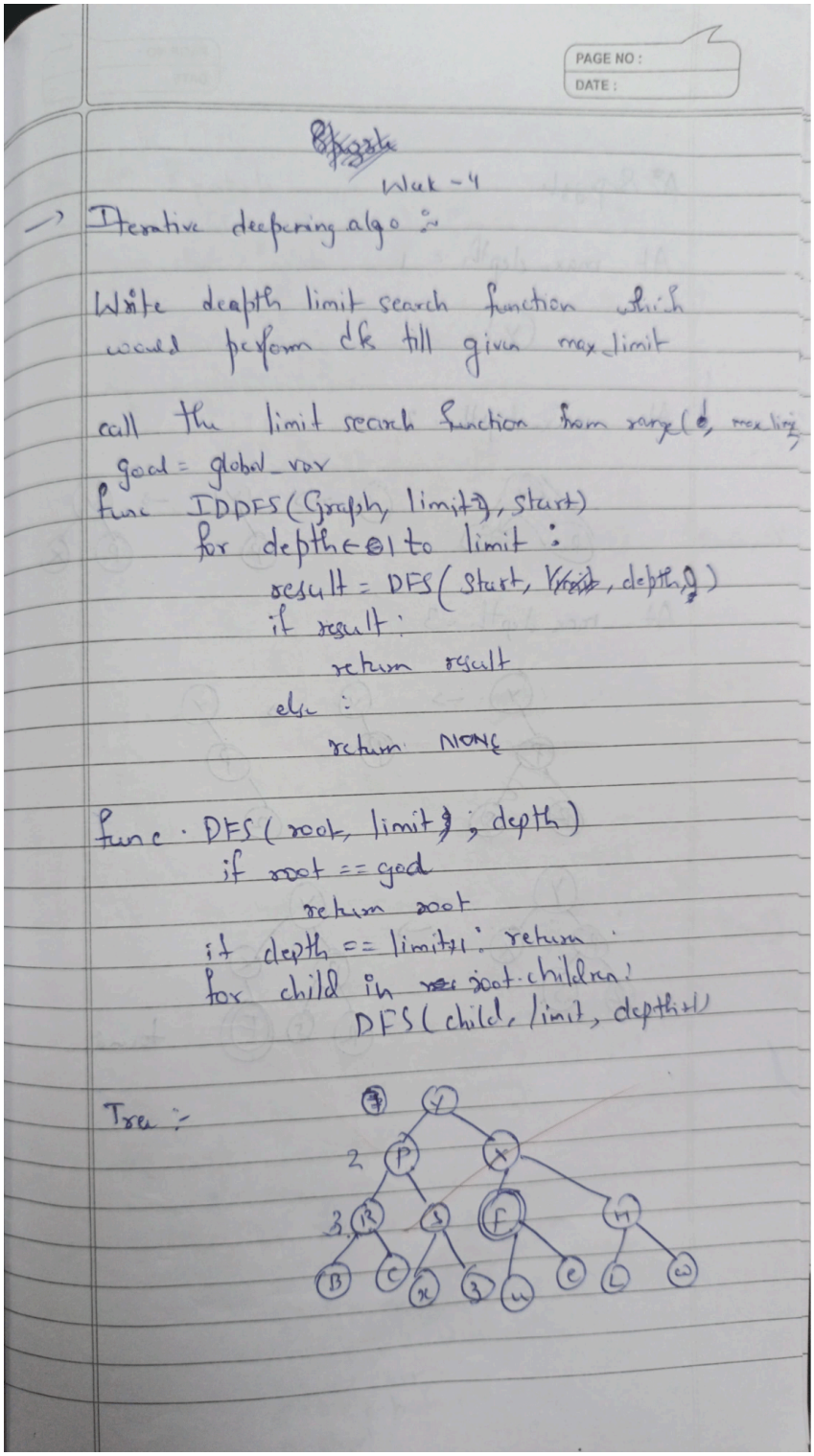
Output:

```
Enter elements of row 1
3 7 6
Enter elements of row 2
4 5 8
Enter elements of row 3
2 0 1
Step 0:
+---+---+---+
| 3 | 7 | 6 |
+---+---+---+
| 4 | 5 | 8 |
+---+---+---+
| 2 |   | 1 |
+---+---+---+
Initial state

Step 1:
+---+---+---+
| 3 | 7 | 6 |
+---+---+---+
| 4 |   | 8 |
+---+---+---+
| 2 | 5 | 1 |
+---+---+---+
 Move empty space up
```

```
Step 57:
+---+---+---+
| 3 | 1 | 2 |
+---+---+---+
| 4 |   | 5 |
+---+---+---+
| 6 | 7 | 8 |
+---+---+---+
 Move empty space down

Step 58:
+---+---+---+
| 3 | 1 | 2 |
+---+---+---+
|   | 4 | 5 |
+---+---+---+
| 6 | 7 | 8 |
+---+---+---+
 Move empty space left

Step 59:
+---+---+---+
|   | 1 | 2 |
+---+---+---+
| 3 | 4 | 5 |
+---+---+---+
| 6 | 7 | 8 |
+---+---+---+
 Move empty space up

Steps taken: 59
```

Implement Iterative deepening search algorithm.

Algorithm:



Code:

```
class TreeNode:
    def __init__(self, value):
        self.value = value
        self.children = []  # List to hold children nodes

    def add_child(self, child_node):
        self.children.append(child_node)

def iddfs(root, goal):
    for i in range(0,100000):
        res=dls(root,goal,i)
        if res:
            print("Found")
            return
    print("Not found")

def dls(root,goal,depth):
    if depth==0:
        if root.value==goal:
            return True
        return False
    for child in root.children:
        if dls(child,goal,depth-1):
            return True
    return False

root=TreeNode("Y")
node1=TreeNode("P")
node2=TreeNode("X")
node3=TreeNode("R")
node4=TreeNode("S")
node5=TreeNode("F")
node6=TreeNode("H")
node7=TreeNode("B")
node8=TreeNode("C")
```

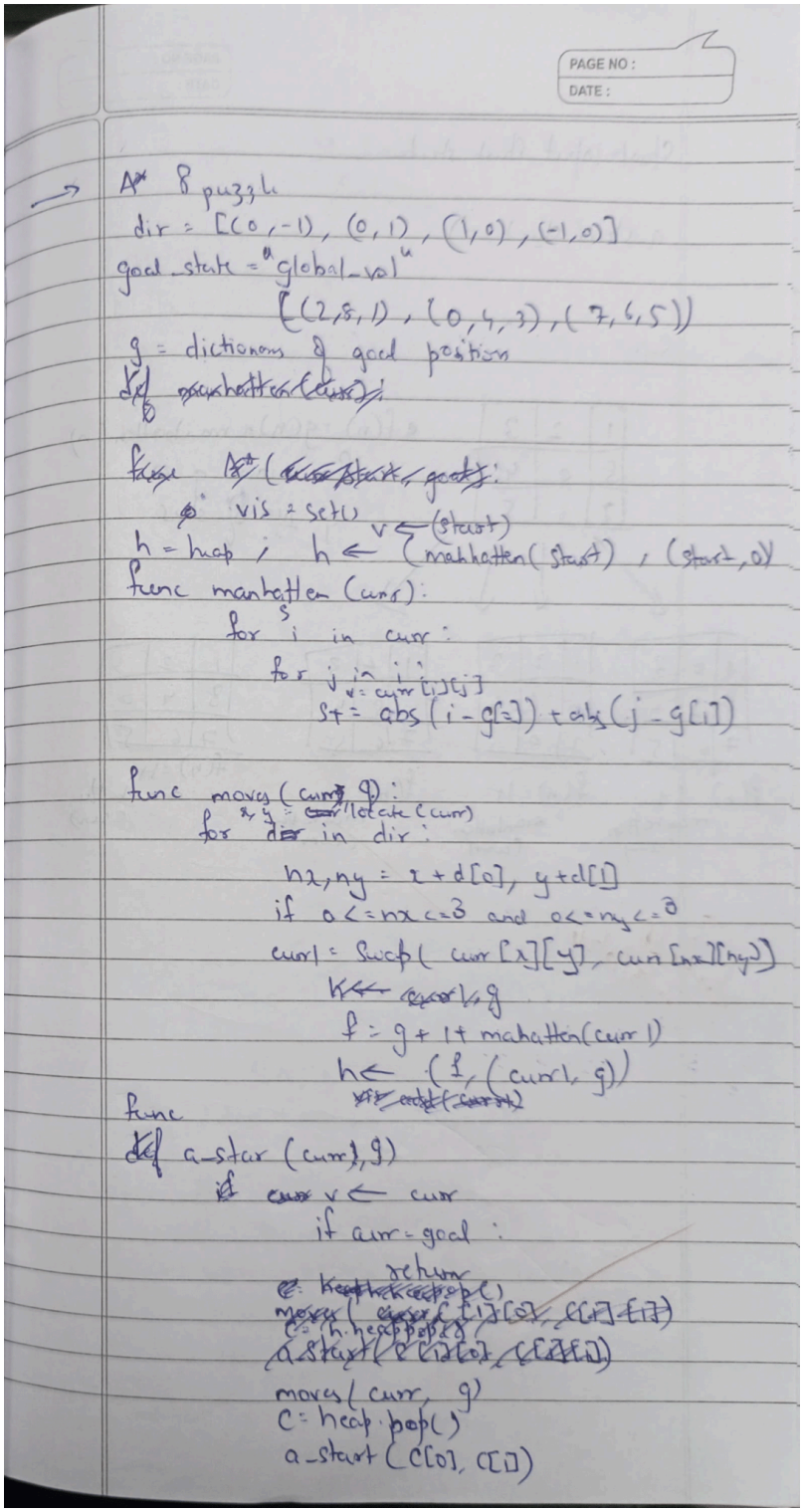
```
node9=TreeNode("S")

root.add_child(node1)
root.add_child(node2)

node1.add_child(node3)
node1.add_child(node4)

node2.add_child(node5)
node2.add_child(node6)

node3.add_child(node7)
node3.add_child(node8)

node4.add_child(node9)

iddfs(root, "F")
iddfs(root, "A")
```

Output:

```
Found
Not found
```

Implement A* search algorithm.

Algorithm:

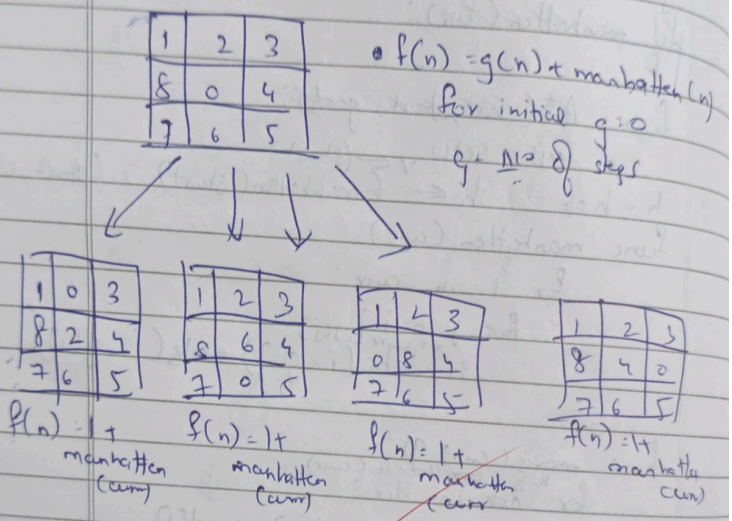


PAGE NO :
DATE :

Start = input Start state

q_start(start, 0)

Sol^n



15/10/24

Code:

```
import heapq
import numpy as np

goal = [[2,8,1], [0,4,3], [7,6,5]]
vis = set()
q = []
parent_map = {}
move_map = {}

def manhattan(curr):
    ans = 0
    pos = {goal[i][j]: (i, j) for i in range(3) for j in range(3)}
    for i in range(3):
        for j in range(3):
            x, y = pos[curr[i][j]]
            ans += abs(i - x) + abs(j - y)
    return ans

def moves(curr,g):
    x, y = [(i, j) for i in range(3) for j in range(3) if curr[i][j] == 0][0]
    poss = [[0, -1, 'left'], [-1, 0, 'up'], [1, 0, 'down'], [0, 1, 'right']]
    for dx, dy, direction in poss:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            curr1 = [row[:] for row in curr]
            curr1[x][y], curr1[nx][ny] = curr1[nx][ny], curr1[x][y]
            tuple_curr1 = tuple(map(tuple, curr1))
            if tuple_curr1 not in vis:
                f=g+1+manhattan(curr1)
                heapq.heappush(q, (f, curr1,g+1))
                vis.add(tuple_curr1)
                parent_map[tuple(map(tuple, curr1))] = curr
                move_map[tuple(map(tuple, curr1))] = direction

def a_star(curr,g):
    vis.add(tuple(map(tuple, curr)))
    if curr == goal:
        return True
    moves(curr,g)
    if q:
        curr = heapq.heappop(q)
        if a_star(curr[1],curr[2]):
            return True
    return False
```

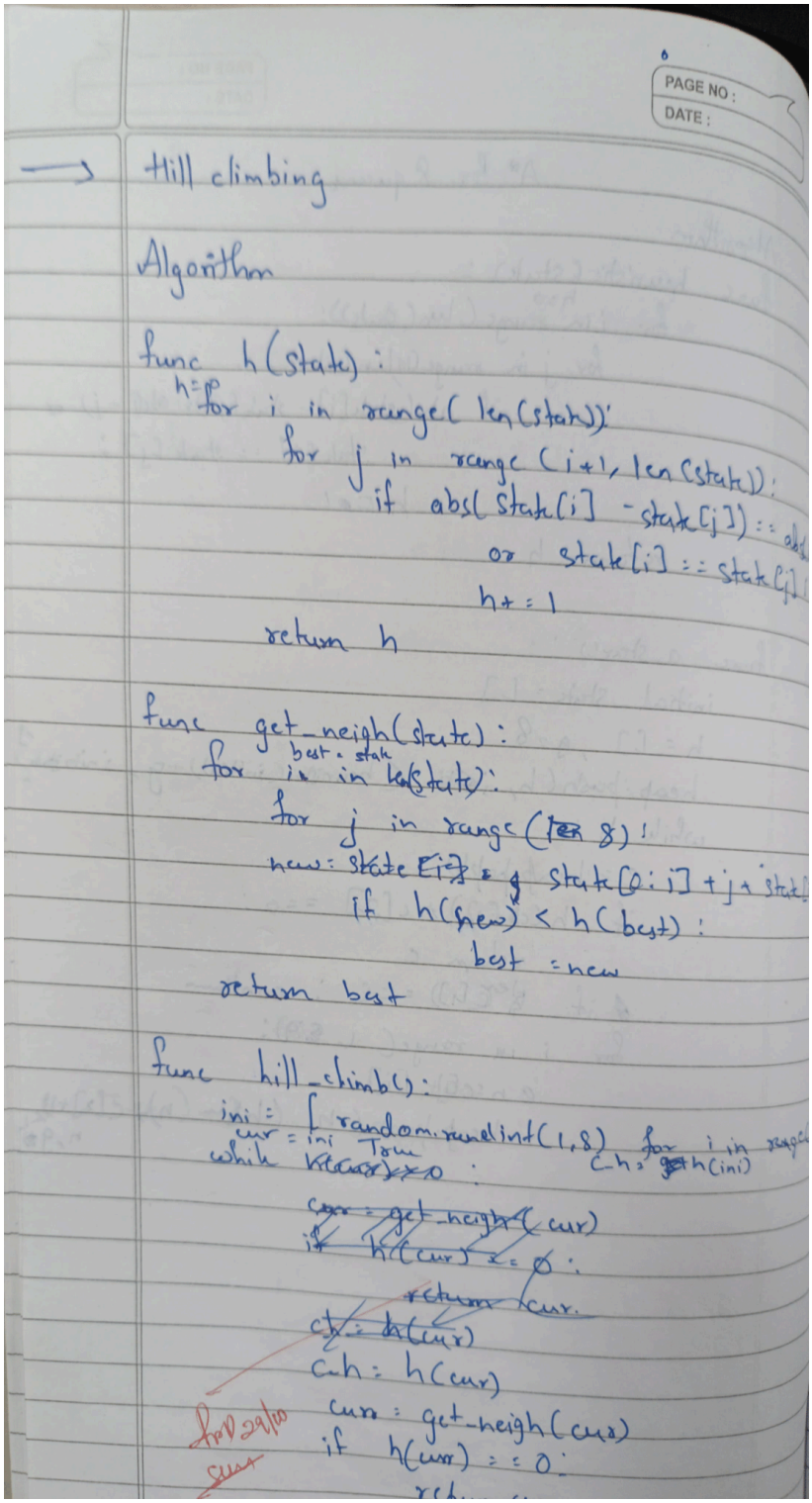
```
def display_board(board):
    print("+---+---+---+")
    for row in board:
        print("| " + " | ".join(str(x) if x != 0 else ' ' for x in row) + " |")
        print("+---+---+---+")

c =[[] for i in range(3)]
for i in range(3):
  print(f"Enter elements of row {i+1}")
  c[i]=list(map(int,input().split()))
a_star(c,0)

result_path = []
directions = []
state = goal
while state:
    result_path.append(state)
    directions.append(move_map.get(tuple(map(tuple, state)), None))
    state = parent_map.get(tuple(map(tuple, state)))

for ind, (state, direction) in enumerate(reversed(list(zip(result_path, directions)))):
    print(f"Step {ind}:")
    display_board(state)
    if ind==0:
      print("Initial state")
    if direction:
        print(f" Move empty space {direction}")
    print()

print(f"Steps taken: {len(result_path) - 1}")
```

Output:

```
Enter elements of row 1
1 2 3
Enter elements of row 2
8 0 4
Enter elements of row 3
7 6 5
Step 0:
+---+---+---+
| 1 | 2 | 3 |
+---+---+---+
| 8 |   | 4 |
+---+---+---+
| 7 | 6 | 5 |
+---+---+---+
Initial state

Step 1:
+---+---+---+
| 1 |   | 3 |
+---+---+---+
| 8 | 2 | 4 |
+---+---+---+
| 7 | 6 | 5 |
+---+---+---+
 Move empty space up
```

Implement Hill Climbing search algorithm to solve N-Queens problem.

Algorithm:

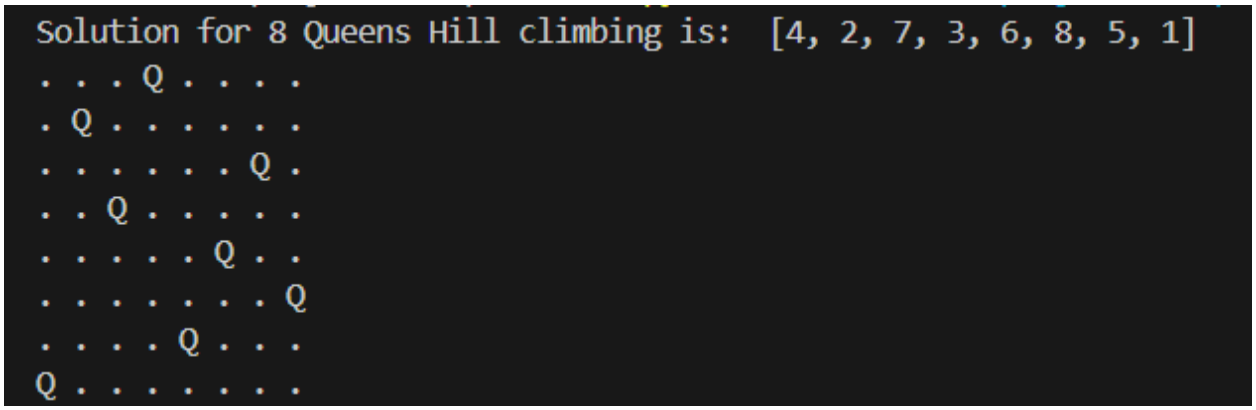


Code:

```
import random
def h(s):
    h = 0
    n = len(s)
    for i in range(n):
        for j in range(i + 1, n):
            if s[i] == s[j] or abs(s[i] - s[j]) == abs(i - j):
                h += 1
    return h

def new(s):
    best=s
    for i in range(len(s)):
        for j in range(1,9):
            if j!=s[i]:
                n=s[:i]+[j]+s[i+1:]
                if h(n)<h(best):
                    best=n
    return best

def hc():
    curr=[random.randint(1,8) for i in range(8)]
    while True:
        ch=h(curr)
        curr=new(curr)
        if h(curr)==0:
            return curr
        if h(curr)>=ch:
            curr=[random.randint(1,8) for i in range(8)]

def print_board(solution):
    print("Solution for 8 Queens Hill climbing is: ",solution)
    if solution is None:
        print("No solution found.")
        return

    board = [['.' for _ in range(8)] for _ in range(8)]

    for row in range(len(solution)):
        col = solution[row] - 1
        board[row][col] = 'Q'

    for row in board:
        print(' '.join(row))
```

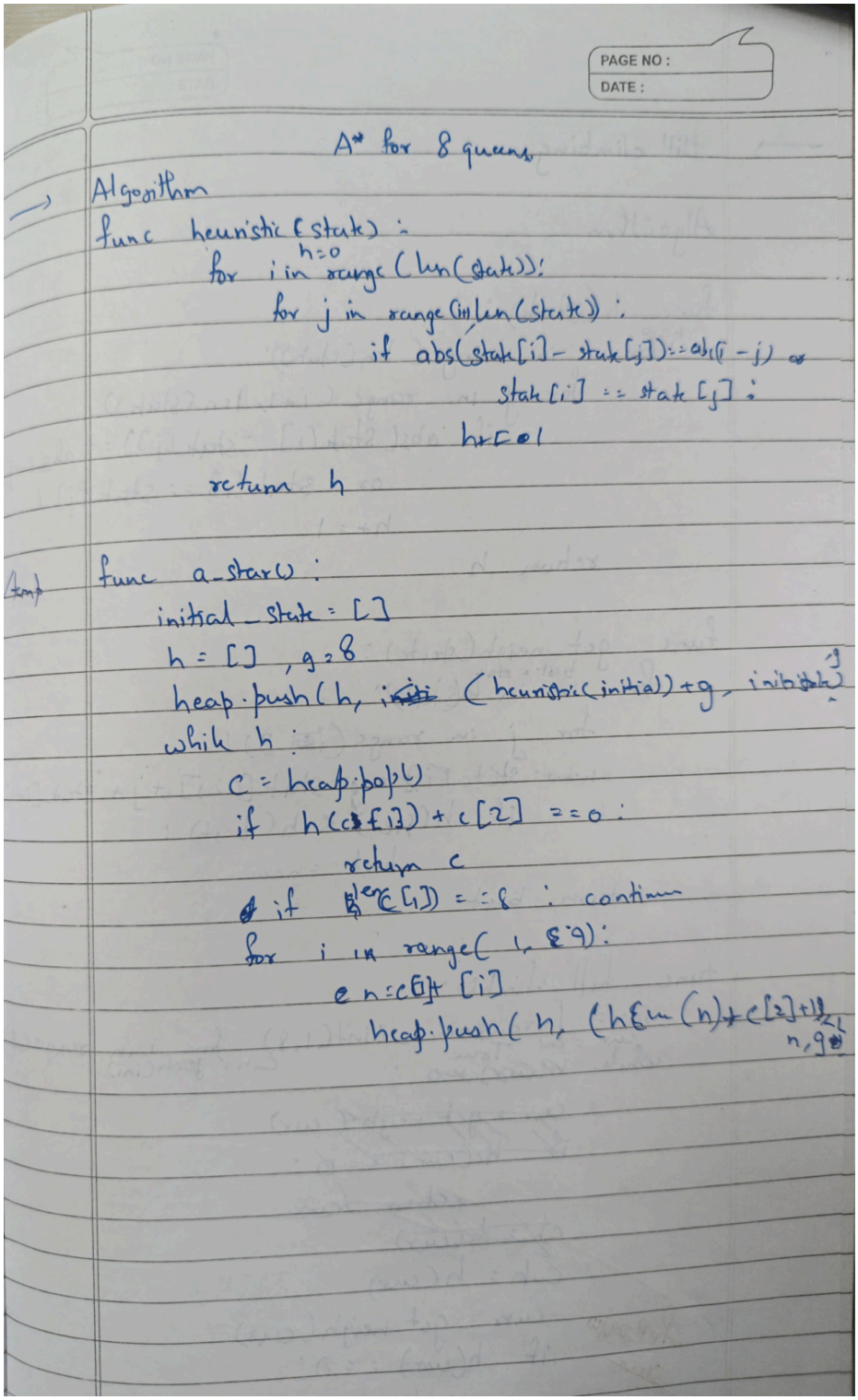
print_board(hc())

Output:



Implement A star algorithm to solve N-Queens problem.

Algorithm:

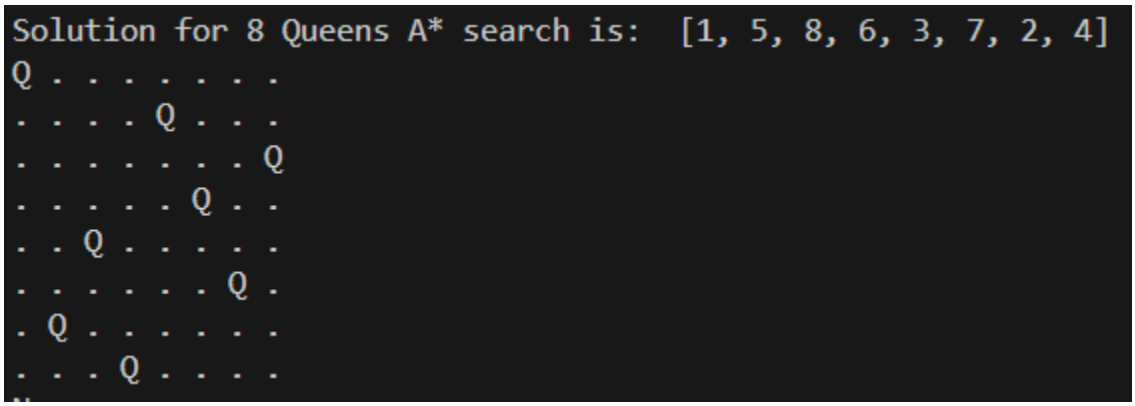


Code:

```
import heapq


def h(s):


    h = 0
    n = len(s)
    for i in range(n):
        for j in range(i + 1, n):
            if s[i] == s[j] or abs(s[i] - s[j]) == abs(i - j):
                h += 1
    return h


def a_star():
    initial_state = []
    q = []
    g = 8
    heapq.heappush(q, (h(initial_state), initial_state, g))


    while q:
        f, state, g = heapq.heappop(q)


        if len(state) == 8 and h(state) == 0:
            return state


        for i in range(1, 9):
            if i not in state:
```

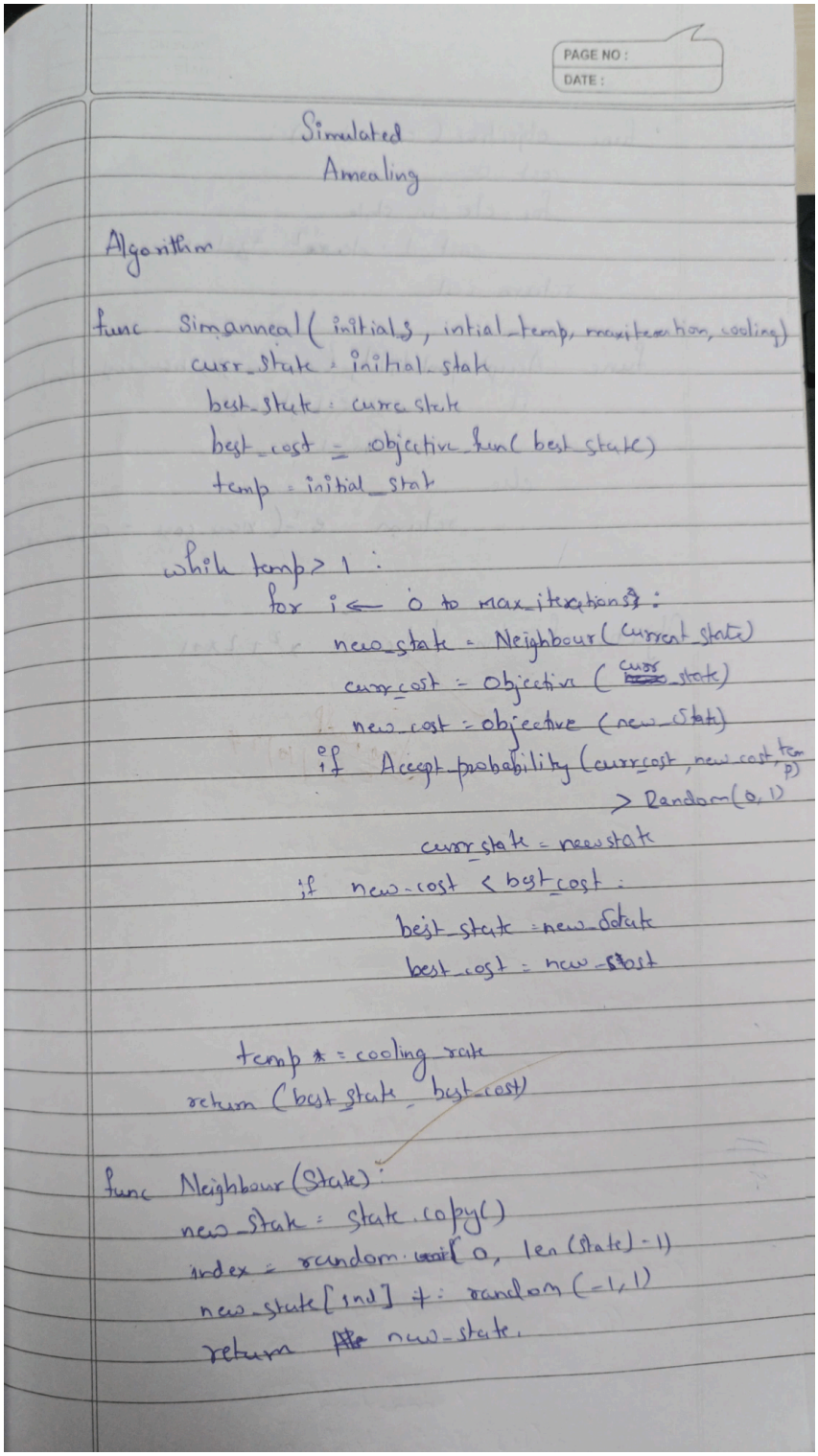
```
            new_state = state + [i]
            heapq.heappush(q, (h(new_state) + g, new_state, g - 1))

    return None

solution = a_star()
print("Solution:", solution)
```

Output:



Implement Simulated Annealing:

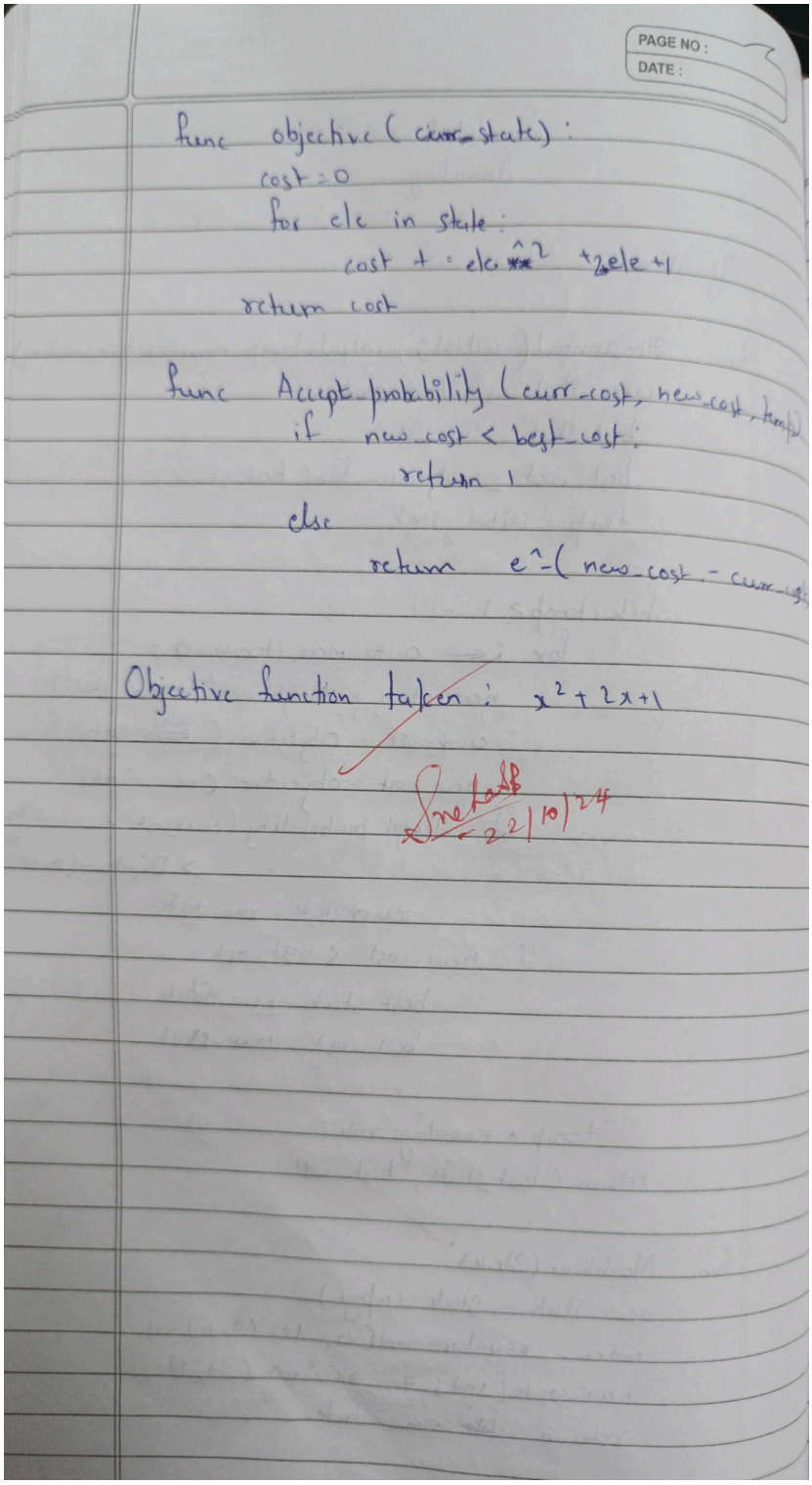
Algorithm:



Simulated
Annealing

Algorithm

```
func Simanneal( initial_s, intial_temp, maxiteration, cooling)
    curr_state = initial_state
    best_state = curr_state
    best_cost = objective_fun( best_state)
    temp = initial_stat

whil temp > 1 :
    for i <- 0 to max_iterations :
        new_state = Neighbour( current_state)
        curr_cost = objective ( curr_state)
        new_cost = objective (new_state)
        if Accept_probability (curr_cost, new_cost, temp)
                                > Random(0, 1)
            curr_state = new_state
        if new_cost < best_cost :
            best_state = new_state
            best_cost = new_cost

    temp *= cooling_rate
return (best_state, best_cost)

func Neighbour (State):
    new_state = state.copy()
    index = random.uniform( 0, len (State) - 1)
    new_state[ind] += random (-1, 1)
    return new_state.
```


PAGE NO :
DATE :
func objective (curr_state) :
cost = 0
for ele in state :
cost += ele ** 2 + 2*ele + 1
return cost
func Accept_probability (curr_cost, new_cost, temp)
if new_cost < best_cost :
return 1
else
return e^-(new_cost - curr_cost
Objective function taken : x^2 + 2x + 1
Implemented
22/10/24

Code:

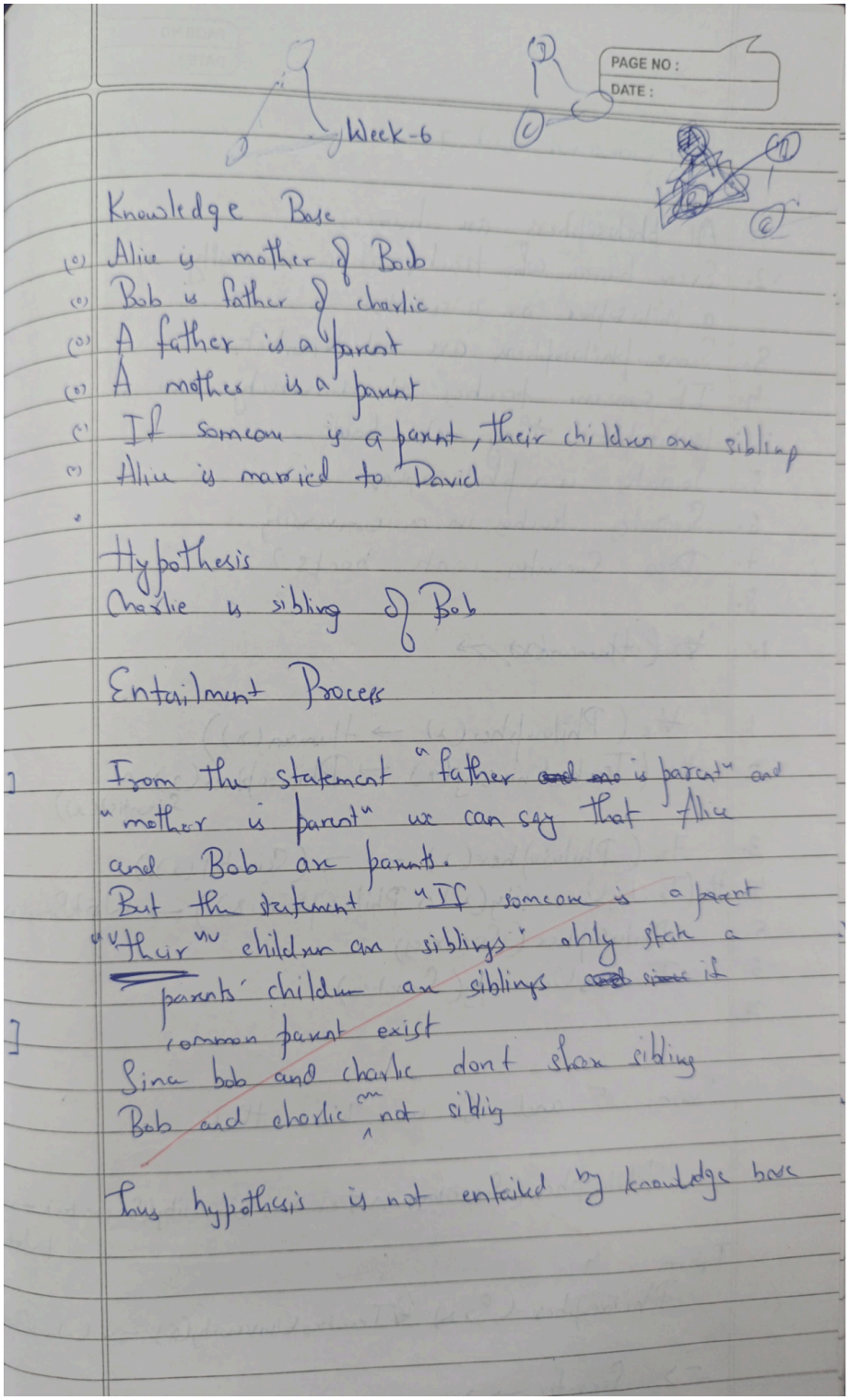
```
import random
import math

def sim_anneal(ini, in_temp, max_iter, cool):
    # Initialize current state and best state
    curr_s = ini
    best_s = curr_s
    best_c = obj(best_s)
    temp = in_temp  # Set the initial temperature

    # While the temperature is above a threshold
    while temp > 1:
        for i in range(max_iter):
            new_s = neig(curr_s)
            curr_c = obj(curr_s)
            new_c = obj(new_s)

            if ap(curr_c, new_c, temp) > random.random():
                curr_s = new_s  # Move to the new state
            if new_c < best_c:
                best_s = new_s
                best_c = new_c
        temp *= cool

    return best_s, best_c

def neig(state):
    new_s = state.copy()
    ind = random.randint(0, len(state) - 1)
    new_s[ind] += random.uniform(-1, 1)
    return new_s

def obj(state):
    c = 1
    for i in state:
        c += i**2 + 2*i + 1
    return c

def ap(curr_c, new_c, temp):
    if new_c < curr_c:
        return 1
    else:
        return math.exp((curr_c - new_c) / temp)

print(sim_anneal([1, 2, 3, 4, 5], 1000, 1000, 0.99))
```

Output:

```
[Running] python -u "c:\Users\bmsce\Desktop\san.py"
([-0.97275454497846, -1.036978056021493, -1.0024102215924622, -1.059180212134072, -0.9858194523412274], 0.0058188860547206955)
```

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

Algorithm:



Code:

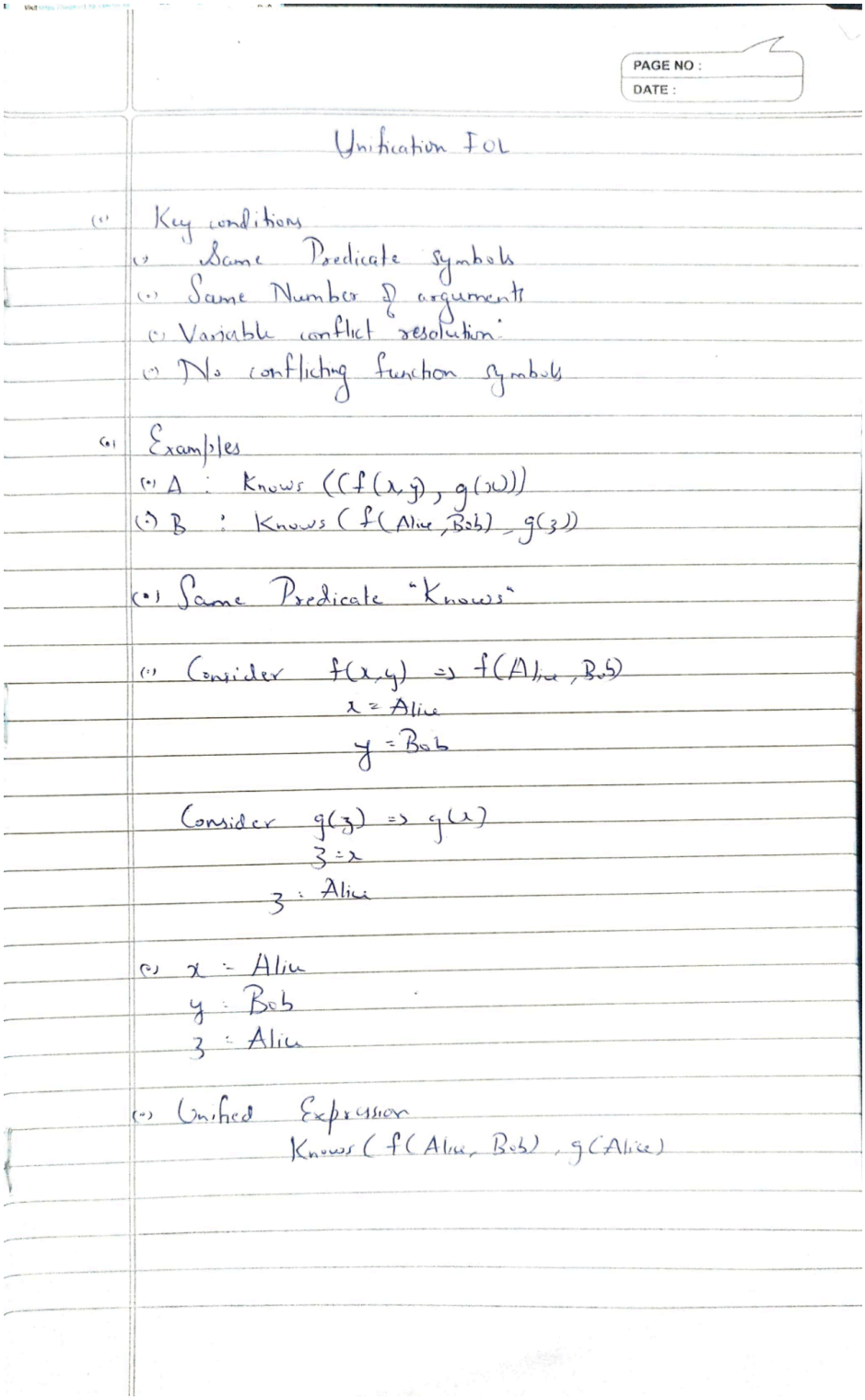
```
from sympy.logic.boolalg import Or, And, Not
from sympy.abc import A, B, C, D, E, F
from sympy import simplify_logic

def is_entailment(kb, query):

    # Negate the query
    negated_query = Not(query)

    # Add negated query to the knowledge base
    kb_with_negated_query = And(*kb, negated_query)

    # Simplify the combined KB to CNF
    simplified_kb = simplify_logic(kb_with_negated_query, form="cnf")

    # If the simplified KB evaluates to False, the query is entailed
    return simplified_kb == False


# Define a larger Knowledge Base
kb = [
    Or(A, B),        # A ∨ B
    Or(Not(A), C),   # ¬A ∨ C
    Or(Not(B), D),   # ¬B ∨ D
    Or(Not(D), E),   # ¬D ∨ E
    Or(Not(E), F),   # ¬E ∨ F
    F              # F
]
# Query to check
query = Or(C, F)  # C ∨ F

# Check entailment
result = is_entailment(kb, query)
print(f"Is the query '{query}' entailed by the knowledge base? {'Yes' if result else 'No'}")
```

Output:

```
PS C:\Users\prajw\Desktop\AI-Lab> python -u "c:\Users\prajw\Desktop\AI-Lab\Week7\entail.py"
Is the query 'C | F' entailed by the knowledge base? Yes
```

Implement unification in first order logic.

Algorithm:



PAGE NO :
DATE :

Unification FOL

(1) Key conditions
(a) Same Predicate symbols
(b) Same Number of arguments
(c) Variable conflict resolution
(d) No conflicting function symbols

(2) Examples
(a) A : Knows (f(x,y), g(x))
(b) B : Knows (f(Alice, Bob), g(z))

(a) Same Predicate "Knows"

(b) Consider f(x,y) => f(Alice, Bob)
x = Alice
y = Bob

Consider g(z) => g(x)
z = x
z = Alice

(c) x = Alice
y = Bob
z = Alice

(d) Unified Expression
Knows (f(Alice, Bob), g(Alice))

Code:

```
import re

def occurs_check(var, x):
    if var == x:
        return True
    elif isinstance(x, list):
        return any(occurs_check(var, xi) for xi in x)
    return False

def unify_var(var, x, subst):
    if var in subst:
        return unify(subst[var], x, subst)
    elif isinstance(x, (list, tuple)) and tuple(x) in subst:
        return unify(var, subst[tuple(x)], subst)
    elif occurs_check(var, x):
        return "FAILURE"
    else:
        subst[var] = tuple(x) if isinstance(x, list) else x
        return subst

def unify(x, y, subst=None):
    if subst is None:
        subst = {}
    if x == y:
        return subst
    elif isinstance(x, str) and x.islower():
        return unify_var(x, y, subst)
    elif isinstance(y, str) and y.islower():
        return unify_var(y, x, subst)
    elif isinstance(x, list) and isinstance(y, list):
        if len(x) != len(y):
            return "FAILURE"
        if x[0] != y[0]:
            return "FAILURE"
        for xi, yi in zip(x[1:], y[1:]):
            subst = unify(xi, yi, subst)
            if subst == "FAILURE":
                return "FAILURE"
        return subst
    else:
        return "FAILURE"

def unify_and_check(expr1, expr2):
    result = unify(expr1, expr2)
    if result == "FAILURE":
```

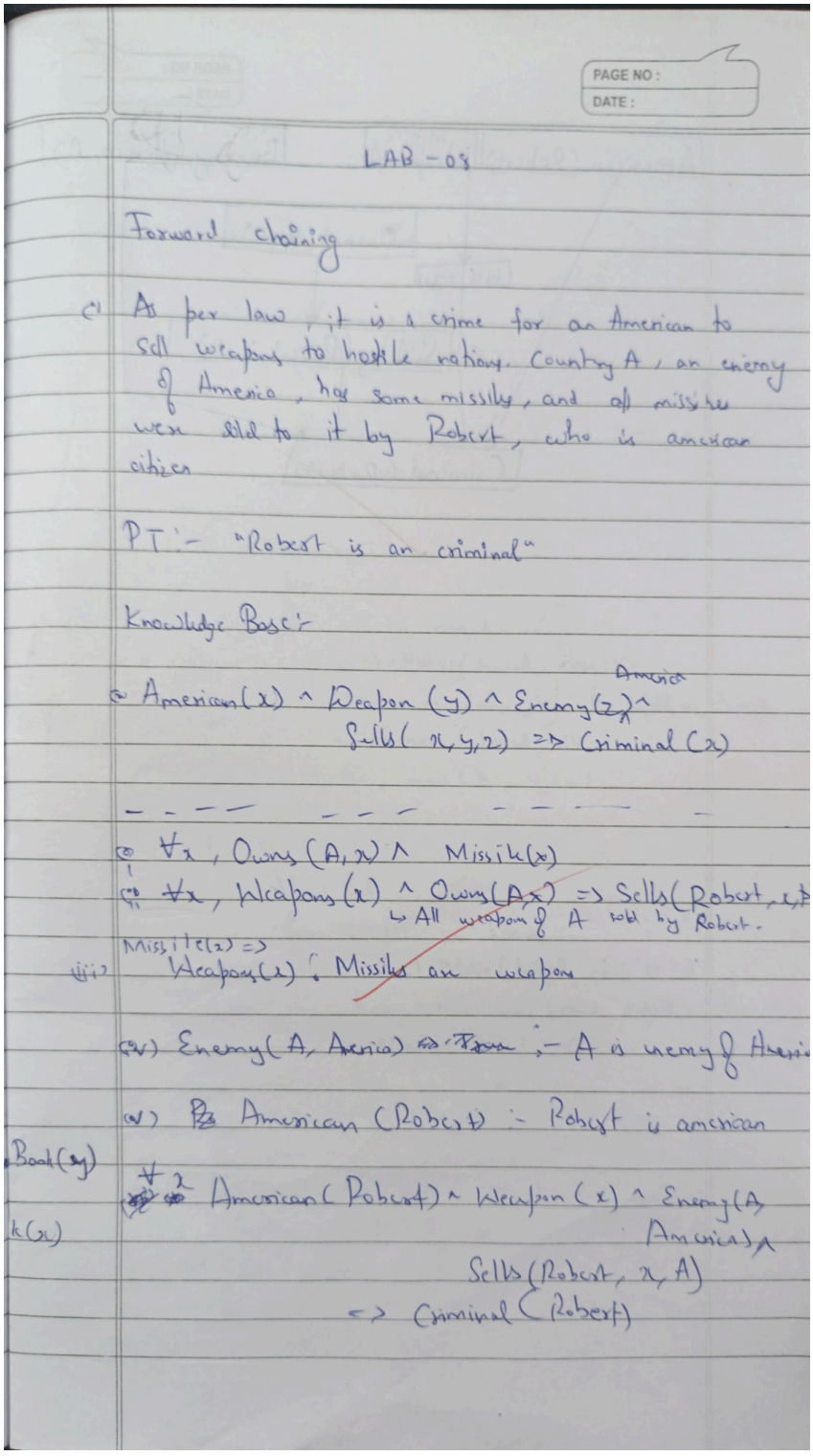
```
        return False, None
    return True, result

def display_result(expr1, expr2, is_unified, subst):
    print("Expression 1:", expr1)
    print("Expression 2:", expr2)
    if not is_unified:
        print("Result: Unification Failed")
    else:
        print("Result: Unification Successful")
        print("Substitutions:", {k: list(v) if isinstance(v, tuple) else v for k, v in subst.items()})

def parse_input(input_str):
    input_str = input_str.replace(" ", "")
    def parse_term(term):
        if '(' in term:
            match = re.match(r'([a-zA-Z0-9_]+)(.*)', term)
            if match:
                predicate = match.group(1)
                arguments_str = match.group(2)
                arguments = [parse_term(arg.strip()) for arg in arguments_str.split(',')]
                return [predicate] + arguments
        return term
    return parse_term(input_str)

def main():
    while True:
        expr1_input = input("Enter the first expression (e.g., p(x, f(y))): ")
        expr2_input = input("Enter the second expression (e.g., p(a, f(z))): ")
        expr1 = parse_input(expr1_input)
        expr2 = parse_input(expr2_input)
        is_unified, result = unify_and_check(expr1, expr2)
        display_result(expr1, expr2, is_unified, result)
            another_test = input("Do you want to test another pair of expressions? (yes/no): 
").strip().lower()
        if another_test != 'yes':
            break

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

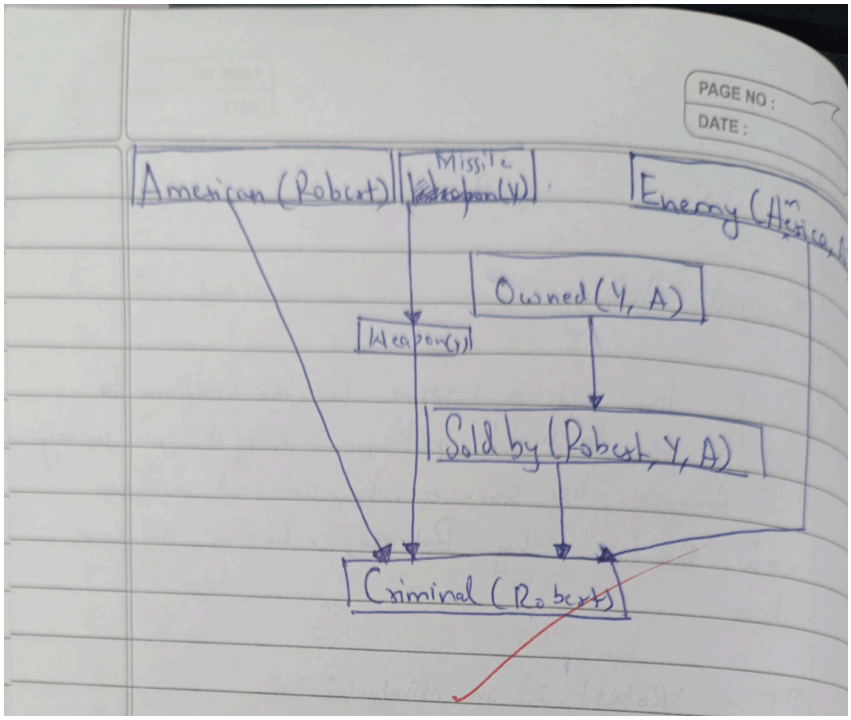
Output:

```
Output: 1BM22CS200
Enter the first expression (e.g., p(x, f(y))): Knows(f(Alice,Bob),g(z))
Enter the second expression (e.g., p(a, f(z))): Knows(f(x,y),g(x))
Expression 1: ['Knows', '(f(Alice', 'Bob)', ['g', '(z))']]
Expression 2: ['Knows', '(f(x', 'y)', ['g', '(x))']]
Result: Unification Successful
Substitutions: {'(f(x': '(f(Alice', 'y)': 'Bob)', '(z))': '(x))'}
Do you want to test another pair of expressions? (yes/no): yes
Output: 1BM22CS200
Enter the first expression (e.g., p(x, f(y))): A(x,y)
Enter the second expression (e.g., p(a, f(z))): A(Bob,Jack)
Expression 1: ['A', '(x', 'y)']
Expression 2: ['A', '(Bob', 'Jack)']
Result: Unification Successful
Substitutions: {'(x': '(Bob', 'y)': 'Jack)'}
Do you want to test another pair of expressions? (yes/no):
```

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

Algorithm:





Code:

```
KB = set()

KB.add('American(Robert)')
KB.add('Enemy(America, A)')
KB.add('Missile(T1)')
KB.add('Owns(A, T1)')

def modus_ponens(fact1, fact2, conclusion):
    if fact1 in KB and fact2 in KB:
        KB.add(conclusion)
        print(f"Inferred: {conclusion}")

def forward_chaining():
    if 'Missile(T1)' in KB:
        KB.add('Weapon(T1)')
        print(f"Inferred: Weapon(T1)")

    if 'Owns(A, T1)' in KB and 'Weapon(T1)' in KB:
        KB.add('Sells(Robert, T1, A)')
        print(f"Inferred: Sells(Robert, T1, A)")

    if 'Enemy(America, A)' in KB:
        KB.add('Hostile(A)')
        print(f"Inferred: Hostile(A)")
```

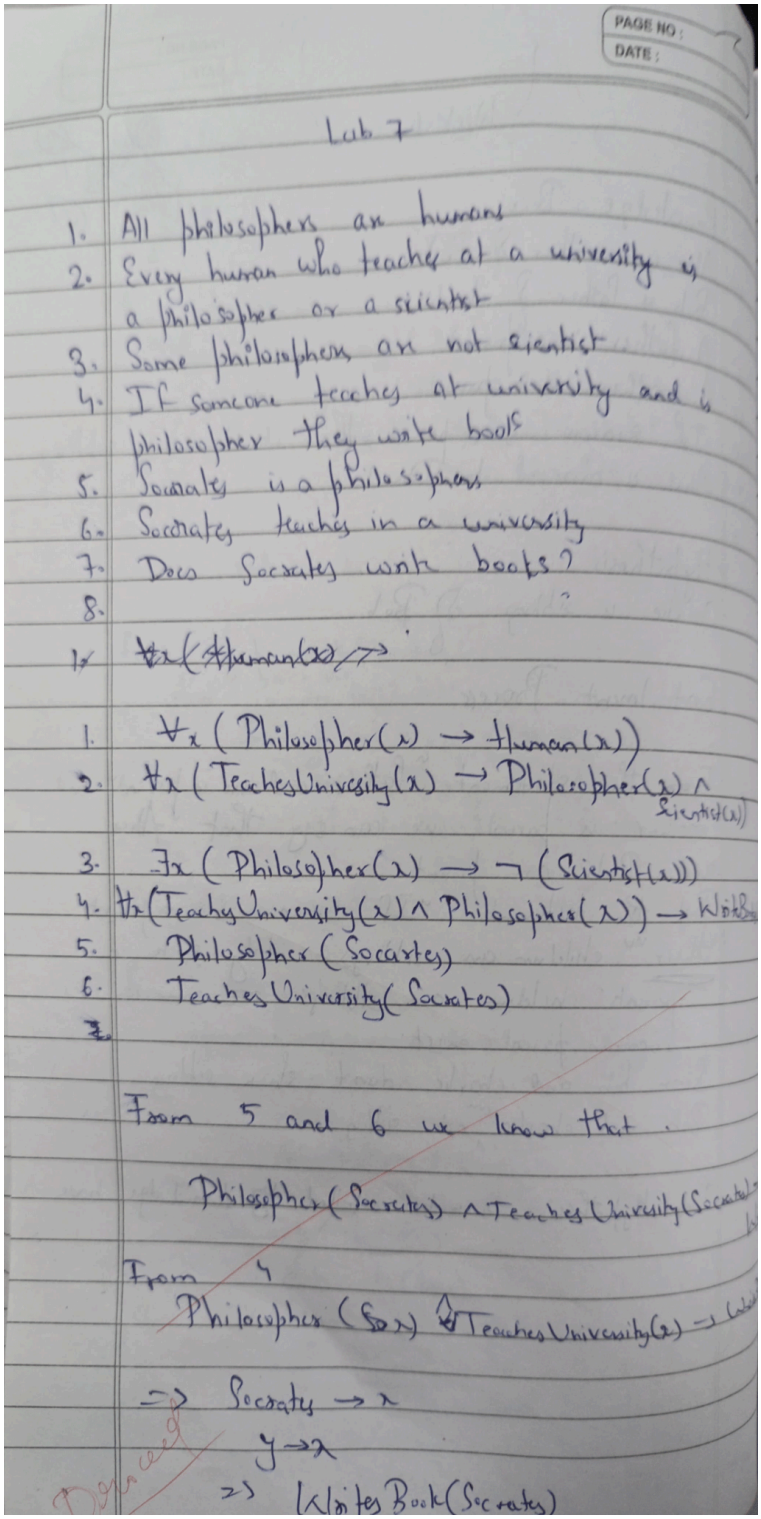
```
    if 'American(Robert)' in KB and 'Weapon(T1)' in KB and 'Sells(Robert, T1, A)' in KB and 'Hostile(A)' in KB:
        KB.add('Criminal(Robert)')
        print("Inferred: Criminal(Robert)")

    if 'Criminal(Robert)' in KB:
        print("Robert is a criminal!")
    else:
        print("No more inferences can be made.")

forward_chaining()
```

Output:

```
PS C:\Users\prajw\Desktop\AI-Lab> python -u "c:\Users\prajw\Desktop\AI-Lab\Week8\tempCodeRunnerFile.py"
Inferred: Weapon(T1)
Inferred: Sells(Robert, T1, A)
Inferred: Hostile(A)
Inferred: Criminal(Robert)
Robert is a criminal!
```

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

Algorithm:



Lab 7

1. All philosophers are humans
2. Every human who teaches at a university is a philosopher or a scientist
3. Some philosophers are not scientist
4. If someone teaches at university and is philosopher they write books
5. Socrates is a philosophers
6. Socrates teaches in a university
7. Does Socrates write books?
8.

1. $\forall x$ (Philosopher(x) → Human(x))
2. $\forall x$ (TeachesUniversity(x) → Philosopher(x) ∧ Scientist(x))
3. $\exists x$ (Philosopher(x) → ¬ (Scientist(x)))
4. $\forall x$ (TeachesUniversity(x) ∧ Philosopher(x) → WritesBook(x))
5. Philosopher (Socartes)
6. TeachesUniversity(Socrates)

From 5 and 6 we know that

Philosopher (Socrates) ∧ TeachesUniversity(Socrates)

From 4

Philosopher (Sox) ∧ TeachesUniversity(x) → WritesBook(x)

=> Socrates → x

y → x

=> WritesBook(Socrates)

Code:

```
# Define the knowledge base (KB)
KB = {
    # Rules and facts
    "philosopher(X)": "human(X)",  # Rule 1: All philosophers are humans
    "human(Socrates)": True,  # Socrates is human (deduced from philosopher)
    "teachesAtUniversity(X)": "philosopher(X) or scientist(X)",  # Rule 2
    "some(philosopher, not scientist)": True,  # Rule 3: Some philosophers are not scientists
    "writesBooks(X)": "teachesAtUniversity(X) and philosopher(X)",  # Rule 4
    "philosopher(Socrates)": True,  # Fact: Socrates is a philosopher
    "teachesAtUniversity(Socrates)": True,  # Fact: Socrates teaches at university
}

# Function to evaluate a predicate based on the KB
def resolve(predicate):
    # If it's a direct fact in KB
    if predicate in KB and isinstance(KB[predicate], bool):
        return KB[predicate]

    # If it's a derived rule
    if predicate in KB:
        rule = KB[predicate]

        if " and " in rule:  # Handle conjunction
            sub_preds = rule.split(" and ")
            return all(resolve(sub.strip()) for sub in sub_preds)
        elif " or " in rule:  # Handle disjunction
            sub_preds = rule.split(" or ")
            return any(resolve(sub.strip()) for sub in sub_preds)
        elif "not " in rule:  # Handle negation
            sub_pred = rule[4:]  # Remove "not "
            return not resolve(sub_pred.strip())
        else:  # Handle single predicate
            return resolve(rule.strip())

    # If the predicate contains variables
    if "(" in predicate:
        func, args = predicate.split("(")
        args = args.strip(")").split(", ")
        # Handle philosopher and human link
        if func == "philosopher":
            return resolve(f"human({args[0]})")
        # Handle writesBooks rule explicitly
        if func == "writesBooks":
            return resolve(f"teachesAtUniversity({args[0]})") and resolve(f"philosopher({args[0]})")
```

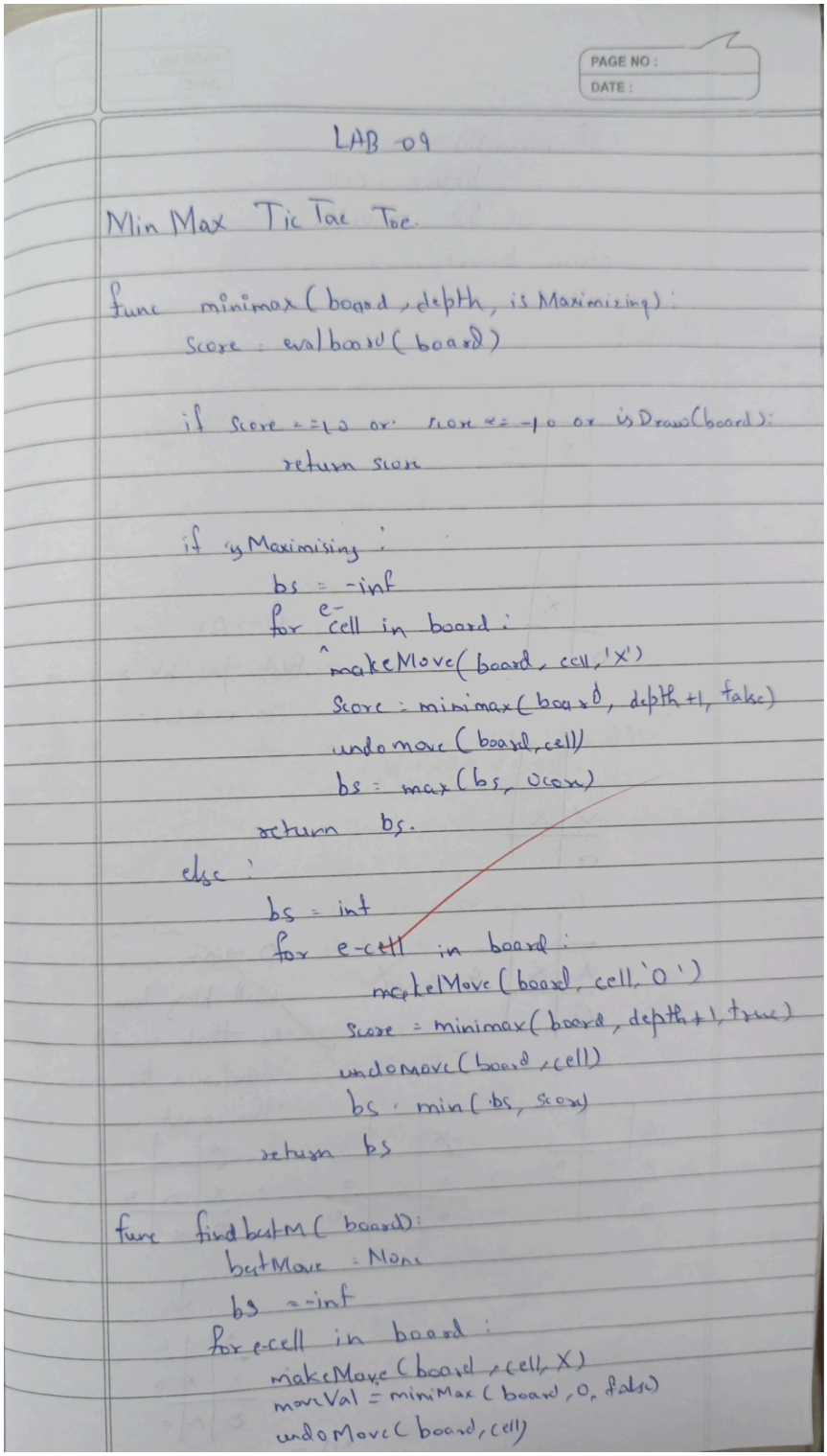
```
    # Default to False if no rule or fact applies
    return False

# Query to check if Socrates writes books
query = "writesBooks(Socrates)"
result = resolve(query)

# Print the result
print("Output: 1BM22CS200")
print(f"Does Socrates write books? {'Yes' if result else 'No'}")
```

Output:

```
PS C:\Users\prajw\Desktop\AI-Lab> python -u "c:\Users\prajw\Desktop\AI-Lab\Week7\resloution.py"
Output: 1BM22CS200
Does Socrates write books? Yes
```

Implement MinMax Algorithm for TicTacToe.

Algorithm:



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PAGE NO :
DATE :

LAB 09

Min Max Tic Tac Toe.

func minimax(board, depth, isMaximizing):
    score = evalboard(board)

    if score == 10 or score == -10 or isDraw(board):
        return score

    if isMaximising:
        bs = -inf
        for cell in board:
            makeMove(board, cell, 'X')
            score = minimax(board, depth+1, false)
            undomove(board, cell)
            bs = max(bs, score)
        return bs.
    else:
        bs = inf
        for e-cell in board:
            makeMove(board, cell, 'O')
            score = minimax(board, depth+1, true)
            undoMove(board, cell)
            bs = min(bs, score)
        return bs

func findbestM(board):
    bestMove = None
    bs = -inf
    for e-cell in board:
        makeMove(board, cell, X)
        moveVal = miniMax(board, 0, false)
        undoMove(board, cell)
```

PAGE NO :
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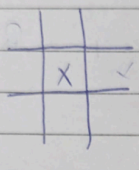
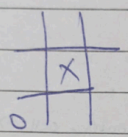
```
if moveVal > bs :
        bmove = cell
        bs = moveVal
return bmove
```

Output :-

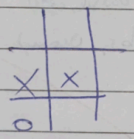


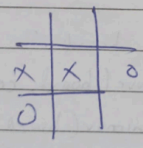
X → player



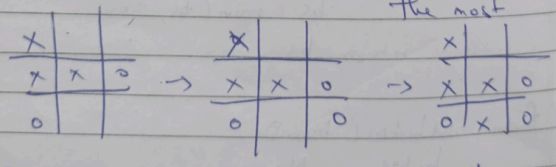
O → AI

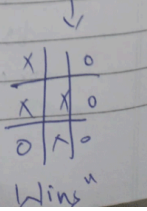
Best possible move is in corners.





O → AI will play here as that would minimize the score the most





"AI Wins"

Code:

```
import math


def printBoard(board):
    for row in board:
        print(" | ".join(cell if cell != "" else " " for cell in row))
        print("-" * 9)


def evaluateBoard(board):
    for row in board:
        if row[0] == row[1] == row[2] and row[0] != "":
            return 10 if row[0] == 'X' else -10
    for col in range(3):
        if board[0][col] == board[1][col] == board[2][col] and board[0][col] != "":
            return 10 if board[0][col] == 'X' else -10
    if board[0][0] == board[1][1] == board[2][2] and board[0][0] != "":
        return 10 if board[0][0] == 'X' else -10
    if board[0][2] == board[1][1] == board[2][0] and board[0][2] != "":
        return 10 if board[0][2] == 'X' else -10
    return 0


def isDraw(board):
    for row in board:
        if "" in row:
            return False
    return True
```

```
def minimax(board, depth, isMaximizing):
    score = evaluateBoard(board)
    if score == 10 or score == -10:
        return score
    if isDraw(board):
        return 0

    if isMaximizing:
        bestScore = -math.inf
        for i in range(3):
            for j in range(3):
                if board[i][j] == "":
                    board[i][j] = 'X'
                    score = minimax(board, depth + 1, False)
                    board[i][j] = ""
                    bestScore = max(bestScore, score)
        return bestScore
    else:
        bestScore = math.inf
        for i in range(3):
            for j in range(3):
                if board[i][j] == "":
                    board[i][j] = 'O'
                    score = minimax(board, depth + 1, True)
                    board[i][j] = ""
                    bestScore = min(bestScore, score)
        return bestScore
```

```
def findBestMove(board):
    bestValue = -math.inf
    bestMove = (-1, -1)
    for i in range(3):
        for j in range(3):
            if board[i][j] == "":
                board[i][j] = 'X'
                moveValue = minimax(board, 0, False)
                board[i][j] = ""
                if moveValue > bestValue:
                    bestMove = (i, j)
                    bestValue = moveValue
    return bestMove

def playGame():
    board = [["" for _ in range(3)] for _ in range(3)]
    print("Tic Tac Toe!")
    print("You are 'O'. The AI is 'X'.")
    printBoard(board)

    while True:
        while True:
            try:
                row, col = map(int, input("Enter your move (row and column: 0, 1, or 2): ").split())
                if board[row][col] == "":
                    board[row][col] = 'O'
```

```
            break
        else:
            print("Cell is already taken. Choose another.")
    except (ValueError, IndexError):
        print("Invalid input. Enter row and column as two numbers between 0 and 2.")

print("Your move:")
printBoard(board)

if evaluateBoard(board) == -10:
    print("You win!")
    break
if isDraw(board):
    print("It's a draw!")
    break

print("AI is making its move...")
bestMove = findBestMove(board)
board[bestMove[0]][bestMove[1]] = 'X'

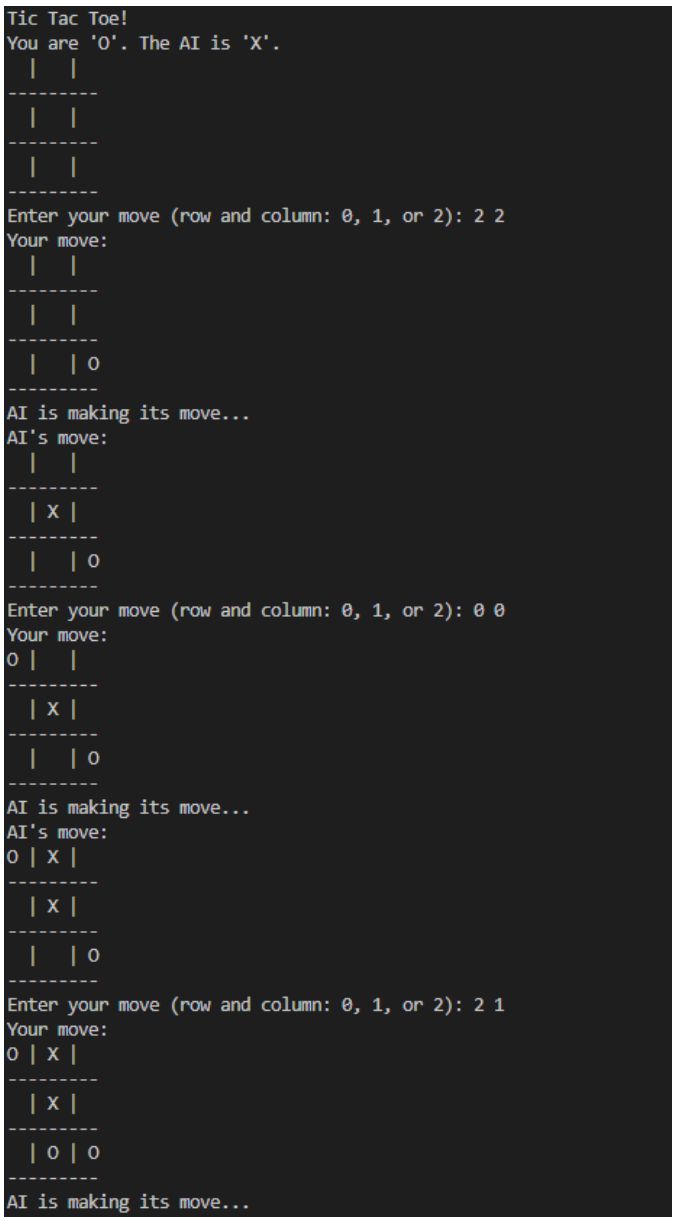
print("AI's move:")
printBoard(board)

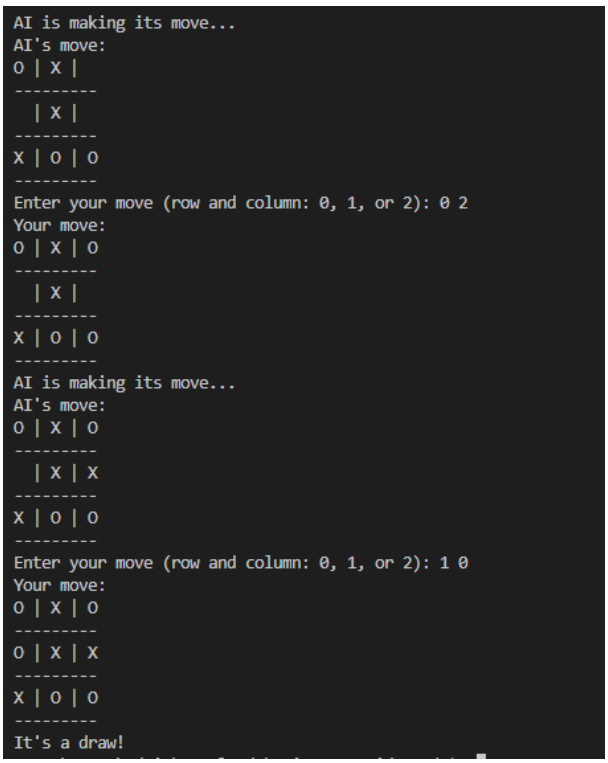
if evaluateBoard(board) == 10:
    print("AI wins!")
    break
if isDraw(board):
```

```
        print("It's a draw!")
        break

playGame()
```

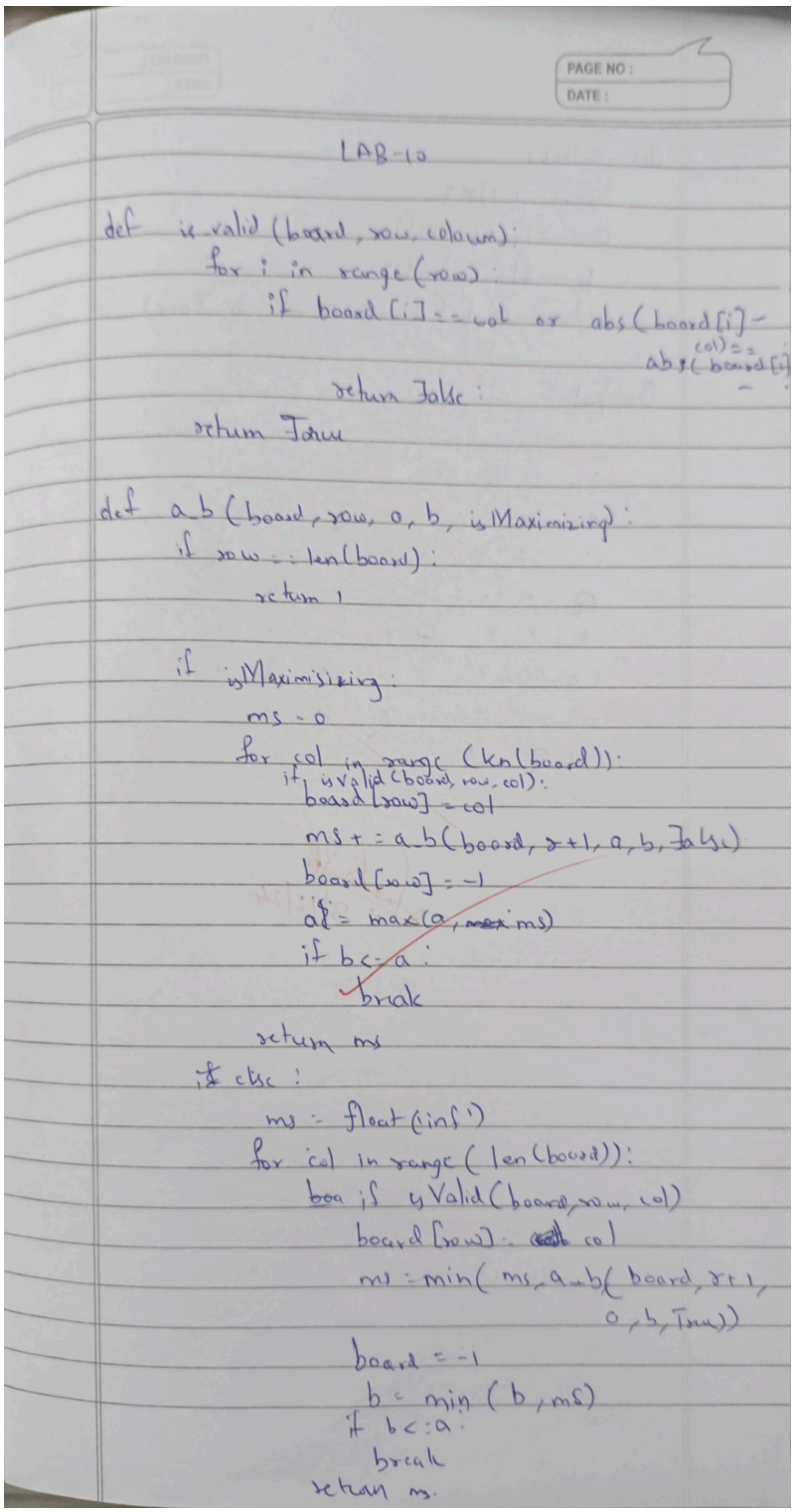
Output:





Implement Alpha-Beta Pruning for 8Queens.

Algorithm:



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LAB-10

def is_valid(board, row, column):
    for i in range(row):
        if board[i] == col or abs(board[i] -
                                  abs(col) == abs(board[i]
            return False
    return True

def a_b(board, row, a, b, isMaximizing):
    if row == len(board):
        return 1

    if isMaximizing:
        ms = 0
        for col in range(len(board)):
            if is_valid(board, row, col):
                board[row] = col
                ms += a_b(board, r+1, a, b, False)
                board[row] = -1
                a = max(a, ms)
                if b <= a:
                    break
        return ms
    if else:
        ms = float('inf')
        for col in range(len(board)):
            boa if is_Valid(board, row, col)
                board[row] = col
                ms = min(ms, a_b(board, r+1,
                                 a, b, True))
                board = -1
                b = min(b, ms)
                if b <= a:
                    break
        return ms
```
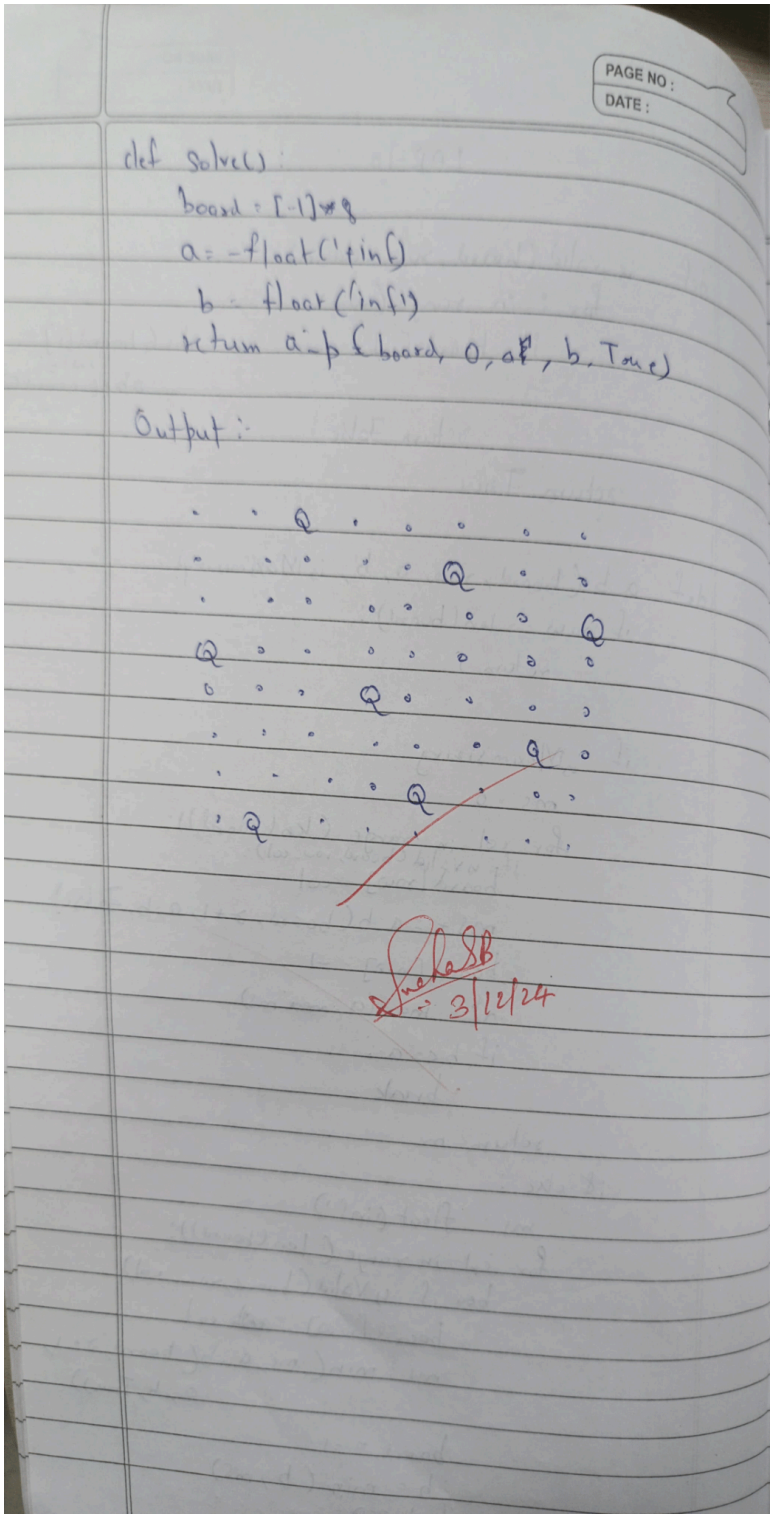
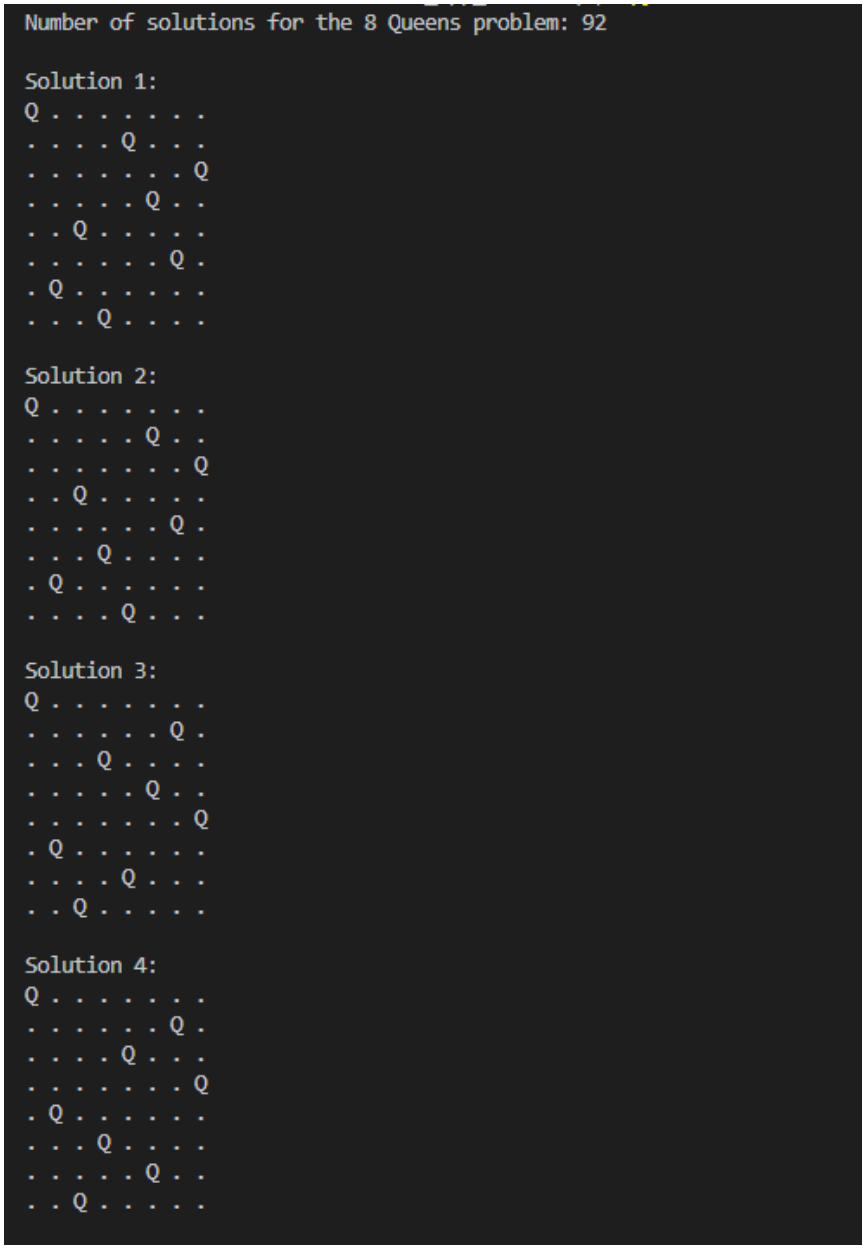



Code:

```
def is_valid(board, row, col):
    for i in range(row):
```

```
        if board[i] == col or \
           abs(board[i] - col) == abs(i - row):
            return False
    return True

def alpha_beta(board, row, alpha, beta, isMaximizing):

    if row == len(board):
        return 1

    if isMaximizing:
        max_score = 0
        for col in range(len(board)):
            if is_valid(board, row, col):
                board[row] = col
                max_score += alpha_beta(board, row + 1, alpha, beta, False)
                board[row] = -1
                alpha = max(alpha, max_score)
                if beta <= alpha:
                    break
        return max_score
    else:
        min_score = float('inf')
        for col in range(len(board)):
            if is_valid(board, row, col):
                board[row] = col
                min_score = min(min_score, alpha_beta(board, row + 1, alpha, beta, True))
                board[row] = -1
                beta = min(beta, min_score)
                if beta <= alpha:
                    break
        return min_score

def solve_8_queens():

    board = [-1] * 8
    alpha = -float('inf')
    beta = float('inf')
    return alpha_beta(board, 0, alpha, beta, True)

solutions = solve_8_queens()
print(f"Number of solutions for the 8 Queens problem: {solutions}")
```

Output:


Number of solutions for the 8 Queens problem: 92
Solution 1:
Q . . . . . .
. . . . Q . . .
. . . . Q
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .
Solution 2:
Q . . . . . .
. . . . . Q . .
. . . . Q
. . Q . . . . .
. . . . . . Q .
. . . Q . . . .
. Q . . . . . .
. . . . Q . . .
Solution 3:
Q . . . . . .
. . . . . . Q .
. . . Q . . . .
. . . . . Q . .
. . . . Q
. Q . . . . . .
. . . . Q . . .
. . Q . . . . .
Solution 4:
Q . . . . . .
. . . . . . Q .
. . . . Q . . .
. . . . Q
. Q . . . . . .
. . . Q . . . .
. . . . . Q . .
. . Q . . . . .