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

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B.M.S. COLLEGE OF ENGINEERING
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(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 **Priyanshu Kumar (1BM22CS210),** 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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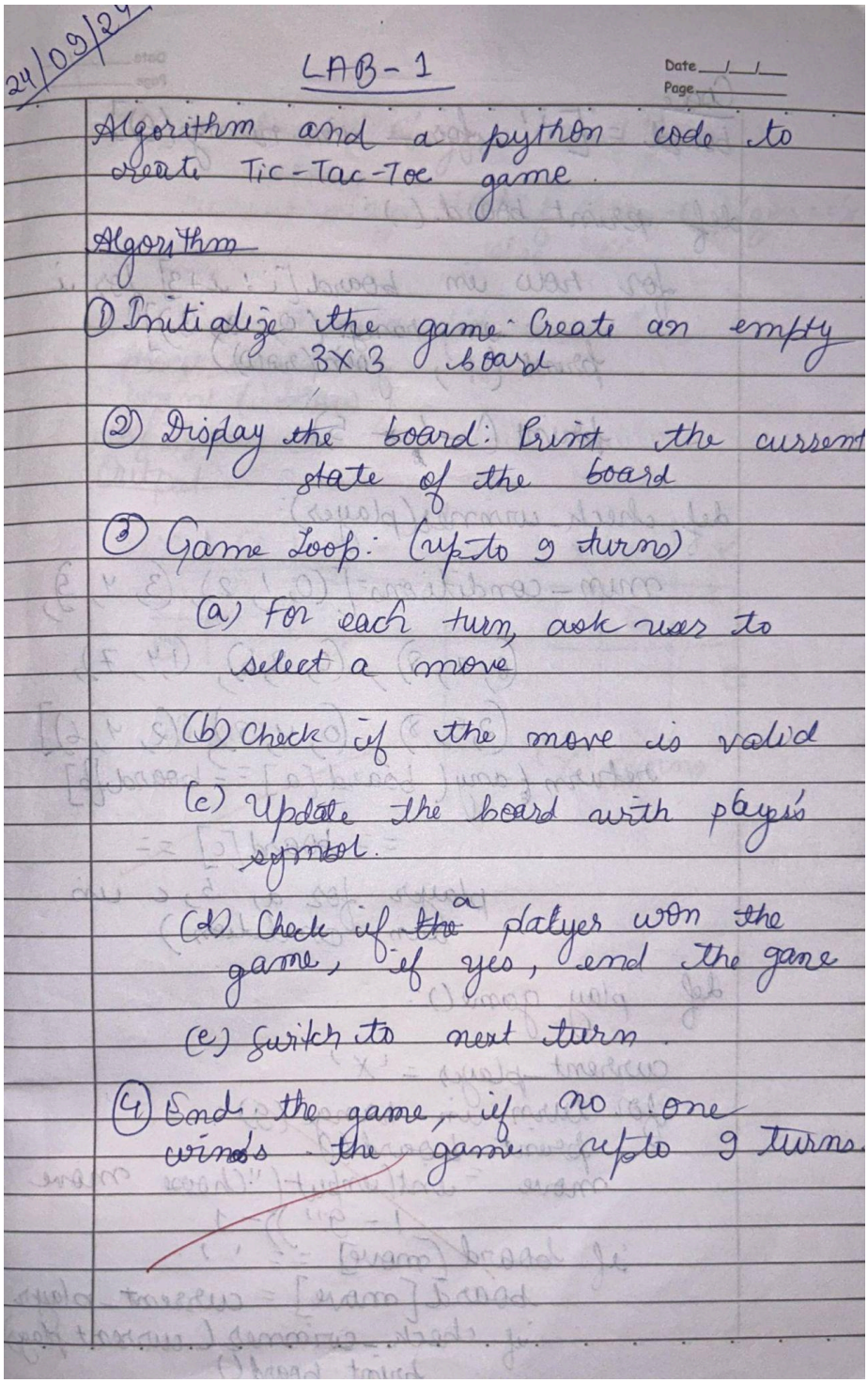
Github Link: https://github.com/pkcs210/AI-Lab

Lab 1

Implement Tic-Tac-Toe Game

Screenshots:



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Algorithm and a python code to create Tic-Tac-Toe game.

Algorithm

① Initialize the game: Create an empty 3×3 board

② Display the board: Print the current state of the board

③ Game Loop: (upto 9 turns)

(a) For each turn, ask user to select a move

(b) Check if the move is valid

(c) Update the board with player's symbol.

(d) Check if a player won the game, if yes, end the game

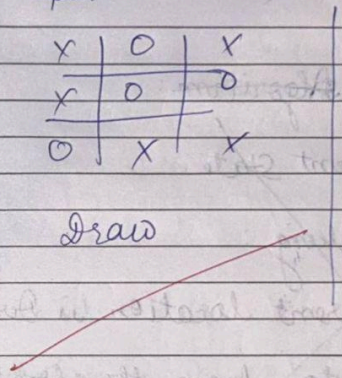
(e) Switch to next turn.

④ End the game, if no one wins the game upto 9 turns.

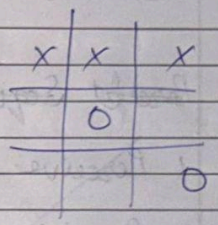
Code

```
board = [' ' for _ in range(9)]

def print_board():
    for row in board[i:i+3] for i
        in range(0, 9, 3)]:
        print('|', join(row))
        print('-' * 5)

def check_winner(player):
    win_conditions = [(0, 1, 2), (3, 4, 5),
                      (6, 7, 8), (0, 3, 6), (1, 4, 7),
                      (2, 5, 8), (0, 4, 8), (2, 4, 6)]
    return any( board[a] == board[b]
                == board[c] ==
                player for a, b, c in
                win_condition )

def play_game():
    current_player = 'X'
    for turn in range(9):
        print_board()
        move = int(input("Choose move
                1 - 9")) - 1
        if board[move] == ' ':
            board[move] = current_player
            if check_winner(current_player):
                print_board()
                print("Player wins!")
                return
            current_player = 'O' if current_player == 'X'
                             else 'X'
        else:
            print("Invalid move")
    print_board()
    print("Draw")
play_game()
```

Output:



Draw



'X' wins

Codes:

```
def print_board(board):
    print(f"{board[0]}|{board[1]}|{board[2]}")
    print("-+-+-")
    print(f"{board[3]}|{board[4]}|{board[5]}")
    print("-+-+-")
    print(f"{board[6]}|{board[7]}|{board[8]}")

def check_winner(board, player):
    win_conditions = [
        [0,1,2],[3,4,5],[6,7,8],
        [0,3,6],[1,4,7],[2,5,8],
        [0,4,8],[2,4,6]
    ]
    for condition in win_conditions:
        if all(board[i] == player for i in condition):
            return True
    return False

def main():
    board = [' ']*9
    current_player = 'X'
    for _ in range(9):
        print_board(board)
        try:
            move = int(input(f"Player {current_player}, enter your move (1-9): ")) -1
            if board[move] == ' ':
                board[move] = current_player
                if check_winner(board, current_player):
                    print_board(board)
                    print(f"Player {current_player} wins!")
                    return
                current_player = 'O' if current_player == 'X' else 'X'
            else:
                print("Invalid move. Try again.")
        except (IndexError, ValueError):
            print("Invalid input. Enter a number from 1 to 9.")
    print_board(board)
    print("It's a draw!")

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

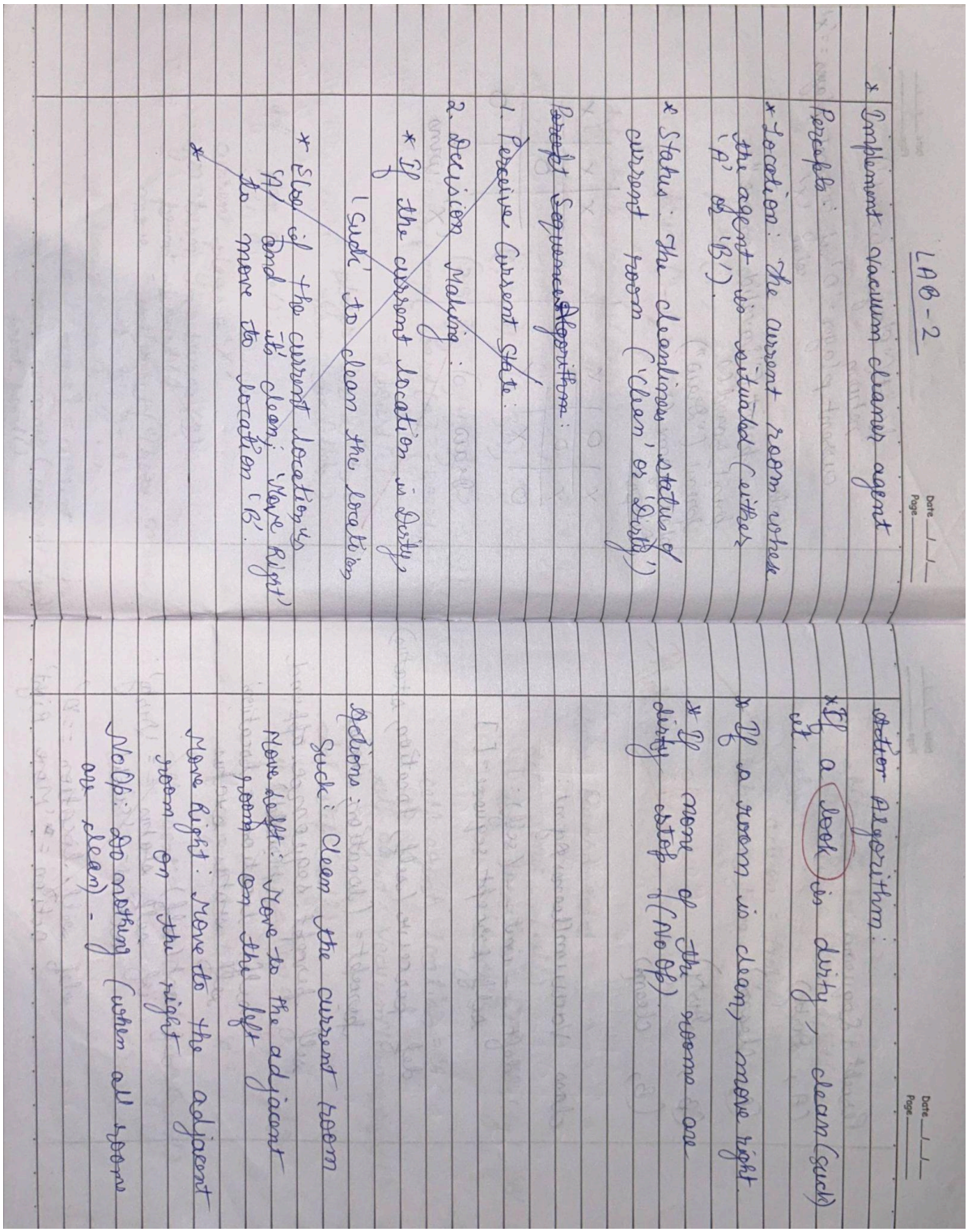
Output:

```
  | |
-+-+-
  | |
-+-+-
  | |
Player X, enter your move (1-9): 1
X| |
-+-+-
  | |
-+-+-
  | |
Player O, enter your move (1-9): 3
X| |O
-+-+-
  | |
-+-+-
  | |
Player X, enter your move (1-9):
```

Lab 2

Implement Tic-Tac-Toe Game

Algorithm:



Percept Sequence:

(A, Dirty)

(A, Clean)

(B, Dirty)

(B, Clean)

```
class VacuumCleanerAgent:
    def __init__(self):
        self.percept_sequence = []

    def perceive(self, location, status):
        percept = (location, status)
        self.percept_sequence.append(percept)
        self.location = location
        self.status = status

    def act(self):
        if self.status == 'Dirty':
            action = 'Suck'
        elif self.location == 'A':
            action = 'Move Right'
        elif self.location == 'B':
            action = 'Move Left'
        else:
            action = 'NoOp'
        return action
```

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```
class Environment:
    def __init__(self):
        self.locations = {'A': 'Dirty', 'B': 'Dirty'}
        self.agent_location = 'A'
        self.agent = VacuumCleanerAgent()

    def step(self):
        self.locations = {'A': 'Dirty', 'B': 'Dirty'}
        self.agent_location = 'A'
        self.agent = VacuumCleanerAgent()
        action = self.agent.act()
```

```
        if action == 'Suck':
            self.locations[location] = 'Clean'
        elif action == 'Move Left':
            self.agent_location = 'A'
        elif action == 'Move Right':
            self.agent_location = 'B'

    def run(self):
        steps = 0

        while True:
            self.step()
            steps += 1

            if all(status == 'Clean' for
                status in self.location.
                                values()):
                print("All rooms are
                        clean")
                break
            if steps >= 10:
                print("Reached maximum
                        steps")
        print("Percept Sequence:")
        for percept in self.agent.
                            percept_sequence:
            print(percept)

if __name__ == "__main__":
    env = Environment()
    env.run()
```

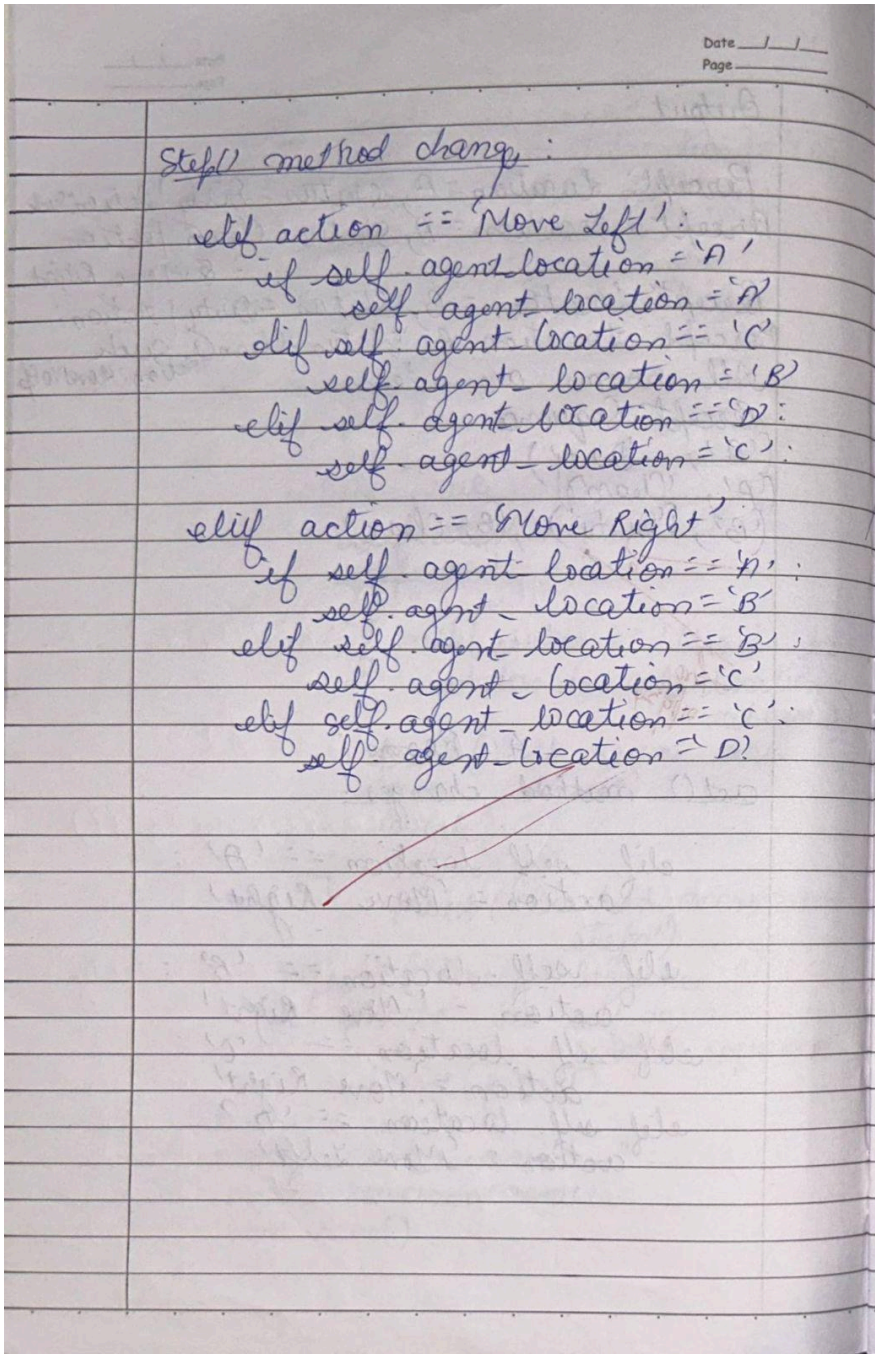
Output:

Percept: Location = A, Status = Dirty | Action: Suck
Percept: Location = A, Status = Clean | Action: Move Right
Percept: Location = B, Status = Dirty | Action: Suck
Percept: Location = B, Status = Clean | Action: NoOp
All rooms are clean
Percept Sequence:
('A', 'Dirty')
('A', 'Clean')
('B', 'Dirty'), ('B', 'Clean')

4 Rooms:

act() method changes:

```
    elif self.location == 'A':
        action = 'Move Right'

    elif self.location == 'B':
        action = 'Move Right'
    elif self.location == 'C':
        action = 'Move Right'
    elif self.location == 'D':
        action = 'Move Left'
```



Codes:

```
def vacuum_cleaner_agent():
    environment = {'A': True, 'B': True}
    position = 'A'
    actions = []
    while True:
        if environment[position]:
            actions.append('Suck')
            environment[position] = False
```

```
        else:
            actions.append('Move')
            position = 'B' if position == 'A' else 'A'
        if not any(environment.values()):
            break
    return actions

print(vacuum_cleaner_agent())
```

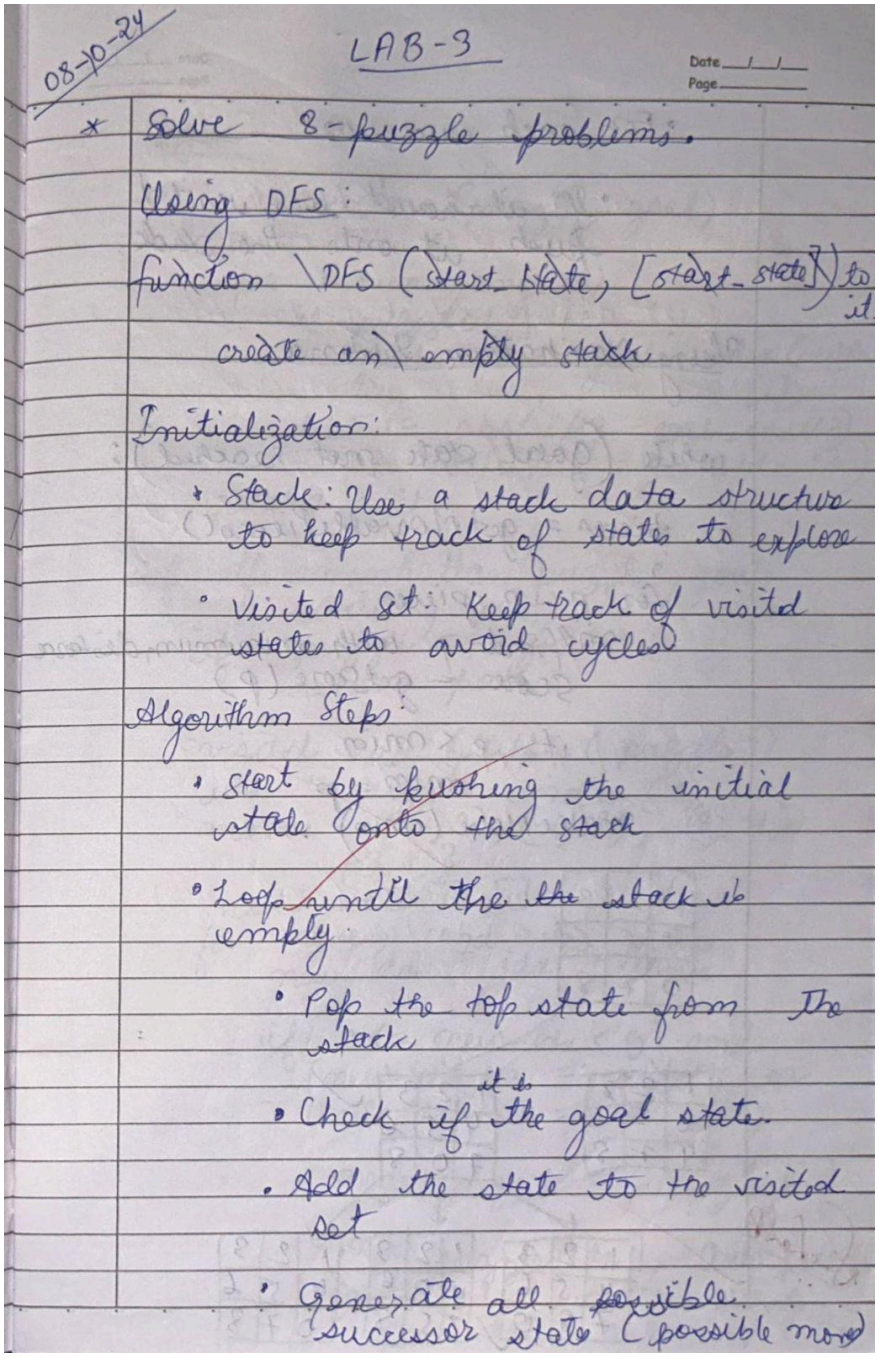
Output:

```
['Suck', 'Move', 'Suck']
```

Lab 3

Implement 8-Puzzle Problem Using Depth-First Search (DFS)

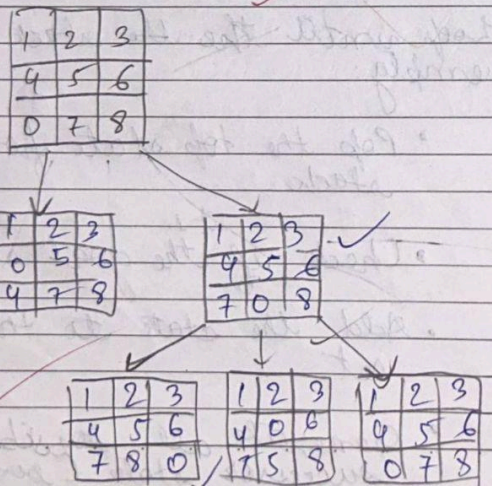
Screenshots:



- For each successor:
  - If it hasn't been visited push it onto the stack.

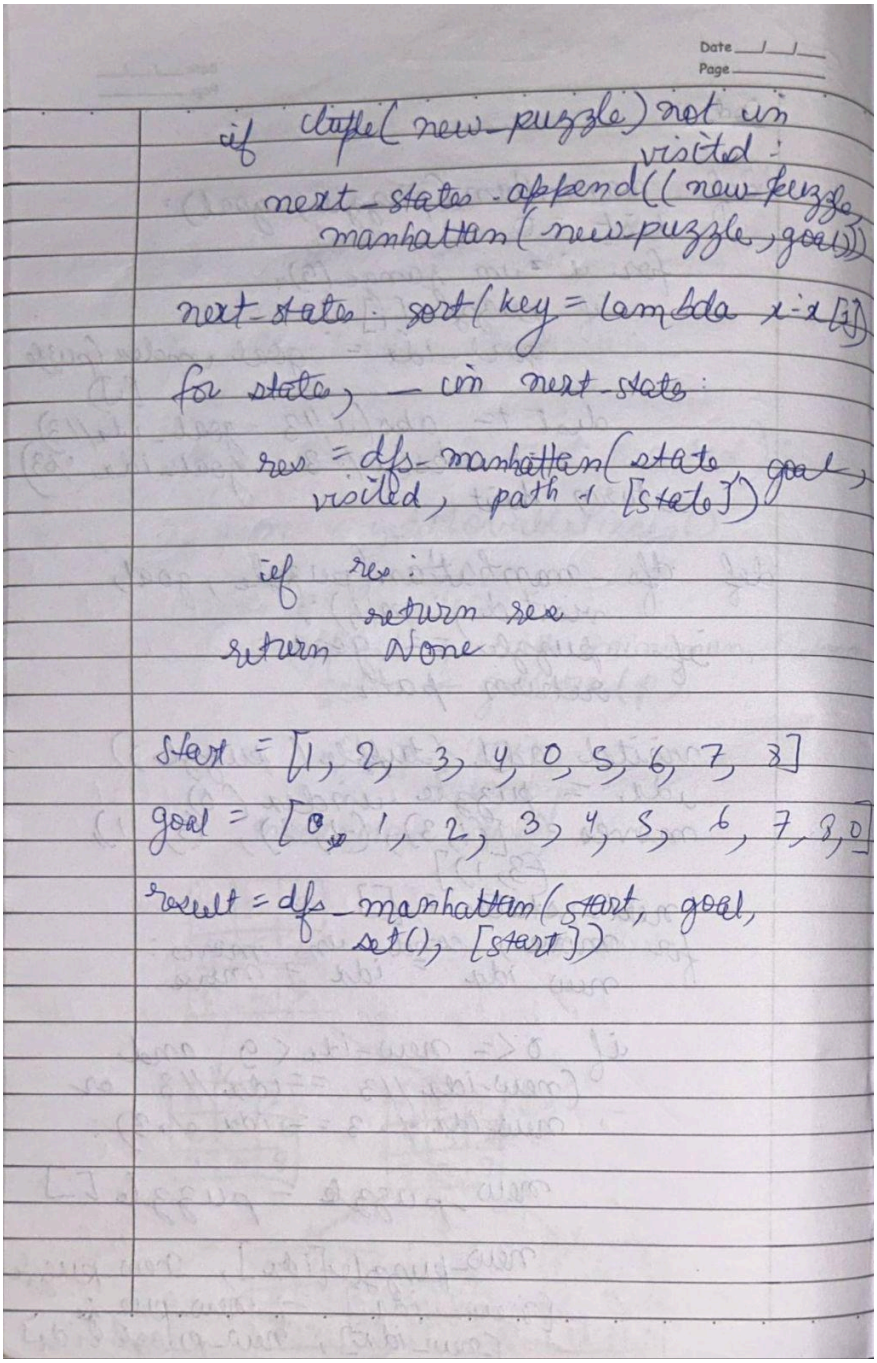
Using Manhattan Distance:

```
while (goal state not reached):
    pieces = getMovablePieces()
    for p in pieces:
        #find p with minimum distance
        score = getScore(p)
        if p < min
            min = p
    makeMove(min)
```



Code:

```
def manhattan(puzzle, goal):
    dist = 0
    for i in range(9):
        if puzzle[i] != 0:
            goal_idx = goal.index(puzzle[i])
            dist += abs(i//3 - goal_idx//3)
                  + abs(i%3 - goal_idx%3)
    return dist

def dfs_manhattan(puzzle, goal, visited, path):
    if puzzle == goal:
        return path

    visited.add(tuple(puzzle))
    idx = puzzle.index(0)
    moves = [(1,3), (-1,3), (3,1), (-3,1)]
    next_states = []
    for move, cond in moves:
        new_idx = idx + move

        if 0<= new_idx < 9 and
            (new_idx//3 == idx//3 or
             new_idx%3 == idx%3):

            new_puzzle = puzzle[:]

            new_puzzle[idx], new_puzzle
            [new_idx] = new_puzzle
            [new_idx], new_puzzle[idx]
```



Codes:

```
import heapq


class Puzzle:
   def __init__(self):
       self.board = [
```

```
    [1, 2, 3],
    [8, 0, 4],
    [7, 6, 5]
]
    self.end = [
    [2, 8, 1],
    [0, 4, 3],
    [7, 6, 5]
]
def getMoves(self, board):
    zero_pos = self.zero_index(board)
    moves = [(0, 1), (1, 0), (0, -1), (-1, 0)]
    valid_moves = []
    for move in moves:
        if 0 <= zero_pos[0] + move[0] < 3 and 0 <= zero_pos[1] + move[1] < 3:
            valid_moves.append(move)
    return valid_moves

def zero_index(self, board):
    for i in range(3):
        for j in range(3):
            if board[i][j] == 0:
                return [i, j]

def bhash(self, board):
   return tuple(map(tuple, board))

def display(self, board):
    for ls in board:
        print(*ls)

def manhattan_distance(self, state):
    distance = 0
    for i in range(9):
        old = self.get_index(i, state)
        final = self.get_index(i, self.end)
        distance += (abs(final[0] - old[0]) + abs(final[1] - old[1]))
    return distance

def get_index(self, el, board):
    for i in range(3):
        for j in range(3):
            if board[i][j] == el:
```

```
                    return [i, j]

    def misplaced(self, state):
        misplaced = 0
        for i in range(3):
            for j in range(3):
                if state[i][j] != self.end[i][j]:
                    misplaced += 1
        return misplaced


    def a_star(self):
        heap = []
        heapq.heappush(heap, (self.manhattan_distance(self.board) +
self.misplaced(self.board), 0, self.board, []))  # (priority, cost, current state, path)
        visited = set()

        while heap:
            priority, cost, state, path = heapq.heappop(heap)

            state_tuple = tuple(map(tuple, state))

            if state_tuple in visited:
                continue

            visited.add(state_tuple)

            if self.bhash(state) == self.bhash(self.end):
                for p in path + [state]:
                    self.display(p)
                    print("------")
                return

            for move in self.getMoves(state):
                new_board = [row[:] for row in state]
                zeroPos = self.zero_index(new_board)
                newPos = [zeroPos[0] + move[0], zeroPos[1] + move[1]]
                new_board[newPos[0]][newPos[1]], new_board[zeroPos[0]][zeroPos[1]] =
new_board[zeroPos[0]][zeroPos[1]], new_board[newPos[0]][newPos[1]]
                if tuple(map(tuple, new_board)) not in visited:
                    new_cost = cost + 1 # Each move has a cost of 1
                    priority = self.manhattan_distance(new_board) + self.misplaced(new_board)
                    heapq.heappush(heap, (priority, new_cost, new_board, path + [state]))
```

```
    def dfs(self):
        stack = []
        visited = []
        stack.append(self.board)
        visited.append(self.bhash(self.board))
        while stack:
            top = stack[-1]
            if self.bhash(top) == self.bhash(self.end):
                break
            valid_moves = self.getMoves(top)
            added = False
            # print(zeroPos, valid_moves)
            for move in valid_moves:
                new_board = [row[:] for row in top]
                zeroPos = self.zero_index(new_board)
                newPos = [zeroPos[0] + move[0], zeroPos[1] + move[1]]
                new_board[newPos[0]][newPos[1]], new_board[zeroPos[0]][zeroPos[1]] =
new_board[zeroPos[0]][zeroPos[1]], new_board[newPos[0]][newPos[1]]
                if self.bhash(new_board) not in visited:
                    stack.append(new_board)
                    visited.append(self.bhash(new_board))
                    added = True
                    break
            if not added:
                stack.pop()
        while stack:
            self.display(stack.pop(0))
            print("--------")


c = Puzzle()
print('DFS: ')
c.dfs()
print("MD: ")
c.a_star()
```

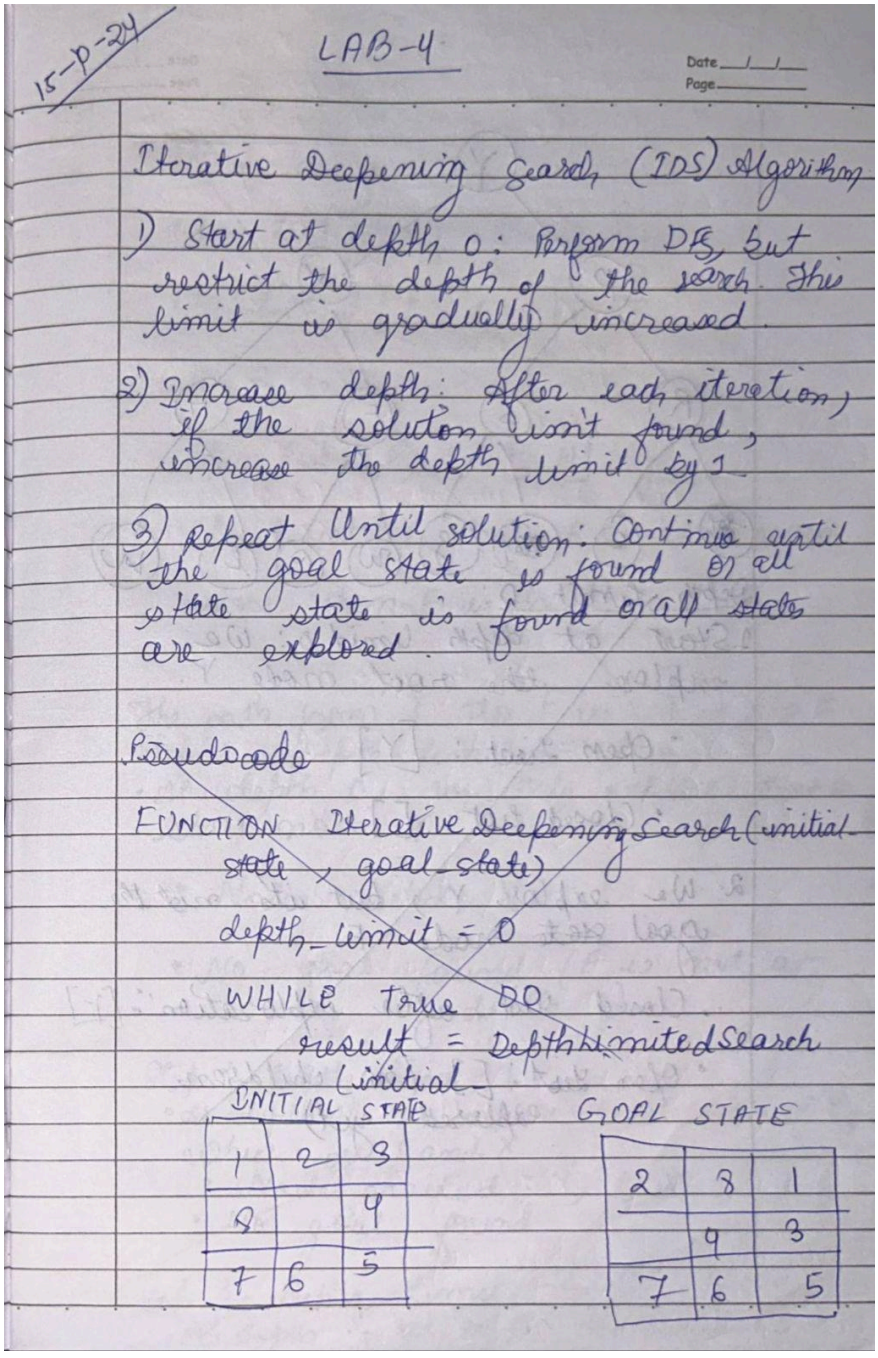
Output:

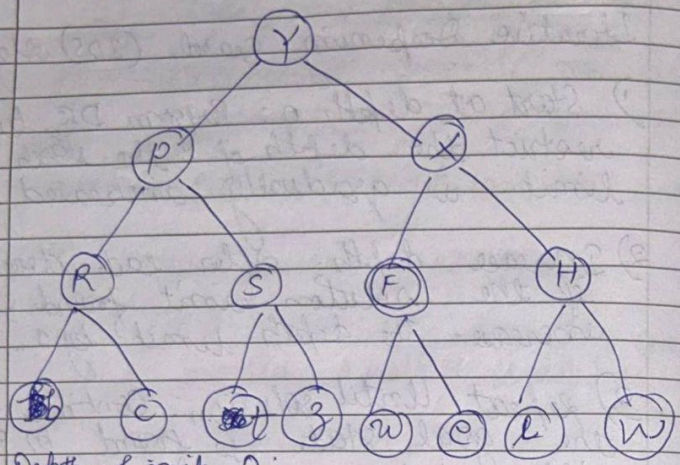
```
8 1 0
2 4 3
7 6 5
------
8 0 1
2 4 3
7 6 5
------
0 8 1
2 4 3
7 6 5
------
2 8 1
0 4 3
7 6 5
------
```

Lab 4

Implement Iterative Deepening Search Algorithm & Implement A Search Algorithm*

Screenshots:





Depth Limit 0:

1. Start at depth limit 0: We explore the root node Y.
   - Open List: [Y]
   - Closed List: []
2. We explore Y, but it's not the goal ~~state~~ node F.
   - Closed list after exploration: [Y]
   - Open List: [] (no children explored yet)

Depth 1:

Open List: [P, X]

Closed List: [P Y, P, X]

Depth 2:

Open List: [R, S, F, H]

Closed List: [Y, P, X, R, S] (the search stops when F is found)

The path from Y to F is: Y → X → F.

Step 1: Depth Limit = 0
- At depth 0, we only explore the start node Y.
  - Nodes visited Y
  - No goal found (F is not at depth 0)

Step 2: Depth Limit = 1
- At depth 1, we explore the children of Y, which are P and X.
  - Nodes visited: Y, P, X
  - No goal found

Step 3: Depth Limit = 2
- At depth 2, we explore the children of P

and X. • P's children: R, S ; • X's children: F, H
Nodes visited: Y, P, R, S, X, F
• Goal state F found at depth 2.
Thus, the solution is found at depth 2, and the path to reach the goal is $Y \rightarrow X \rightarrow F$.

The initial state of the puzzle is:

1	2	3
8		4
7	6	5

Manhattan Distance $h(n)$ for initial state:

Tile 1: Current pos (0,0)
Goal pos (0,2) Distance = 2

Tile 2: Distance = 1

Tile 3: Distance = 1

Tile 4: " 2

Tile 5: " 0

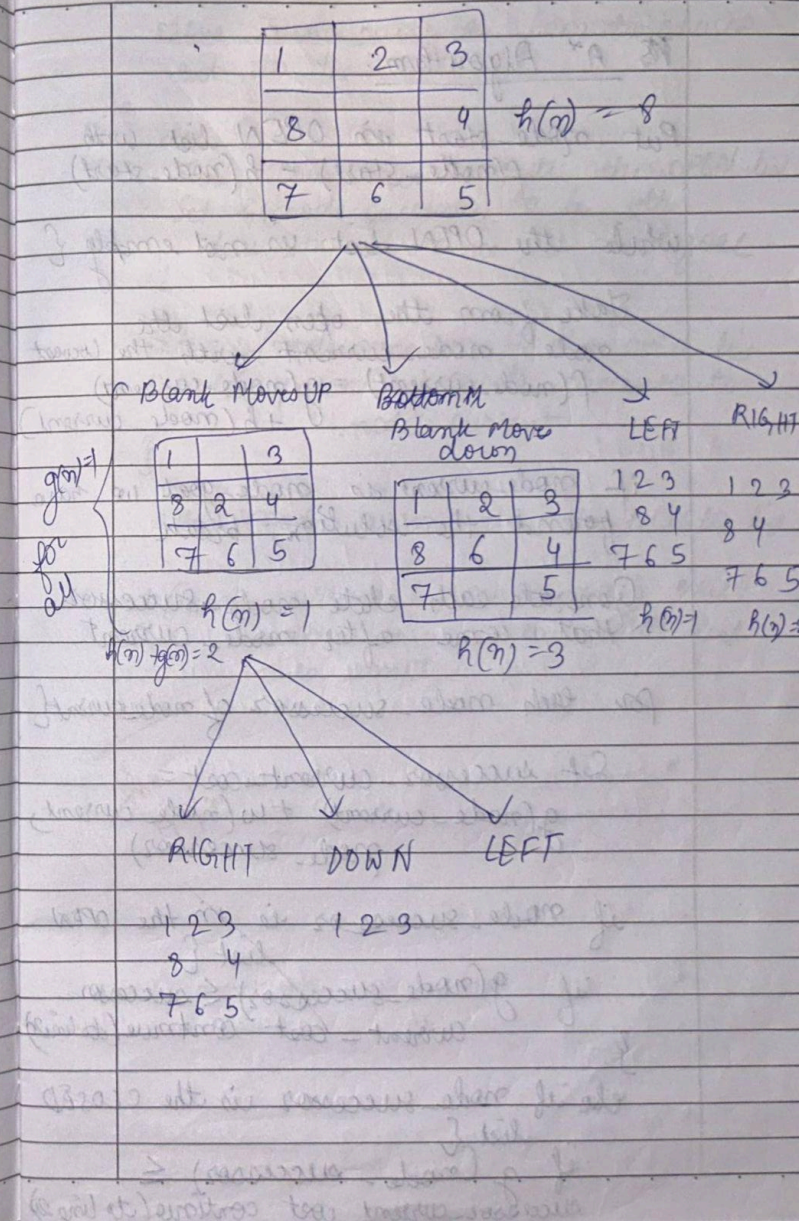
Tile 6: " 0

Tile 7: " 2

Tile 8: " 2

Total Manhattan Distance

$h(n) = 2+1+1+2+0+0+0+2 = 8$



A* Algorithm:

Put node_start in OPEN list with
f(node_start) = h(node_start)

while the OPEN list is not empty {

Take from the open list the node node_current with the lowest f(node_current) = g(node_current) + h(node_current)

if node_current is node_goal we have found the solution; break

Generate each state node_successor that come after node_current

for each node_successor of node_current {

Set successor_current_cost = g(node_current) + w(node_current, node_successor)

if node_successor is in the OPEN list {

if g(node_successor) ≤ successor_current_cost continue (do line 2)

}

else if node_successor is the CLOSED list {

if g(node_successor) ≤ successor_current_cost continue (do line 2)

Move node_successor from the CLOSED list to the OPEN list

} else {

Add node_successor to the OPEN list

Set h(node_successor) to be the heuristic distance to node_goal

}

Set g(node_successor to the OPEN list

Set the parent of node_successor to node_current

}

Add node_current to the CLOSED list

}

if (node_current != node_goal) exit with error (the OPEN list is empty)

Codes:

iterative_deepening.py

```
class TreeNode:
    def __init__(self, value):
        self.value = value
        self.children = []

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

def iddfs(root, goal):
    for d in range(100000):
        res = dls(root, goal, d)
        if res:
            return "Found"
    return "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')
node2 = TreeNode('P')
node3 = TreeNode('X')
node4 = TreeNode('R')
node5 = TreeNode('S')
node6 = TreeNode('F')
node7 = TreeNode('H')

root.add_child(node2)
root.add_child(node3)
node2.add_child(node4)
node2.add_child(node5)
node3.add_child(node6)
node3.add_child(node7)
```

```
print(iddfs(root, 'F'))
```

a_star_search.py

```
import heapq

def manhattan(curr, goal):
    ans = 0
    for i in range(3):
        for j in range(3):
            for k in range(3):
                for l in range(3):
                    if goal[i][j] == curr[k][l]:
                        ans += abs(i - k) + abs(j - l)
    return ans

def astar(start, goal):
    open_set = []
    heapq.heappush(open_set, (manhattan(start, goal), start))
    close_set = set()
    gscore = {}
    gscore[tuple(map(tuple, start))] = 0
    parent = {}

    while open_set:
        _, curr = heapq.heappop(open_set)
        if curr == goal:
            return path(parent, curr)
        close_set.add(tuple(map(tuple, curr)))
        for neighbour in neighbours(curr):
            if tuple(map(tuple, neighbour)) in close_set:
                continue
            new_g = gscore[tuple(map(tuple, curr))] + 1
            if tuple(map(tuple, neighbour)) not in gscore or new_g < gscore[tuple(map(tuple,
neighbour))]:
                parent[tuple(map(tuple, neighbour))] = curr
                gscore[tuple(map(tuple, neighbour))] = new_g
                heapq.heappush(open_set, (new_g + manhattan(neighbour, goal), neighbour))
    return "No solution"

def neighbours(curr):
    n = []
    x, y = 0, 0
    directions = [[1, 0], [0, 1], [-1, 0], [0, -1]]
    for i in range(3):
```

```
        for j in range(3):
            if curr[i][j] == 0:
                x, y = i, j
                break
    for dx, dy in directions:
        if 0 <= x + dx < 3 and 0 <= y + dy < 3:
            new_state = [row.copy() for row in curr]
            new_state[x][y], new_state[x + dx][y + dy] = new_state[x + dx][y + dy],
new_state[x][y]
            n.append(new_state)
    return n

def path(parent, curr):
    fol = [curr]
    while tuple(map(tuple, curr)) in parent:
        curr = parent[tuple(map(tuple, curr))]
        fol.append(curr)
    return list(reversed(fol))

start = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]
goal = [[2, 8, 1], [0, 4, 3], [7, 6, 5]]
result = astar(start, goal)
if result != "No solution":
    for ind,state in enumerate(result):
        print(f"Step: {ind}")
        for row in state:
            print(row)
        print()
    print("Goal Reached")
else:
    print(result)
```

Output:

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

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

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

Step: 9
[2, 8, 1]
[0, 4, 3]
[7, 6, 5]

Goal Reached
```

Lab 5

Use Simulated Annealing to Solve the 8-Queens Problem

Screenshots:

22-10-24

LAB-5

Simulated Annealing

algorithm based on the physical annealing process.

The following pseudocode presents the simulated annealing heuristic:

1) Initialise parameters
   - Set the initial solution S
   - Set the initial temperature T
   - Define cooling rate α (0 < α < 1)
   - Set the stopping criterion

2) Iterate:
   - Repeat until a stopping condition (like a low temperature or a certain no. of iteration) is met:
   - Generate a neighboring state: Slightly modify the current state to explore new solutions.
   - Evaluate energy: Calculate the energy (objective function) of the new state.

Acceptance Decision

- If the new state has a lower energy than the previous accept it.
- If the higher energy is found accept it with probability that it is

and have much worse the new state is,

metropolis criteria

$P(\text{accept}) = e^{-[E_{new} - E_{current}]/T}$

1) Cool down: Gradually reduce the temperature according to the cooling schedule

2) Stop: Once the temperature is low or after a set number of iterations, stop and return the best solution found

$T \leftarrow T \times \alpha$

CODE

```
import numpy as np
import matplotlib.pyplot as plt

def rastrigin(x):
    A = 10
    return A * len(x) + sum([(xi**2
        - A * np.cos(2 * np.pi * xi))
        for xi in x])
```

```
def simulated_annealing(start, initial_temp, cooling_rate, max_iter):
    current_solution = start
    current_energy = rastrigin(current_solution)
    best_solution = current_solution
    best_energy = current_solution_energy
    temp = initial_temp

    energies = [current_energy]

    for i in range(max_iter):

        candidate_solution = current_solution
            + np.random.uniform(-1, 1,
                size = len(start))

        candidate_solution = np.clip(
            candidate_solution, -5.12, 5.12)

        candidate_energy = rastrigin(candidate
                _solution)

        delta_energy = candidate_energy -
                current_energy

        if delta_energ > 0:
            current_solution = candidate
                Solution
            current_energy = candidate_energy
        else:
            acceptance_prob = np.exp(delta_energ/
                temp)
            if np.random.rand() < acceptance_pro
                current_solution = candidate_soluti
                best_energy = current_energy

        temp *= cooling_rate
        energies.append(current_energy)

    return best_solution, best_energy,
            energies
```

Output:

Best solution : [-4.549..., 4.519...]

Best energy : 80.642...

Jm 22/10/24

Code:

```
import random
import math


class Annealing:
    def __init__(self) -> None:
        self.initial_sol = random.uniform(-10, 10)
        self.temp = 10
        self.cooling = 0.99
        self.final = 0.01
        self.annealing()
    def cost(self, x):
        # return x**2
        return x**4 + 5*math.sin(5*math.pi*x)
    def getNeighbors(self, sol):
        return sol + random.uniform(-1, 1)
    def annealing(self):
        current = self.initial_sol
        new = current
        best = current
        while self.temp > self.final:
            new = self.getNeighbors(current)
            dE = self.cost(new) - self.cost(current)
            print(f"Temp diff: {((self.temp - self.final)*100)/self.temp:.2f}%; Current sol:
{current}; New sol: {new}; Best: {best}")
            if dE < 0 or random.random() < math.exp(-dE/self.temp):
                current = new
            if self.cost(new) < self.cost(best):
                best = new
            self.temp *= self.cooling
        print(f"Final solution: {best}")


c = Annealing()
```

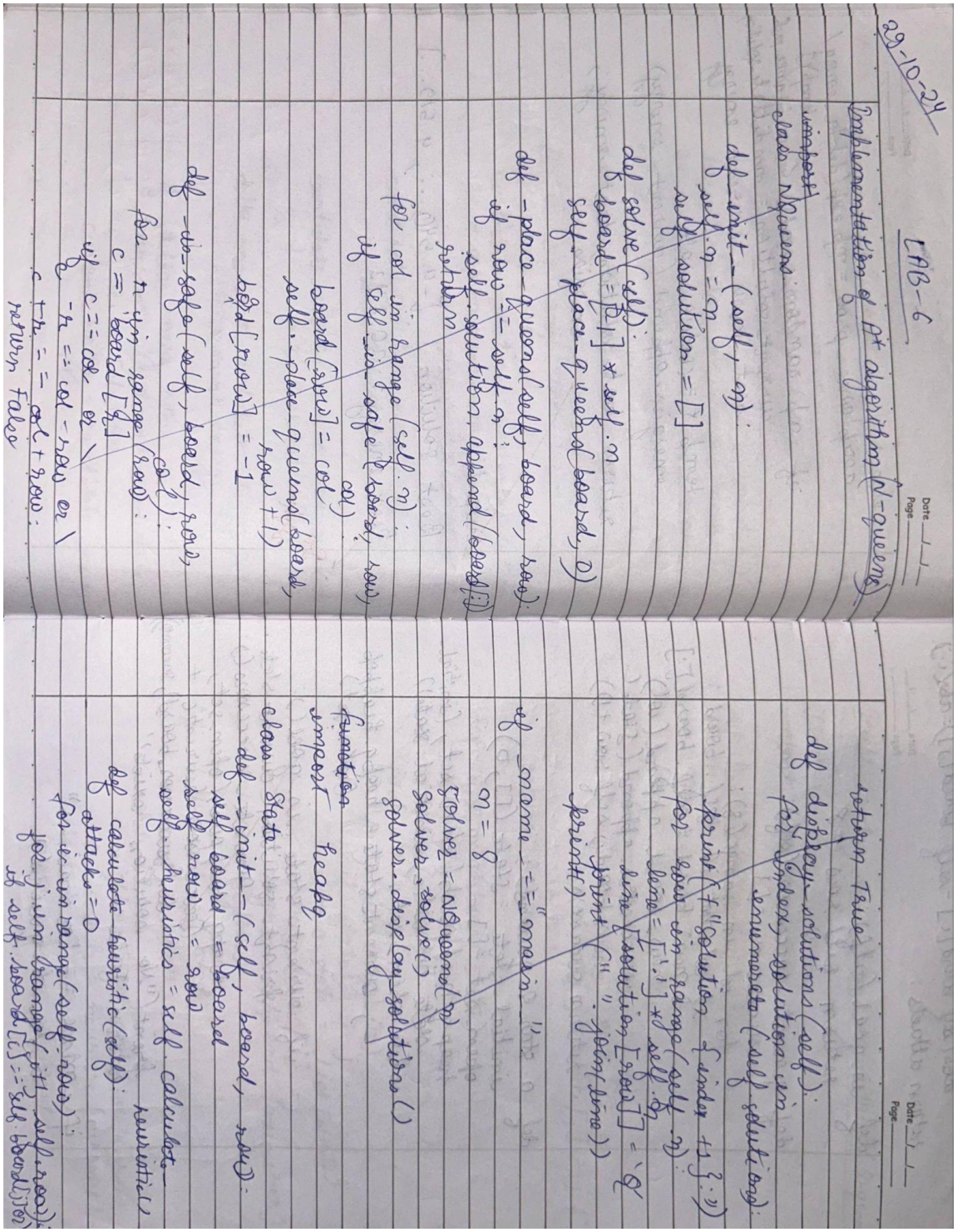
Output:

```
Temp diff: 8.02%; Current sol: -0.10524791597666172; New sol: -0.5199592973272358; Best: -0.10044379288794336
Temp diff: 7.09%; Current sol: -0.10524791597666172; New sol: -0.04562821938109707; Best: -0.10044379288794336
Temp diff: 6.15%; Current sol: -0.10524791597666172; New sol: -0.6717496506340699; Best: -0.10044379288794336
Temp diff: 5.20%; Current sol: -0.10524791597666172; New sol: -0.08008245645276957; Best: -0.10044379288794336
Temp diff: 4.24%; Current sol: -0.10524791597666172; New sol: -0.0734785559577622; Best: -0.10044379288794336
Temp diff: 3.28%; Current sol: -0.10524791597666172; New sol: 0.3864540085802399; Best: -0.10044379288794336
Temp diff: 2.30%; Current sol: -0.10524791597666172; New sol: 0.14231659835465837; Best: -0.10044379288794336
Temp diff: 1.31%; Current sol: -0.10524791597666172; New sol: -0.5267249842132364; Best: -0.10044379288794336
Temp diff: 0.32%; Current sol: -0.10524791597666172; New sol: -0.8089796006183425; Best: -0.10044379288794336
Final solution: -0.10044379288794336
```

Lab 6

Implement Hill Climbing Search Algorithm to Solve the N-Queens Problem

Screenshots:



```
            abs(self.board[i] - self.board[j]) == abs(i-j):
    return attacks:

def is_goal(self):
    return self.row == 8

def generate_successors(self):
    successors = []
    for col in range(8):
        if col not in self.board:
            new_board = self.board[:]
            new_board.append(col)
            successors.append(State(
                new_board, self.row + 1))
    return successors

def a_star_8_queens():
    initial_state = State([], 0)
    open_set = []
    heapq.heappush(open_set, (initial_
        state.heuristic, initial_state))
    while open_set:
        _, current_state = heapq.heappop
                            (open_set)

        if current_state.is_goal():
            print_solution(current_state.
                        generate_successors():
                heapq.heappush(open_set,
                (successor.heuristic +
                    len(successor.board), successor))
    print("No solution exists")
    return False

if __name__ == "__main__":
    a_star_8_queens()
```

Implementing hill climbing method (8-queen

CODE:-

```
import random

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

def get_neighbors(state):
    neighbors = []
    n = len(state)
    for i in range(n):
        for j in range(n):
            if state[i] != j:
                new_state = list(state)
                new_state[i] = j
                neighbors.append(new_state)
    return neighbors

def hill_climbing(state):
    current = state
    while True:
        neighbors = get_neighbors(current)
        current_h = heuristic(current)
        best_h = current_h
        best_neighbor = current
```

12-11-24

LAB - 07

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Knowledge Base:

1. Alice is the mother of Bob.
2. Bob is the father of Charlie.
3. A father is a parent.
4. A mother is a parent.
5. All parents have children.
6. If someone is a parent, their children are siblings.

Hypothesis:

- "Charlie is a sibling of Bob"

Entailment Process:

- Bob is a parent (from premise 2 and 3)
- Since Bob is a parent, his children (including Charlie) are siblings (from premise 6)
- Therefore, Charlie and Bob are siblings

Conclusions:

- The hypothesis is entailed by the knowledge base.

Code:

```
import math
import random
def cost(x):
   return math.sin(x)

def hill_climbing(initial_sol=0, steps=0.01, max_steps=1000):
   print(f"Initial sol: {initial_sol}; steps: {steps}")
   current = initial_sol
   best = current
   for _ in range(max_steps):
       neighbor = [current + steps, current - steps]
       # print(neighbor)
       neighbor.sort(key=lambda x : cost(x))
       current = neighbor[-1]
       if cost(best) < cost(current):
           best = current
       else:
           break
       print(f"Current: {current}, Best: {best}")
   return best
initial_sol = random.uniform(-10, 10)
steps = random.choice((00.01, 0.001))
print(hill_climbing(initial_sol, steps))
```

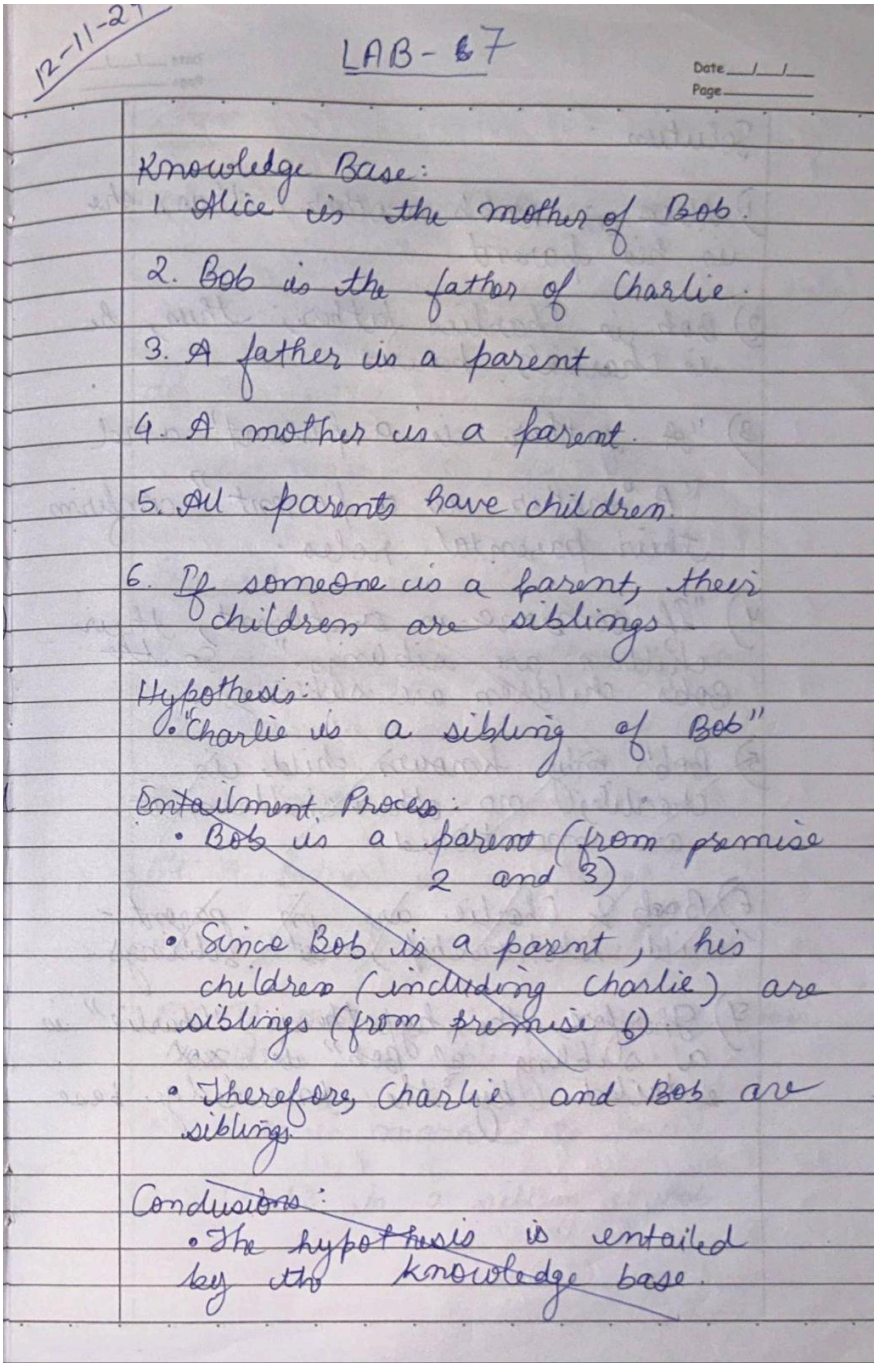
Output:

```
Current: 1.5099927602763248, Best: 1.5099927602763248
Current: 1.5199927602763248, Best: 1.5199927602763248
Current: 1.5299927602763248, Best: 1.5299927602763248
Current: 1.5399927602763248, Best: 1.5399927602763248
Current: 1.5499927602763248, Best: 1.5499927602763248
Current: 1.5599927602763248, Best: 1.5599927602763248
Current: 1.5699927602763248, Best: 1.5699927602763248
1.5699927602763248
```

Lab 7

Create a Knowledge Base Using Propositional Logic and Test Query Entailment

Screenshots:



Solution:

1) Alice is Bob's mother; thus, she is his parent.

2) Bob is Charlie's father; thus, he is Charlie's parent.

3) "A father is a parent" and "A mother is a parent" confirm their parental roles.

4) "If someone is a parent, their children are siblings." So the Bob's children are siblings.

5) Bob's only known child is Charlie; no other children are mentioned.

6) Bob & Charlie are in parent-child relationship, not siblings.

7) Therefore, the hypothesis "Charlie" is a sibling of "Bob" is not entailed by the knowledge base.

CODE:

```
def pl_true(statement, model):
    return model.get(statement, False)

def tt_entails(kb, alpha):
    symbols = list(set(kb
```

Propositional Variables

P1: Alice is the mother of Bob

P2: Bob is the father of Charlie

P3: A mother is a parent.

P4: A father is a parent.

P5: All parents have children.

P6: If someone is a parent, their children are siblings

P7: Alice is married to David.

H: Charlie is a sibling of Bob.

Step	Logical Expression	Conclusion
1.	P1	Alice is the mother of Bob.
2.	P3	A mother is a parent
3.	P1 ∧ P3 → P8	Alice is a parent (P8)
4.	P2	Bob is the father of Charlie.
5.	P4	A father is a parent
6.	P2 ∧ P4 → P9	Bob is a parent (P9)
7.	P5	All parents have children.
8.	P8 ∧ P5 → P10	Alice has children (P10)
9.	P9 ∧ P5 → P11	Bob has children (P11)
10.	P6	Parents children are siblings
11.	P9 ∧ P6 → (Bob's children are siblings)	From Bob being a parent.
12	[From step 4 & P11] Bob only known child is Charlie.	& No other children are specified.
13.	Cannot conclude Charlie has siblings via Bob	
14.	P8 ∧ P6 → (Alice's children are siblings)	From Alice being a parent
15.	[From step 2 & P10] Alice's only known child is Bob	No other children are specified. Cannot

Hence Proved.

Code:

```
def AND(a, b):
    return a and b

def OR(a, b):
    return a or b

def NOT(a):
    return not a

def IMPLIES(a, b):
    return (not a) or b

def infix_to_postfix(expr):
    precedence = {'NOT': 3, 'AND': 2, 'OR': 2, 'IMPLIES': 1}
    output = []
    stack = []
    tokens = expr.replace('(', ' ( ').replace(')', ' ) ').split()

    for token in tokens:
        if token not in precedence and token not in {'(', ')'}:
            output.append(token)
        elif token in precedence:
            while stack and stack[-1] != '(' and precedence[stack[-1]] >= precedence[token]:
                output.append(stack.pop())
            stack.append(token)
        elif token == '(':
            stack.append(token)
        elif token == ')':
            while stack and stack[-1] != '(':
                output.append(stack.pop())
            stack.pop()
    while stack:
        output.append(stack.pop())

    return ' '.join(output)

def eval_postfix(postfix_expr, assignment):
    tokens = postfix_expr.split()
    stack = []
    for token in tokens:
        if token == 'NOT':
```

```
            a = stack.pop()
            stack.append(NOT(a))
        elif token in {'AND', 'OR', 'IMPLIES'}:
            b = stack.pop()
            a = stack.pop()
            if token == 'AND':
                stack.append(AND(a, b))
            elif token == 'OR':
                stack.append(OR(a, b))
            elif token == 'IMPLIES':
                stack.append(IMPLIES(a, b))
        else:
            stack.append(assignment.get(token, False))
    return stack.pop()

def generate_assignments(propositions):
    n = len(propositions)
    for i in range(2**n):
        assignment = {}
        for j, prop in enumerate(propositions):
            assignment[prop] = (i & (1 << j)) != 0
        yield assignment

def entails(kb, query, propositions):
    kb_postfix = [infix_to_postfix(sentence) for sentence in kb]
    query_postfix = infix_to_postfix(query)

    for assignment in generate_assignments(propositions):
        kb_true = all(eval_postfix(sentence, assignment) for sentence in kb_postfix)
        if kb_true and not eval_postfix(query_postfix, assignment):
            return False
    return True

if __name__ == "__main__":
    knowledge_base = [
        "A IMPLIES B",
        "B IMPLIES C",
        "A"
    ]
    query = "C"
    propositions = set()
    for sentence in knowledge_base + [query]:
```

```
        tokens = sentence.replace('(', ' ').replace(')', ' ').split()
        for token in tokens:
            if token not in {'AND', 'OR', 'NOT', 'IMPLIES'} and token.strip():
                propositions.add(token)
    result = entails(knowledge_base, query, sorted(propositions))
    print("KB entails Query:", "Yes" if result else "No")
```

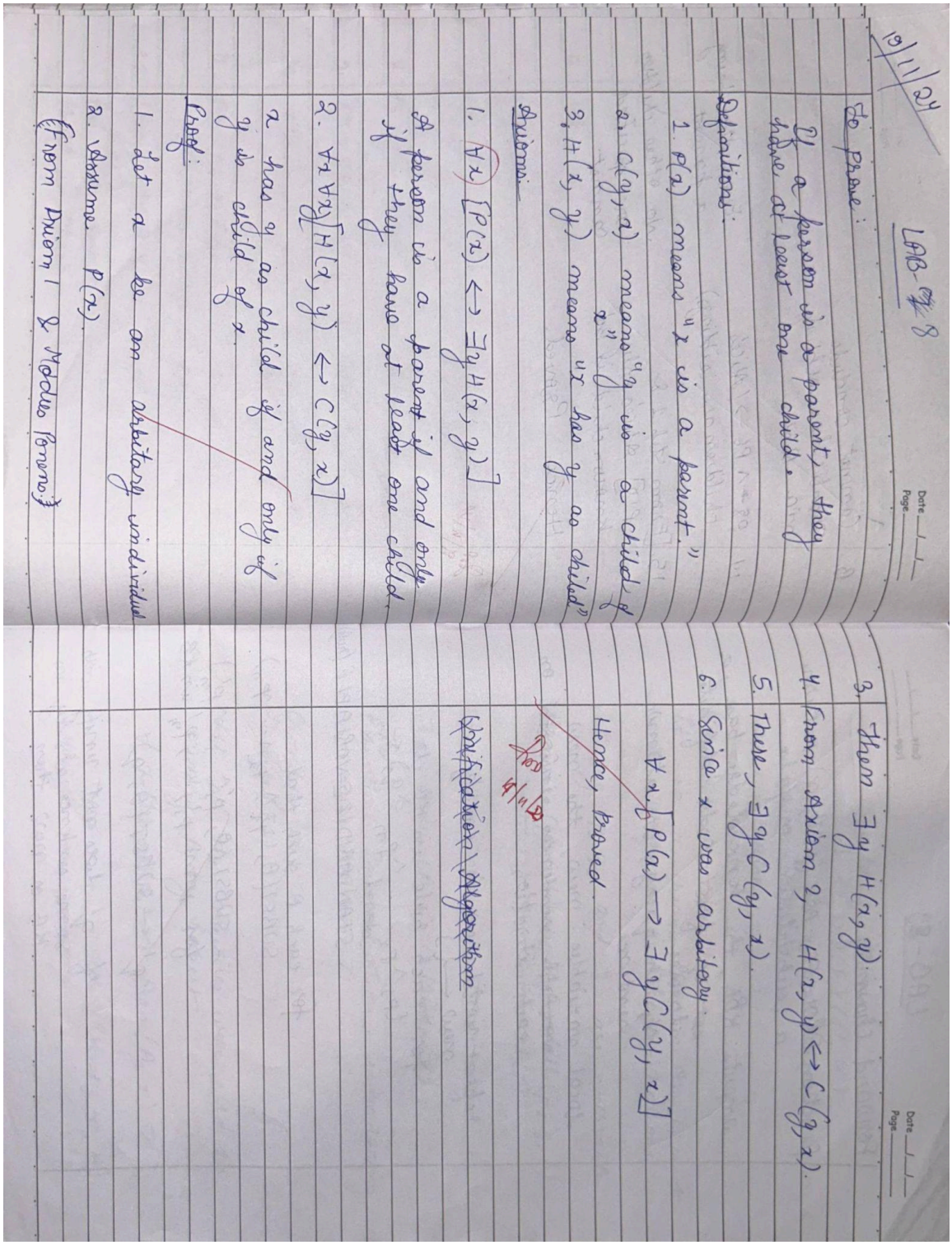
Output:

```
KB entails Query: Yes
```

Lab 8

Implement Unification in First-Order Logic

Screenshots:



Code:

```
def parse_predicate(predicate):
    name, args = predicate.split('(')
    args = args.rstrip(')').split(', ')
    return name, args

def is_variable(term):
    return term[0].islower()

def unify(x, y, subst={}):
    name1, args1 = parse_predicate(x)
    name2, args2 = parse_predicate(y)
    if name1 != name2 or len(args1) != len(args2):
        return None
    for a, b in zip(args1, args2):
        subst = unify_terms(a, b, subst)
        if subst is None:
            return None
    return subst

def unify_terms(a, b, subst):
    a = apply_substitution(a, subst)
    b = apply_substitution(b, subst)
    if a == b:
        return subst
    if is_variable(a):
        return extend_subst(a, b, subst)
    if is_variable(b):
        return extend_subst(b, a, subst)
    return None

def apply_substitution(term, subst):
    while is_variable(term) and term in subst:
        term = subst[term]
    return term

def extend_subst(var, value, subst):
    if occurs_check(var, value, subst):
        return None
    subst = subst.copy()
    subst[var] = value
```

```
    return subst

def occurs_check(var, value, subst):
    if var == value:
        return True
    if is_variable(value) and value in subst:
        return occurs_check(var, subst[value], subst)
    return False

predicate1 = "Parent(x, y)"
predicate2 = "Parent(John, Mary)"
substitution = unify(predicate1, predicate2)

if substitution is not None:
    print("Unification Successful!")
    print("Substitution:", substitution)
else:
    print("Unification Failed.")
```

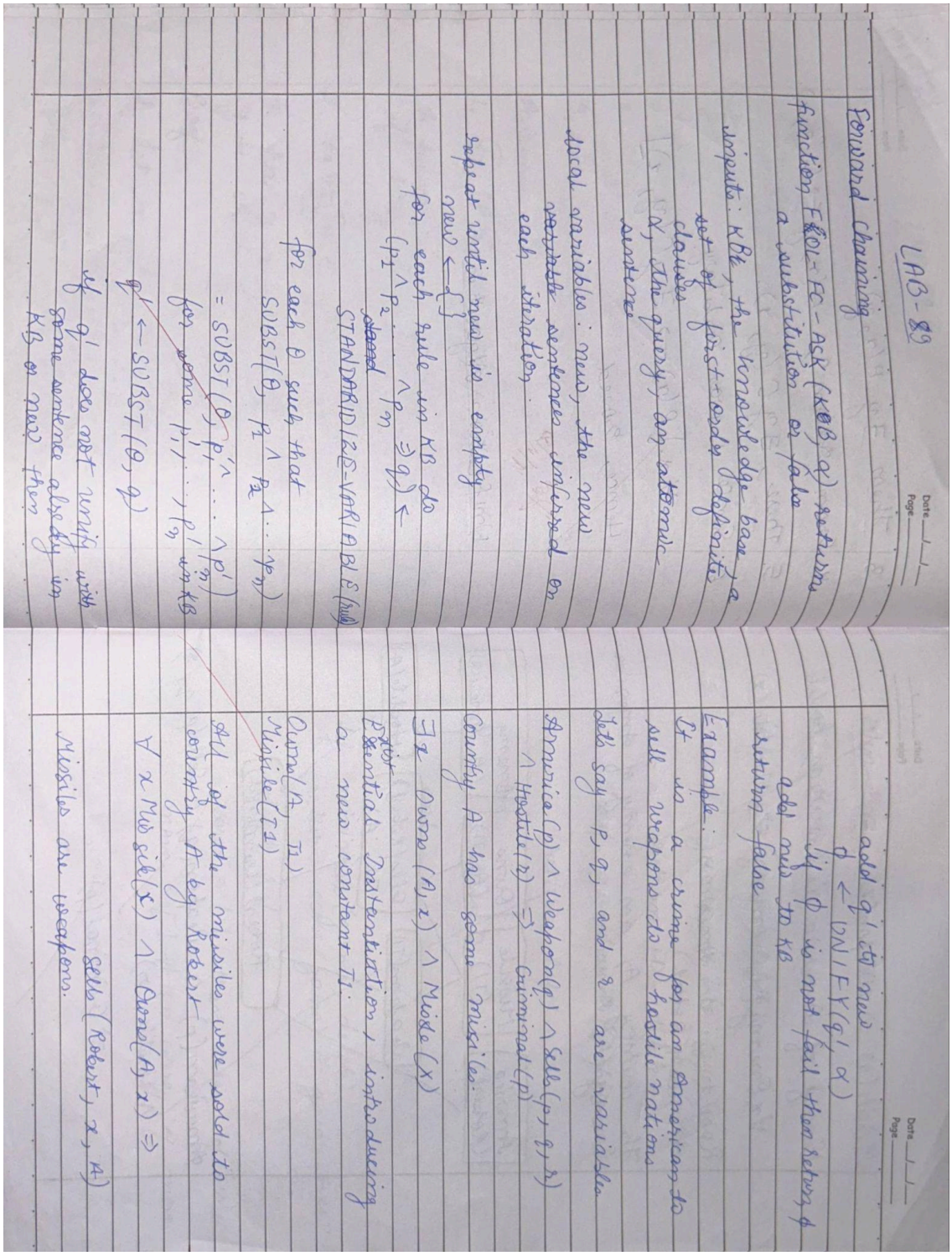
Output:

```
Unification Successful!
Substitution: {'x': 'John', 'y': 'Mary'}
```

Lab 9

Use Forward Reasoning to Prove a Query from a First-Order Logic Knowledge Base

Screenshots:



Missile(x) ⇒ Weapon(x)

Enemy of America is known as hostile

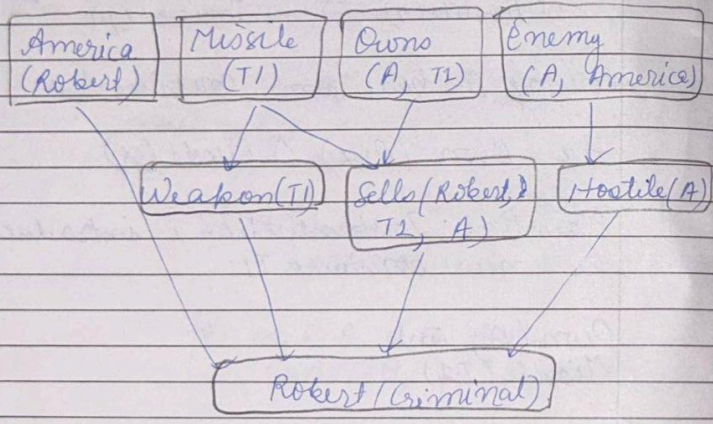
∀x Enemy(x, America) ⇒ Hostile(x)

Robert is an American

American(Robert)

The country A, an enemy of America

Enemy(A, America)



American(p) ∧ Weapon(q) ∧ Sells(p, q, r)

∧ Hostile(r)

⇒ Criminal(p)

Min-Max

Algorithm:

```
def score(game, depth)
    if game.win?(@player)
        return 10 - depth
    elsif game.win?(@opponent)
        return depth - 10
    else
        return 0
    end
end

def minimax(game, depth)
    return score(game) if game.over?
    depth += 1
    scores = [] # an array of scores
    moves = [] # an array of moves
```

Code:

```
def forward_chaining_fol(kb, facts, query):
    inferred = set(facts)
    while True:
        new_inferences = set()
        for premises, conclusion in kb:
            if premises.issubset(inferred) and conclusion not in inferred:
                new_inferences.add(conclusion)
        if query in new_inferences:
            return True
        if not new_inferences:
            break
        inferred.update(new_inferences)
    return query in inferred

knowledge_base = [
    ({"Human(John)"}, "Mortal(John)"),
    ({"Parent(John, Mary)", "Human(Mary)"}, "Human(John)"),
    ({"Father(John, Mary)"}, "Parent(John, Mary)"),
    ({"Human(Mary)"}, "Human(John)")
]

facts = {"Father(John, Mary)", "Human(Mary)"}
query = "Mortal(John)"

result = forward_chaining_fol(knowledge_base, facts, query)
print("Query Result:", "Proved" if result else "Not Proved")
```

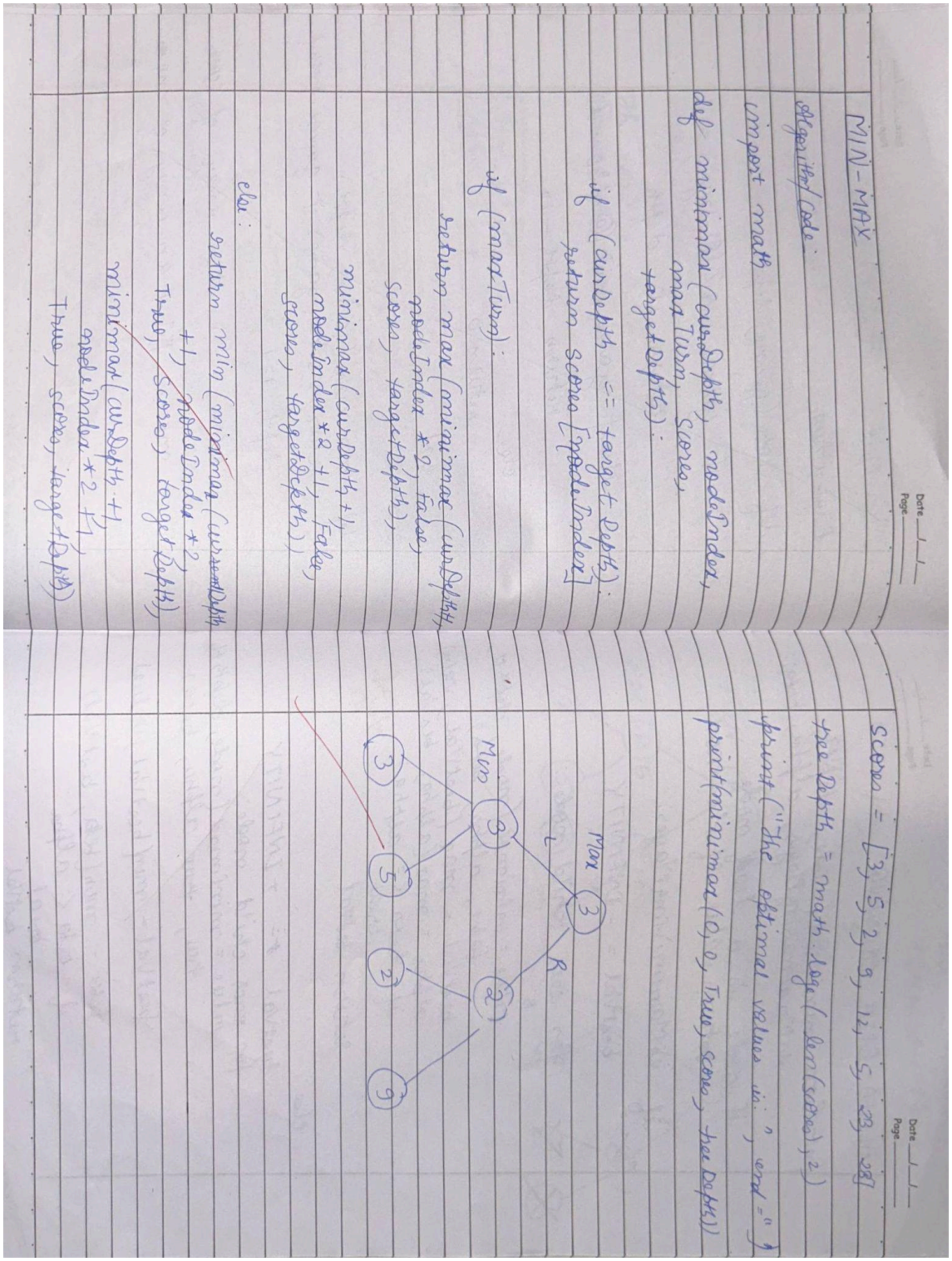
Output:

```
Query Result: Proved
```

Lab 10

Implement Alpha-Beta Pruning

Screenshots:



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ALPHA-BETA PRUNING

```
function minimax(node, depth,
        isMaximisingPlayer, alpha, beta):

  if node is a leaf node:
      return value of the node

  if isMaximisingPlayer:
      bestVal = -INFINITY

      for each child node:
          value = minimax(node, depth+1,
                  false, alpha, beta)
          bestVal = max(bestVal, value)
          alpha = max(alpha, bestVal)
          if beta <= alpha:
              break
      return bestVal

  else:
      bestVal = +INFINITY
      for each child node:
          value = minimax(node, depth+1,
                  true, alpha, beta)
          bestVal = min(bestVal, value)
          beta = min(beta, bestVal)
          if beta <= alpha:
              break
      return bestVal
```

minimax(0, 0, true, -INFINITY, +INFINITY)

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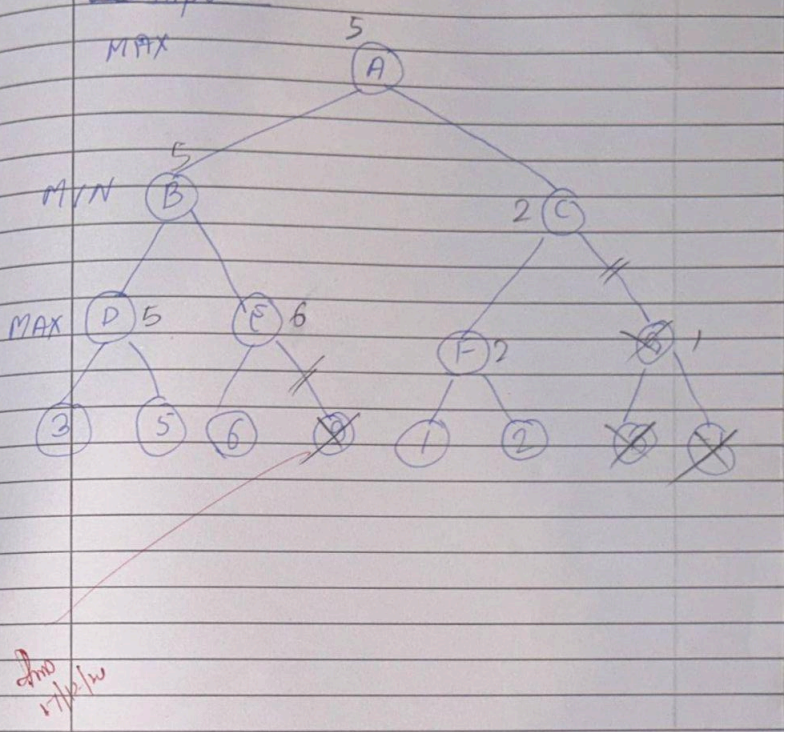
Example:



Code:

minimax.py

```
def minimax(board, depth, is_maximizing):
    winner = check_winner(board)
    if winner == "X":
        return -10
    if winner == "O":
        return 10
    if " " not in board:
        return 0

    if is_maximizing:
        best_score = -float('inf')
        for i in range(9):
            if board[i] == " ":
                board[i] = "O"
                score = minimax(board, depth + 1, False)
                board[i] = " "
                best_score = max(best_score, score)
        return best_score
    else:
        best_score = float('inf')
        for i in range(9):
            if board[i] == " ":
                board[i] = "X"
                score = minimax(board, depth + 1, True)
                board[i] = " "
                best_score = min(best_score, score)
        return best_score

def check_winner(board):
    for i in range(3):
        if board[i*3] == board[i*3+1] == board[i*3+2] != " ":
            return board[i*3]
        if board[i] == board[i+3] == board[i+6] != " ":
            return board[i]
    if board[0] == board[4] == board[8] != " " or board[2] == board[4] == board[6] != " ":
        return board[4]
    return None

def best_move(board):
    best_score = -float('inf')
    move = -1
```

```
    for i in range(9):
        if board[i] == " ":
            board[i] = "O"
            score = minimax(board, 0, False)
            board[i] = " "
            if score > best_score:
                best_score = score
                move = i
    return move

# Example usage:
board = [" " for _ in range(9)]
board[0], board[4], board[8] = "X", "O", "X"  # Sample state
move = best_move(board)
print("Best move for O:", move)
```

alpha_beta_pruning.py

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

def alpha_beta(board, row, alpha, beta, is_maximizing):
    if row == len(board):
        return 1

    if is_maximizing:
        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: 6
```