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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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled “Artificial Intelligence (23CS5PCAIN)” carried out by **Sanvi Nadiga (1BM22CS245),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

Dr. Seema Patil Assistant Professor Department of CSE, BMSCE	Dr. Jyothi S Nayak Professor & HOD Department of CSE, BMSCE

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Github Link:
https://github.com/Sakshishetty24/Artificial-Intelligence

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Lab 1

tic-tac-toe game

Algorithm

1. Create a 3×3 board using 2D array.

2. Display an empty board.

3. Define a function called evaluate() to check whether the board is filled or not.

4. Create a function called row_win() to check whether the rows are filled by winner.

5. Similarly, create column_win() & diag_win

6. Randomly choose a player to begin playing.

7. Display output (the board) after each move

8. The player inputs the x coordinate & Y-coordinate to move.

9. Repeatedly check if any of the winning arrangement returns true.

Code:

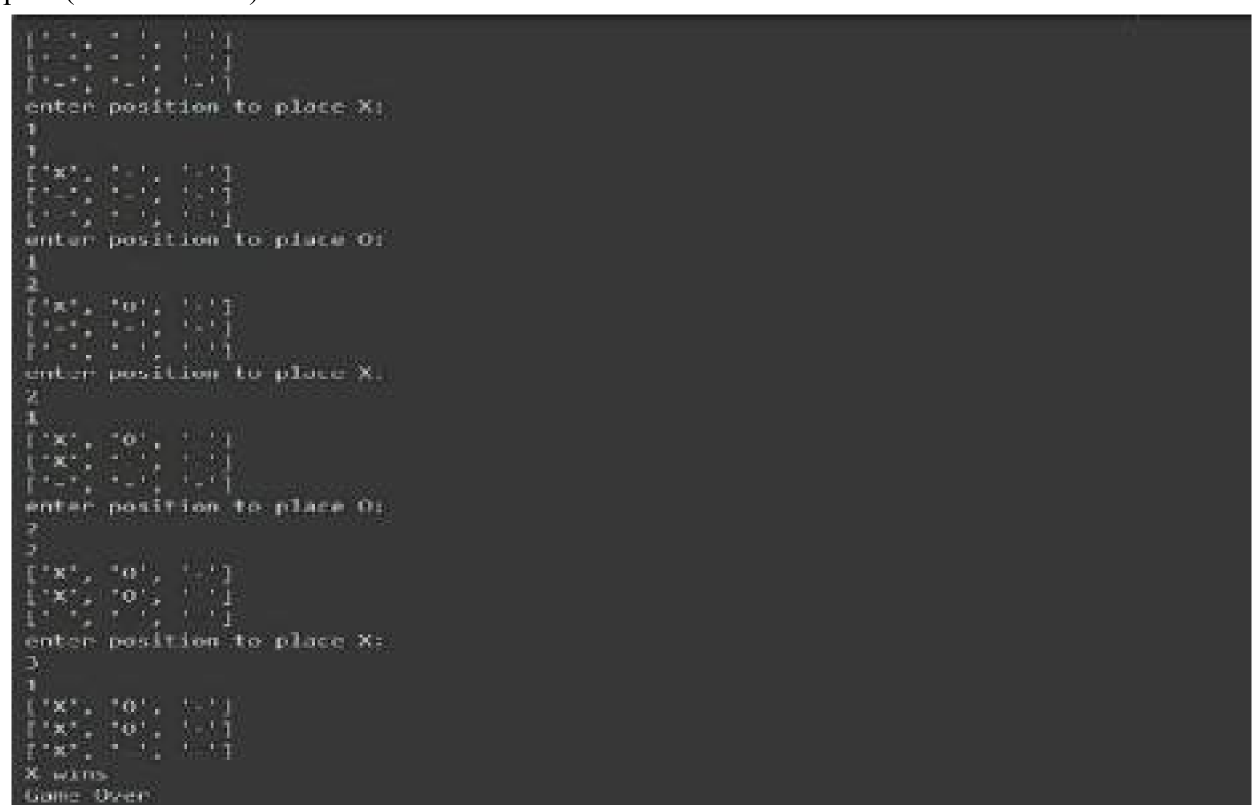
```
def check_win(board, r, c):
    if board[r - 1][c - 1] == 'X':
        ch = "O"
    else:
        ch = "X"
    if ch not in board[r - 1] and '-' not in board[r - 1]:
        return True
    elif ch not in (board[0][c - 1], board[1][c - 1], board[2][c - 1]) and '-' not in (board[0][c - 1], board[1][c - 1], board[2][c - 1]):
        return True
    elif ch not in (board[0][0], board[1][1], board[2][2]) and '-' not in (board[0][0], board[1][1], board[2][2]):
        return True
    elif ch not in (board[0][2], board[1][1], board[2][0]) and '-' not in (board[0][2], board[1][1], board[2][0]):
        return True
    return False

def displayb(board):
  print(board[0])
  print(board[1])
  print(board[2])

board=[['-','-','-'],['-','-','-'],['-','-','-']]
displayb(board)
xo=1
flag=0
while '-' in board[0] or '-' in board[1] or '-' in board[2]:

  if xo==1:
    print("enter position to place X:")
    x=int(input())
    y=int(input())
    if(x>3 or y>3):
      print("invalid position")
      continue
    if(board[x-1][y-1]=='-'):
      board[x-1][y-1]='X'
      xo=0
      displayb(board)
    else:
      print("invalid position")
      continue
    if(check_win(board,x,y)):
```

```
        print("X wins")
        flag=1
        break
  else :
    print("enter position to place O:")
    x=int(input())
    y=int(input())
    if(x>3 or y>3):
      print("invalid position")
      continue
    if(board[x-1][y-1]=='-'):
      board[x-1][y-1]='O'
      xo=1
      displayb(board)
    else:
      print("invalid position")
      continue
    if(check_win(board,x,y)):
        print("0 wins")
        flag=1
        break
if flag==0:
  print("Draw")
print("Game Over")
```



```
['-', '-', '-']
['-', '-', '-']
['-', '-', '-']
enter position to place X:
1
1
['X', '-', '-']
['-', '-', '-']
['-', '-', '-']
enter position to place O:
2
2
['X', '-', '-']
['-', 'O', '-']
['-', '-', '-']
enter position to place X:
3
3
['X', '-', '-']
['-', 'O', '-']
['-', '-', 'X']
enter position to place O:
1
2
['X', 'O', '-']
['-', 'O', '-']
['-', '-', 'X']
enter position to place X:
3
2
['X', 'O', '-']
['-', 'O', '-']
['-', 'X', 'X']
enter position to place O:
3
1
['X', 'O', '-']
['-', 'O', '-']
['O', 'X', 'X']
```

```
enter position to place X:
2
1
['X', 'O', '-']
['X', 'O', '-']
['O', 'X', 'X']
enter position to place O:
2
3
['X', 'O', '-']
['X', 'O', 'O']
['O', 'X', 'X']
enter position to place X:
1
3
['X', 'O', 'X']
['X', 'O', 'O']
['O', 'X', 'X']
Draw
Game Over
```

Vacuum Cleaner

Algorithm:

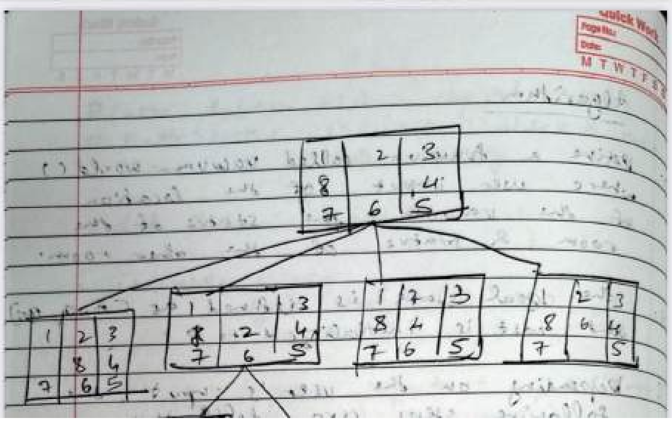
Algorithm

1. Define a function called vacuum_world() where user input of the location of the vacuum, the status of the room & status of the other room.

2. The goal state is defined as {A, 0, B:0} and cost is initialized to 0.

3. Depending on the user's input, the following steps are followed –
   1. Location is specified as A/B & status is 0 when clean, 1 when room is dirty.
   2. If the input location is A & the room is dirty, then vacuum has to 'suck' & the goal state for room A is changed to zero.
   3. Increament the cost variable
   4. If the other's room status is dirty, then the vacuum has to move right & suck.
   5. If the i/p location is A & the room is clean, then depending on the other room's status the vacuum will remain in room A or move right to room B.

4. Goal state attained. Cost calculated.



Code:

count = 0

```
def rec(state, loc):
    global count
    if state['A'] == 0 and state['B'] == 0:
        print("Turning vacuum off")
        return

    if state[loc] == 1:
        state[loc] = 0
        count += 1
        print(f"Cleaned {loc}.")
        next_loc = 'B' if loc == 'A' else 'A'
        state[loc] = int(input(f"Is {loc} clean now? (0 if clean, 1 if dirty): "))
        if(state[next_loc]!=1):
          state[next_loc]=int(input(f"Is {next_loc} dirty? (0 if clean, 1 if dirty): "))
    if(state[loc]==1):
```



```
       rec(state,loc)
    else:
      next_loc = 'B' if loc == 'A' else 'A'
      dire="left" if loc=="B" else "right"
      print(loc,"is clean")
      print(f"Moving vacuum {dire}")
      if state[next_loc] == 1:
          rec(state, next_loc)

state = {}
state['A'] = int(input("Enter state of A (0 for clean, 1 for dirty): "))
state['B'] = int(input("Enter state of B (0 for clean, 1 for dirty): "))
loc = input("Enter location (A or B): ")
rec(state, loc)
print("Cost:",count)
print(state)
```

```
Enter state of A (0 for clean, 1 for dirty): 0
Enter state of B (0 for clean, 1 for dirty): 0
Enter location (A or B): A
Turning vacuum off
Cost: 0
{'A': 0, 'B': 0}
```

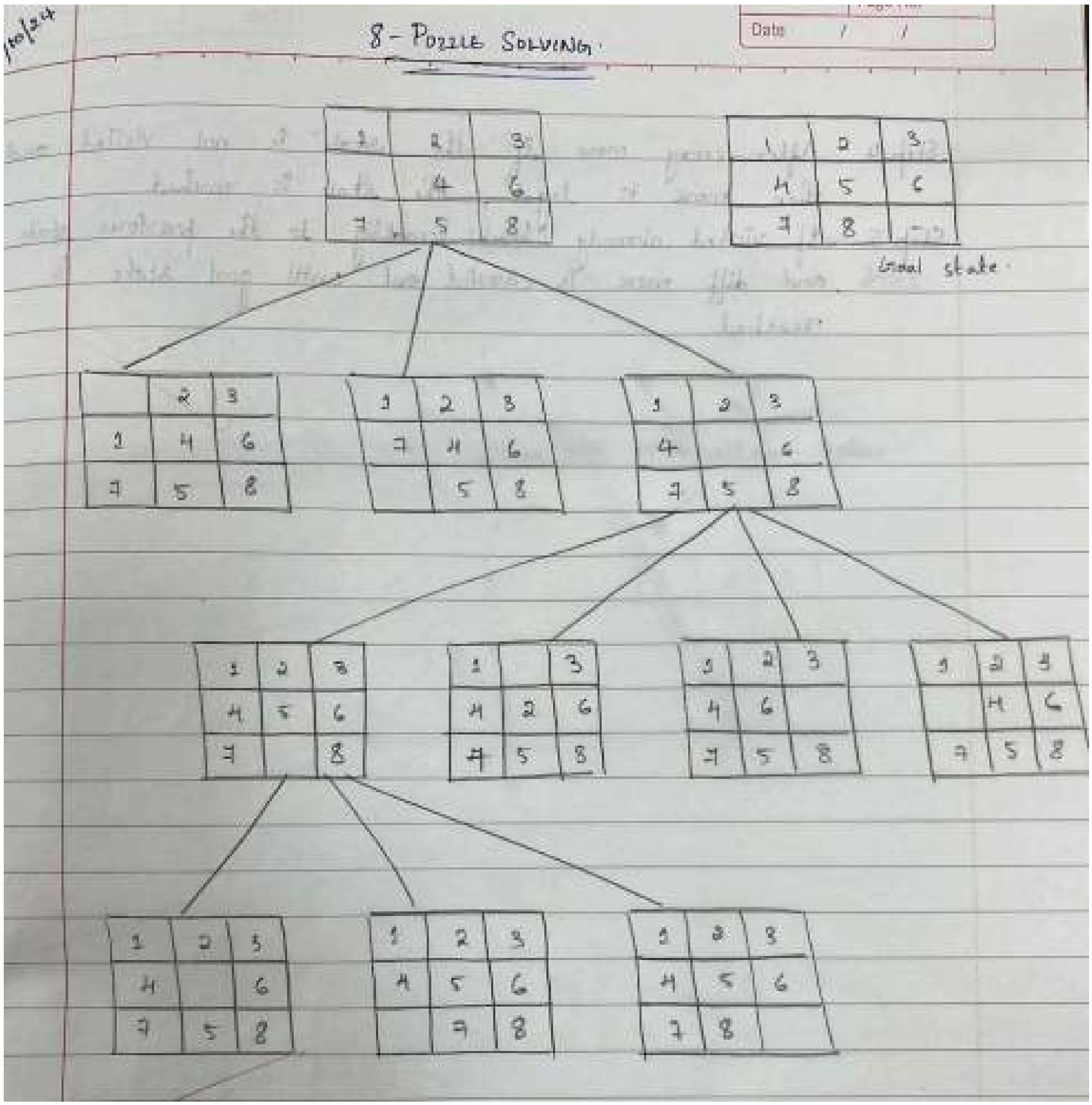
```
Enter state of A (0 for clean, 1 for dirty): 0
Enter state of B (0 for clean, 1 for dirty): 1
Enter location (A or B): A
A is clean
Moving vacuum right
Cleaned B.
Is B clean now? (0 if clean, 1 if dirty): 0
Is A dirty? (0 if clean, 1 if dirty): 0
B is clean
Moving vacuum left
Cost: 1
{'A': 0, 'B': 0}
```

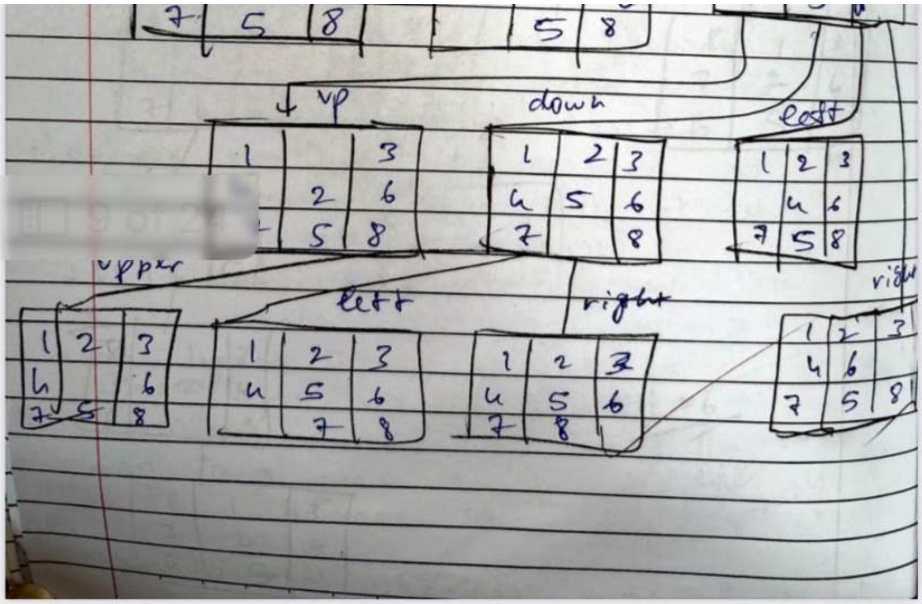
```
Enter state of A (0 for clean, 1 for dirty): 1
Enter state of B (0 for clean, 1 for dirty): 0
Enter location (A or B): A
Cleaned A.
Is A clean now? (0 if clean, 1 if dirty): 0
Is B dirty? (0 if clean, 1 if dirty): 0
A is clean
Moving vacuum right
Cost: 1
{'A': 0, 'B': 0}
```

```
Enter state of A (0 for clean, 1 for dirty): 1
Enter state of B (0 for clean, 1 for dirty): 1
Enter location (A or B): A
Cleaned A.
Is A clean now? (0 if clean, 1 if dirty): 0
A is clean
Moving vacuum right
Cleaned B.
Is B clean now? (0 if clean, 1 if dirty): 0
Is A dirty? (0 if clean, 1 if dirty): 0
B is clean
Moving vacuum left
Cost: 2
{'A': 0, 'B': 0}
```

Program 2
Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

8 puzzle using DFS
Algorithm:





Algorithm :

1. using the BFS algorithm, to solve the 8 puzzle. The slider should swap the empty space with a no. to create a unique state. We need to make sure that no state is repeated so as to avoid infinite looping.

2. BFS:
We start traversing from a selected node and traverse the graph layerwise thus exploring the neighbouring nodes.

3. Action & move set :
the algo. generates new states : [up, down, right, left]. Using these, the algo. generates new states & checks whether each new state is the required goal state.

```
def dfs(initial_board, zero_pos):
    stack = [(initial_board, zero_pos, [])]
    visited = set()

    while stack:
        current_board, zero_pos, moves = stack.pop()

        if is_goal(current_board):
            return moves, len(moves) # Return moves and their count

        visited.add(tuple(current_board))

        for neighbor_board, neighbor_pos in get_neighbors(current_board, zero_pos):
            if tuple(neighbor_board) not in visited:
                stack.append((neighbor_board, neighbor_pos, moves + [neighbor_board]))
```

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```
    return None, 0 # No solution found, return count as 0

# Initial state of the puzzle
initial_board = [1, 2, 3, 0, 4, 6, 7, 5, 8]
zero_position = (1, 0) # Position of the empty tile (0)

# Solve the puzzle using DFS
solution, move_count = dfs(initial_board, zero_position)

if solution:
    print("Solution found with moves ({} moves):".format(move_count))
    for move in solution:
        print_board(move)
        print() # Print an empty line between moves
else:
    print("No solution found.")
```

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

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

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

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

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

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

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

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

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

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

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


Implement Iterative deepening search algorithm

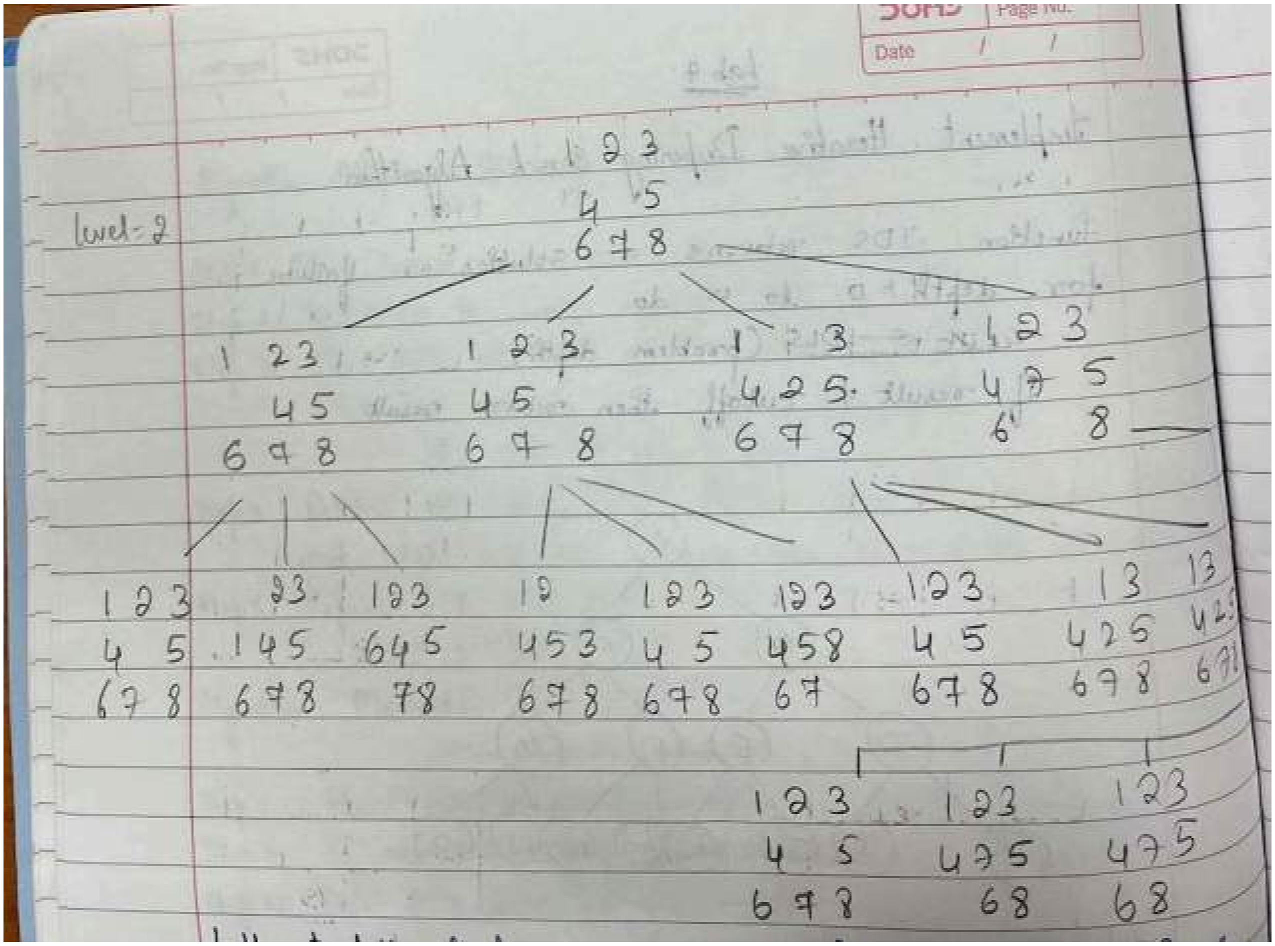
Algorithm:

Algorithm :

Using the BFS algorithm, to solve the 8 puzzle. The slider should swap the empty space with a no. to create a unique state. We need to make sure that no state is repeated so as to avoid infinite looping.

BFS :
We start traversing from a selected node and traverse the graph laywise thus exploring the neighbouring nodes.

3. Action & move set :
the algo. generates new states [up, down, right, left]. Using these, the algo. generates new states & checks whether each new state is the required goal state.



Code:
```
from collections import deque

class PuzzleState:
    def __init__(self, board, zero_pos, moves=0, previous=None):
        self.board = board
        self.zero_pos = zero_pos # Position of the zero tile
        self.moves = moves # Number of moves taken to reach this state
        self.previous = previous # For tracking the path

    def is_goal(self, goal_state):
        return self.board == goal_state

    def get_possible_moves(self):
        moves = []
        x, y = self.zero_pos
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)] # Up, Down, Left, Right
        for dx, dy in directions:
            new_x, new_y = x + dx, y + dy
            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_board = [row[:] for row in self.board]
```

```
                # Swap the zero tile with the adjacent tile
                new_board[x][y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[x][y]
                moves.append((new_board, (new_x, new_y)))
        return moves

def ids(initial_state, goal_state, max_depth):
    for depth in range(max_depth):
        visited = set()
        result = dls(initial_state, goal_state, depth, visited)
        if result:
            return result
    return None

def dls(state, goal_state, depth, visited):
    if state.is_goal(goal_state):
        return state
    if depth == 0:
        return None

    visited.add(tuple(map(tuple, state.board))) # Mark this state as visited
    for new_board, new_zero_pos in state.get_possible_moves():
        new_state = PuzzleState(new_board, new_zero_pos, state.moves + 1, state)
        if tuple(map(tuple, new_board)) not in visited:
            result = dls(new_state, goal_state, depth - 1, visited)
            if result:
                return result
    visited.remove(tuple(map(tuple, state.board))) # Unmark this state
    return None

def print_solution(solution):
    path = []
    while solution:
        path.append(solution.board)
        solution = solution.previous
    for board in reversed(path):
        for row in board:
            print(row)
        print()

# Define the initial state and goal state
initial_state = PuzzleState(
    board=[[1, 2, 3],
           [4, 0, 5],
           [7, 8, 6]],
    zero_pos=(1, 1)
)
```

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

# Perform Iterative Deepening Search
max_depth = 20 # You can adjust this value
solution = ids(initial_state, goal_state, max_depth)

if solution:
    print("Solution found:")
    print_solution(solution)
else:
    print("No solution found.")
```

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

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

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

Program 3

Implement A* search algorithm

Algorithm:

For 8 puzzle problem using A* implementation to calculate $f(n)$ using.

(a) $g(n)$ = depth of a node

$h(n)$ = heuristic value + no. of misplaced tiles.

$f(n) = g(n) + h(n)$

(b) $g(n)$ = depth.

$h(n)$ = heuristic value → manhattan value.

$f(n) = g(n) + h(n)$

2	8	3
1	6	4
7		5

initial

1	2	3
8		4
7	6	5

goal

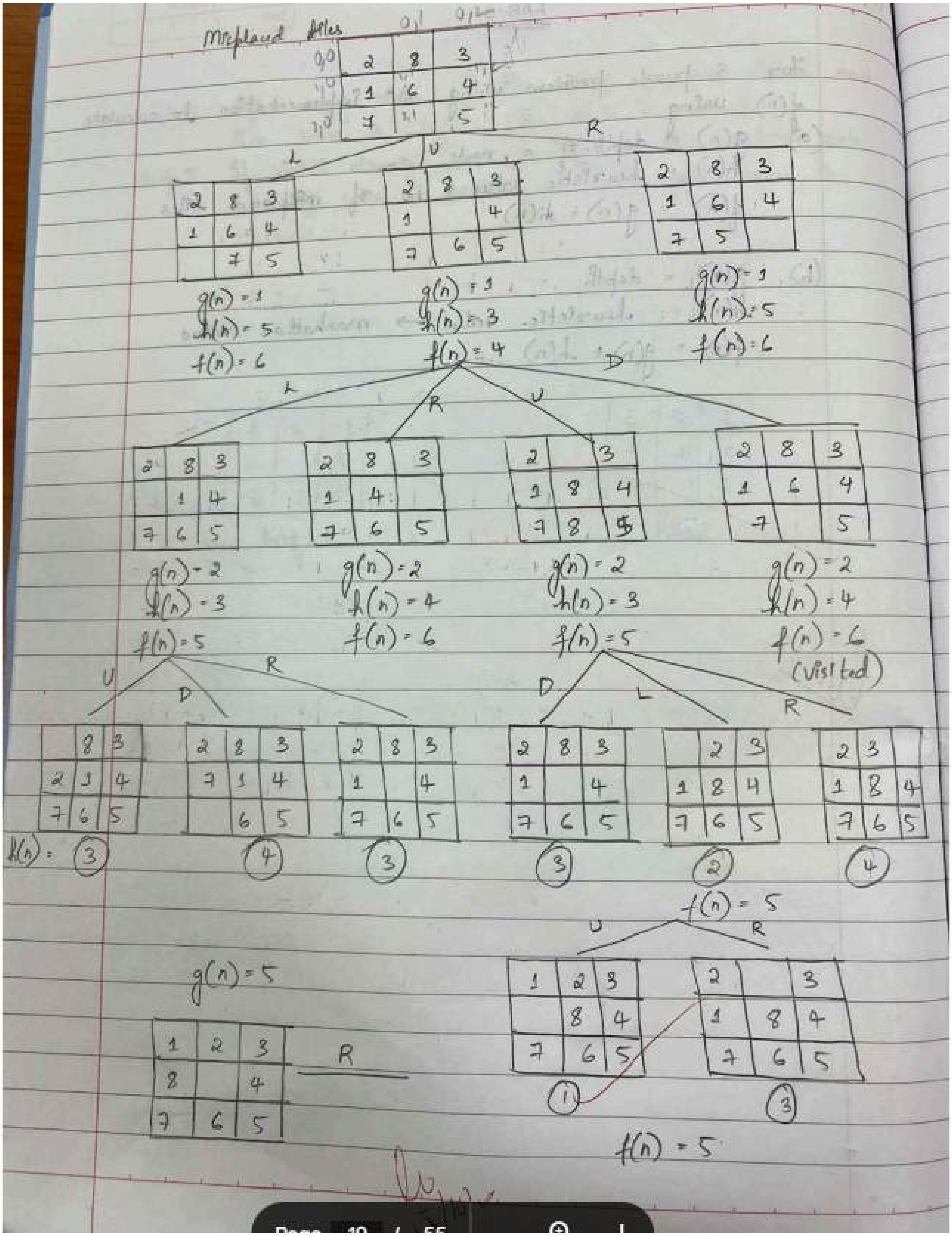
7

Algorithm Misplaced tiles

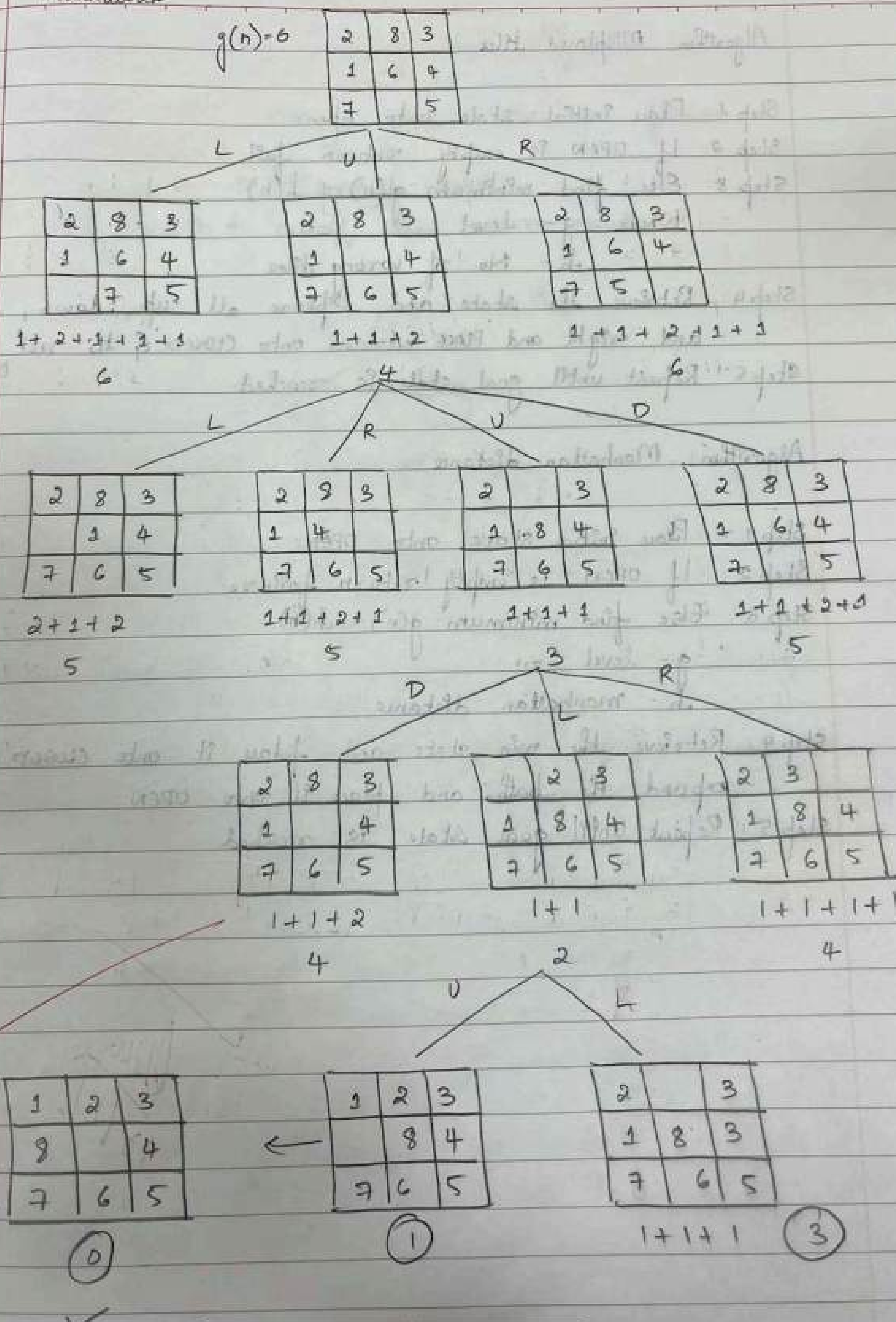
Step 1: Place initial state onto open.
Step 2: If OPEN is empty return fail.
Step 3: Else find minimum $g(n) + h(n)$
Where g - level
h - No. of wrong tiles
Step 4: Retrieve the state and explore all up, down, left and right and PLACE retrieved onto CLOSED & the rest onto OPEN.
Step 5: Repeat until goal state is reached.

Algorithm: Manhattan distance

Step 1: Place initial state onto OPEN.
Step 2: If OPEN is empty return failure.
Step 3: Else find minimum $g(n) + h(n)$
g - level
h - manhattan distance
Step 4: Retrieve the min state and place it onto CLOSED and expand the path and place it onto OPEN.
Step 5: Repeat until goal state is reached.


Misplaced tiles
L
U
R
g(n) = 1
h(n) = 5
f(n) = 6
g(n) = 1
h(n) = 3
f(n) = 4
g(n) = 1
h(n) = 5
f(n) = 6
L
R
U
D
g(n) = 2
h(n) = 3
f(n) = 5
g(n) = 2
h(n) = 4
f(n) = 6
g(n) = 2
h(n) = 3
f(n) = 5
g(n) = 2
h(n) = 4
f(n) = 6
(visited)
U
D
R
D
L
R
h(n) = 3
4
3
3
2
4
f(n) = 5
U
R
1
3
g(n) = 5
R
f(n) = 5

Manhattan


g(n)=0
L
U
R
1+2+1+1+1
6
1+1+2
4
1+1+2+1+1
6
L
R
U
D
2+1+2
5
1+1+2+1
5
1+1+1
1+1+2+1
5
3
D
L
R
1+1+2
4
1+1
1+1+1+1
4
2
U
L
0
1
1+1+1
3

Code:

Misplaced Tiles

```
def mistil(state, goal):
    count = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != goal[i][j]:
                count += 1
    return count

def findmin(open_list, goal):
    minv = float('inf')
    best_state = None
    for state in open_list:
        h = mistil(state['state'], goal)
        f = state['g'] + h
        if f < minv:
            minv = f
            best_state = state
    open_list.remove(best_state)
    return best_state

def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
                'move': move,
                'g': state['g'] + 1
            })
    return next_states

def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None

def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
```

```
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j], new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j], new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1], new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1], new_state[i][j]
    else:
        return None
    return new_state

def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))

initial_state = [[2,8,3], [1,6,4], [7,0,5]]
goal_state = [[1,2,3], [8,0,4], [7,6,5]]
open_list = [{'state': initial_state, 'parent': None, 'move': None, 'g': 0}]
visited_states = []

while open_list:
    best_state = findmin(open_list, goal_state)
    print("Current state:")
    print_state(best_state['state'])
    h = mistil(best_state['state'], goal_state)
    f = best_state['g'] + h
    print(f"g(n): {best_state['g']}, h(n): {h}, f(n): {f}")
    if best_state['move'] is not None:
        print(f"Move: {best_state['move']}")
    print()
    if mistil(best_state['state'], goal_state) == 0:
        goal_state_reached = best_state
        break
    visited_states.append(best_state['state'])
    next_states = operation(best_state)
    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

moves = []
while goal_state_reached['move'] is not None:
    moves.append(goal_state_reached['move'])
    goal_state_reached = goal_state_reached['parent']
moves.reverse()
```

```
print("\nMoves to reach the goal state:", moves)
print("\nGoal state reached:")


print_state(goal_state)
```

```
Current state:
2 8 3
1 6 4
7 0 5
g(n): 0, h(n): 5, f(n): 5

Current state:
2 8 3
1 0 4
7 6 5
g(n): 1, h(n): 3, f(n): 4
Move: up

Current state:
2 0 3
1 8 4
7 6 5
g(n): 2, h(n): 4, f(n): 6
Move: up

Current state:
2 8 3
0 1 4
7 6 5
g(n): 2, h(n): 4, f(n): 6
Move: left

Current state:
0 2 3
1 8 4
7 6 5
g(n): 3, h(n): 3, f(n): 6
Move: left

Current state:
1 2 3
0 8 4
7 6 5
g(n): 4, h(n): 2, f(n): 6
Move: down
```

```
Current state:
1 2 3
8 0 4
7 6 5
g(n): 5, h(n): 0, f(n): 5
Move: right


Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']

Goal state reached:
1 2 3
8 0 4
7 6 5
```

Manhattan Distance

```
def manhattan_distance(state, goal):
    distance = 0
    for i in range(3):
        for j in range(3):
            tile = state[i][j]
            if tile != 0: # Ignore the blank space (0)
                # Find the position of the tile in the goal state
                for r in range(3):
                    for c in range(3):
                        if goal[r][c] == tile:
                            target_row, target_col = r, c
                            break
                # Add the Manhattan distance (absolute difference in rows and columns)
                distance += abs(target_row - i) + abs(target_col - j)
    return distance

def findmin(open_list, goal):
    minv = float('inf')
    best_state = None
    for state in open_list:
        h = manhattan_distance(state['state'], goal) # Use Manhattan distance here
        f = state['g'] + h
        if f < minv:
            minv = f
            best_state = state
    open_list.remove(best_state)
    return best_state

def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
                'move': move,
                'g': state['g'] + 1
            })
    return next_states
```

```
def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:


                return i, j
    return None

def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j], new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j], new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1], new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1], new_state[i][j]
    else:
        return None
    return new_state

def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))

# Initial state and goal state
initial_state = [[2,8,3], [1,6,4], [7,0,5]]
goal_state = [[1,2,3], [8,0,4], [7,6,5]]

# Open list and visited states
open_list = [{'state': initial_state, 'parent': None, 'move': None, 'g': 0}]
visited_states = []

while open_list:
    best_state = findmin(open_list, goal_state)

    print("Current state:")
    print_state(best_state['state'])

    h = manhattan_distance(best_state['state'], goal_state) # Using Manhattan distance here
   f = best_state['g'] + h
    print(f"g(n): {best_state['g']}, h(n): {h}, f(n): {f}")
```

```
    if best_state['move'] is not None:
        print(f"Move: {best_state['move']}")
    print()
    if h == 0: # Goal is reached if h == 0
        goal_state_reached = best_state
        break



    visited_states.append(best_state['state'])
    next_states = operation(best_state)

    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

# Reconstruct the path of moves
moves = []
while goal_state_reached['move'] is not None:
    moves.append(goal_state_reached['move'])
    goal_state_reached = goal_state_reached['parent']
moves.reverse()

print("\nMoves to reach the goal state:", moves)
print("\nGoal state reached:")
print_state(goal_state)
```

```
Current state:
2 8 3
1 6 4
7 0 5
g(n): 0, h(n): 5, f(n): 5

Current state:
2 8 3
1 0 4
7 6 5
g(n): 1, h(n): 4, f(n): 5
Move: up

Current state:
2 0 3
1 8 4
7 6 5
g(n): 2, h(n): 3, f(n): 5
Move: up

Current state:
0 2 3
1 8 4
7 6 5
g(n): 3, h(n): 2, f(n): 5
Move: left

Current state:
1 2 3
0 8 4
7 6 5
g(n): 4, h(n): 1, f(n): 5
Move: down
```

```
Current state:
1 2 3
8 0 4
7 6 5
g(n): 5, h(n): 0, f(n): 5
Move: right


Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']

Goal state reached:
1 2 3
8 0 4
7 6 5
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:

Implement hill climbing search algorithm to solve ~~N-Queens~~

function Hill-Climbing (problem) returns a state that is local maxima

current ← MAKE-NODE (problem · INITIAL_STATE)

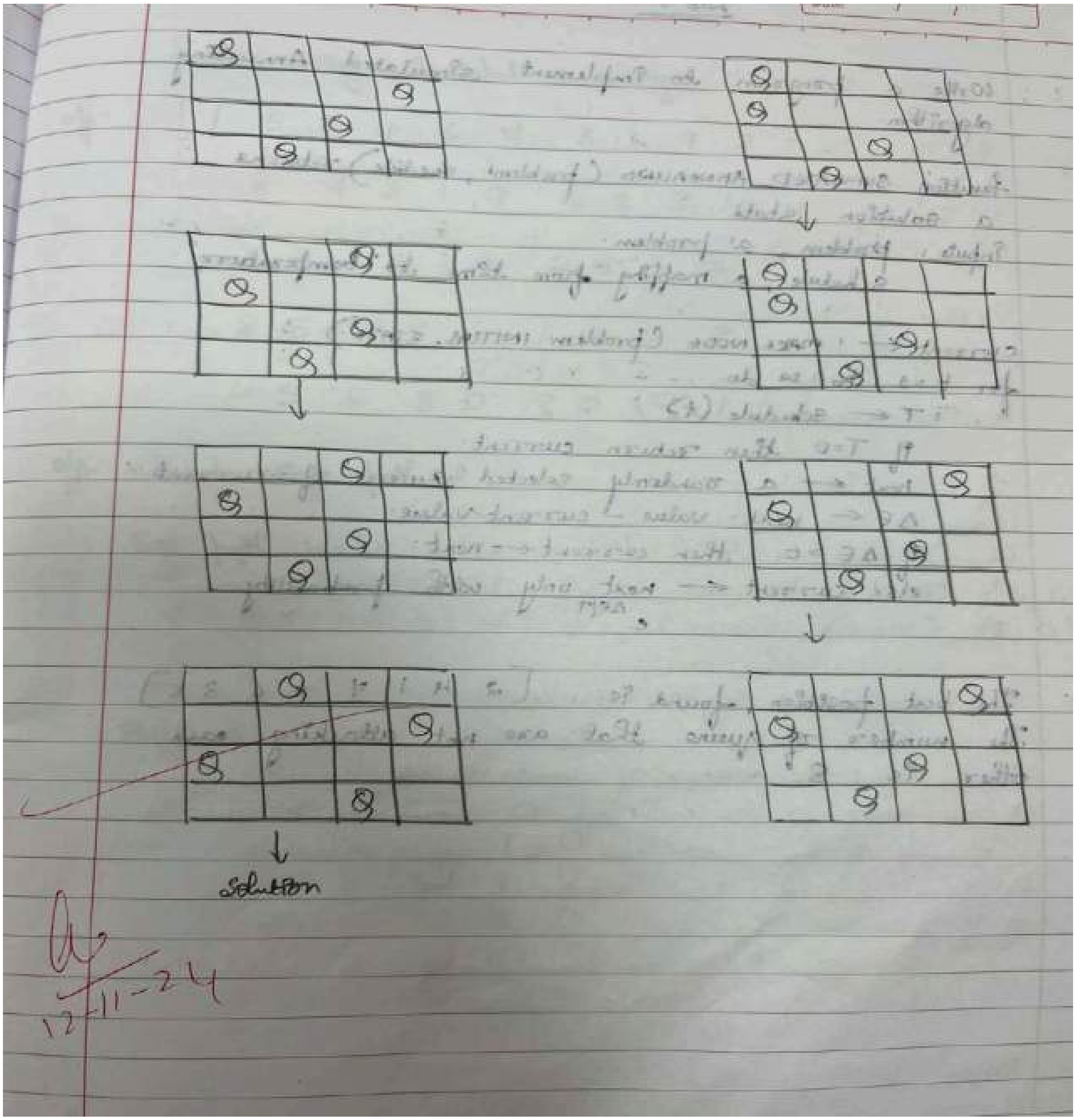
loop do

neighbours ← a highest valued successor of current

if neighbours. VALUES ≤ current· value then return CURRENT-STATE·

current ← neighbours·

cost = No. of pairs of queens attacking each other·



Code:

```
import random

def calculate_conflicts(board):
    conflicts = 0
    n = len(board)
    for i in range(n):
```

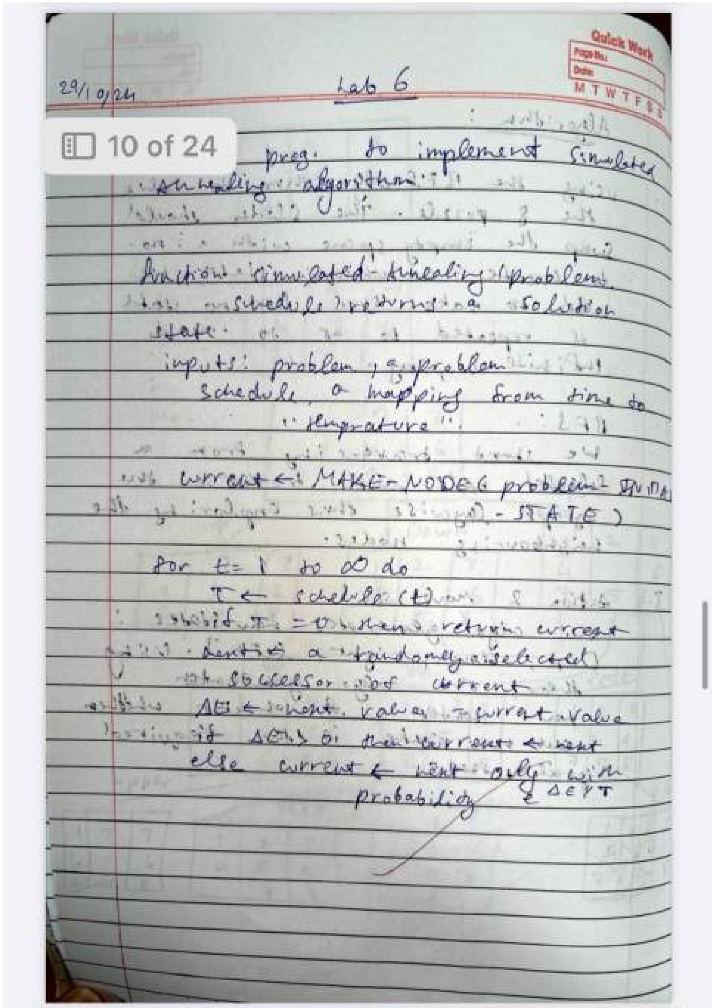
```
        for j in range(i + 1, n):
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                conflicts += 1

    return conflicts

def hill_climbing(n):
    cost=0
    while True:
        # Initialize a random board
        current_board = list(range(n))
        random.shuffle(current_board)
        current_conflicts = calculate_conflicts(current_board)

        while True:
            # Generate neighbors by moving each queen to a different position
            found_better = False
            for i in range(n):
                for j in range(n):
                    if j != current_board[i]: # Only consider different positions
                        neighbor_board = list(current_board)
                        neighbor_board[i] = j
                        neighbor_conflicts = calculate_conflicts(neighbor_board)
                        if neighbor_conflicts < current_conflicts:
                            print_board(current_board)
                            print(current_conflicts)
                            print_board(neighbor_board)
                            print(neighbor_conflicts)
                            current_board = neighbor_board
                            current_conflicts = neighbor_conflicts
                            cost+=1
                            found_better = True
                            break
                if found_better:
                    break

            # If no better neighbor found, stop searching
            if not found_better:
                break

        # If a solution is found (zero conflicts), return the board
        if current_conflicts == 0:
            return current_board, current_conflicts, cost

def print_board(board):
    n = len(board)
    for i in range(n):
```

```
        row = ['.'] * n
        row[board[i]] = 'Q' # Place a queen
        print(' '.join(row))
    print()


print("===============")
# Example Usage
n = 4
solution, conflicts, cost = hill_climbing(n)
print("Final Board Configuration:")
print_board(solution)
print("Number of Cost:", cost)
```

```
===============
Q . . .
. . . Q
. . Q .
. Q . .

4
Q . . .
Q . . .
. . Q .
. Q . .

3
Q . . .
Q . . .
. . Q .
. Q . .

3
. . Q .
Q . . .
. . Q .
. Q . .

2
. . Q .
Q . . .
. . Q .
. Q . .

2
. . . Q
Q . . .
. . Q .
. Q . .

1
Final Board Configuration:
. Q . .
. . . Q
Q . . .
. . Q .
```

Program 5

Simulated Annealing to Solve 8-Queens problem



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Lab 6

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prog. to implement simulated annealing algorithm.

function simulated-Annealing (problem, schedule) returns a solution state.

inputs: problem, a problem

schedule, a mapping from time to "temperature"

current ← MAKE-NODE (problem. INITIAL-STATE)

for t = 1 to ∞ do

T ← schedule (t)

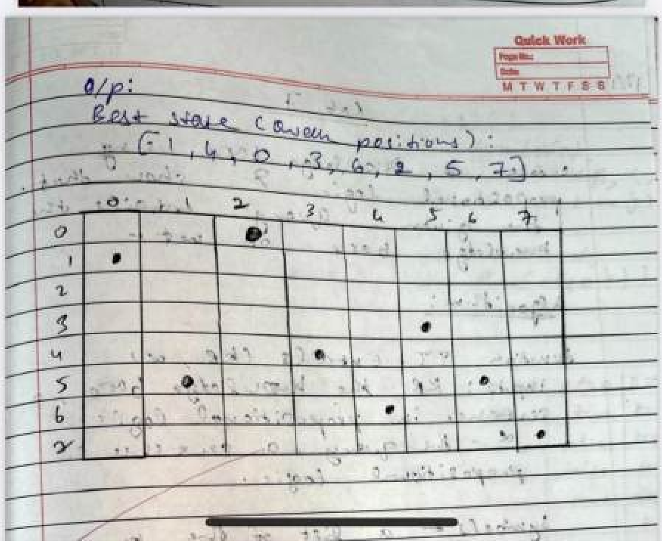
if T = 0 then return current

next ← a randomly selected successor of current

ΔE ← next. value − current. value

if ΔE > 0 then current ← next

else current ← next only with probability $e^{\Delta E/T}$



O/p:

Best state (Queen positions):

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

Algorithm:

Code:

```
import numpy as np
from scipy.optimize import dual_annealing

def queens_max(position):
    # This function calculates the number of pairs of queens that are not attacking each other
    position = np.round(position).astype(int) # Round and convert to integers for queen positions
    n = len(position)
    queen_not_attacking = 0

    for i in range(n - 1):
        no_attack_on_j = 0
        for j in range(i + 1, n):
            # Check if queens are on the same row or on the same diagonal
            if position[i] != position[j] and abs(position[i] - position[j]) != (j - i):
                no_attack_on_j += 1
        if no_attack_on_j == n - 1 - i:
            queen_not_attacking += 1
    if queen_not_attacking == n - 1:
        queen_not_attacking += 1
    return -queen_not_attacking # Negative because we want to maximize this value

# Bounds for each queen's position (0 to 7 for an 8x8 chessboard)
bounds = [(0, 8) for _ in range(8)]

# Use dual_annealing for simulated annealing optimization
result = dual_annealing(queens_max, bounds)

# Display the results
best_position = np.round(result.x).astype(int)
best_objective = -result.fun # Flip sign to get the number of non-attacking queens

print('The best position found is:', best_position)
print('The number of queens that are not attacking each other is:', best_objective)
```

```
The best position found is: [0 8 5 2 6 3 7 4]
The number of queens that are not attacking each other is: 8
```

Program 6

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

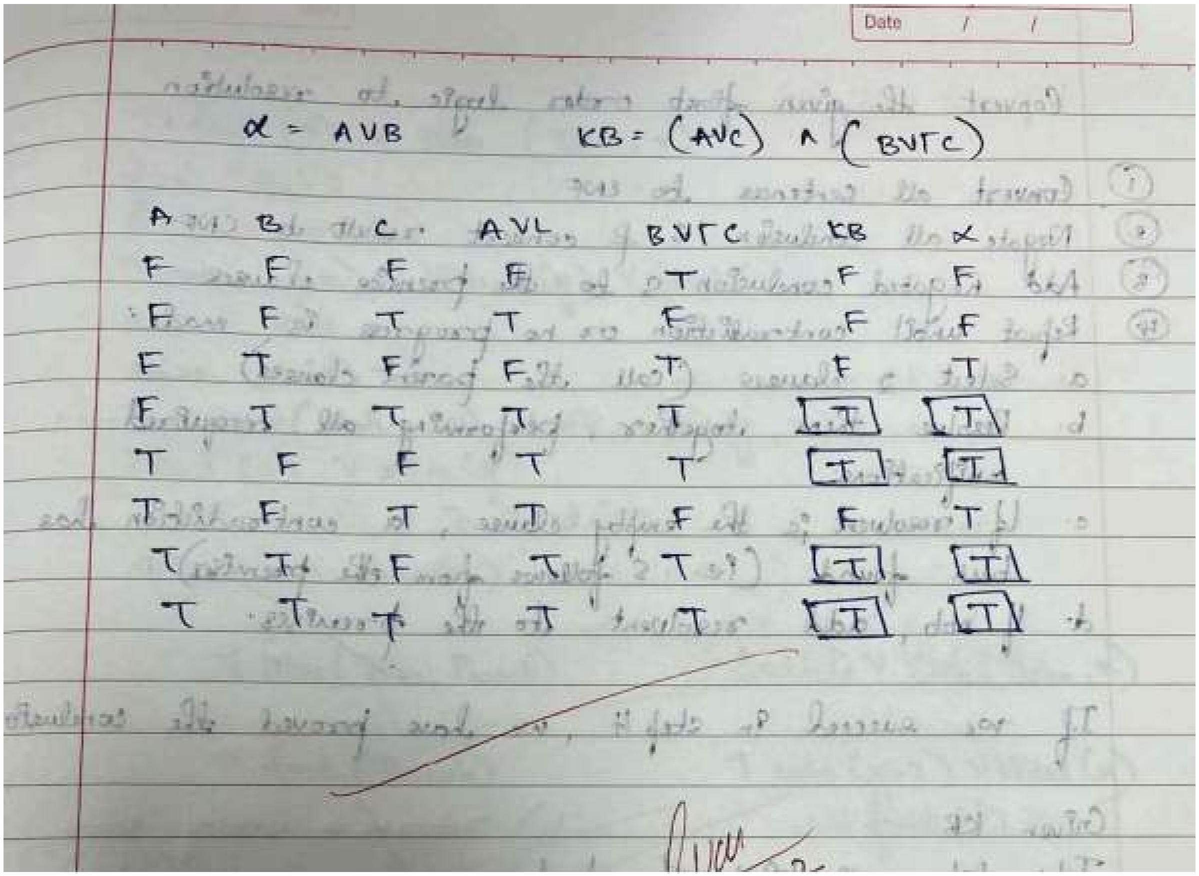
Algorithm:

Write a program for propositional logic

Algorithm:

function TT-Entails? (KB, α) returns true or false
  inputs: KB, the knowledge base
  α, a query.
  symbols ← a list of all the propositional symbols in KB and α
  return TT-check-ALL (KB, α, symbols, {})

function TT-check-All (KB, α, symbols, model) returns true or false.
  if Empty? (symbols) then
    if PL-true? (KB, model) then return PL-True? (α, model)
    else return true when KB is false, always return true
  else do
    P ← First (symbols)
    rest ← Rest (symbols)
    return (TT-check-All (KB, α, rest, model ∪ {P=true})
      and
      TT-check-All (KB, α, rest, model ∪ {P=false}))



Code:

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

# Function to evaluate an expression
def evaluate_expression(a, b, c, expression):
    # Use eval() to evaluate the logical expression
    return eval(expression)

# Function to generate the truth table and evaluate a logical expression
def truth_table_and_evaluation(kb, query):
    # All possible combinations of truth values for a, b, and c
    truth_values = [True, False]
    combinations = list(itertools.product(truth_values, repeat=3))

    # Reverse the combinations to start from the bottom (False -> True)
    combinations.reverse()

    # Header for the full truth table
    print(f"{'a':<5} {'b':<5} {'c':<5} {'KB':<20}{'Query':<20}")

    # Evaluate the expressions for each combination
```

```
    for combination in combinations:
        a, b, c = combination

        # Evaluate the knowledge base (KB) and query expressions
        kb_result = evaluate_expression(a, b, c, kb)
        query_result = evaluate_expression(a, b, c, query)

        # Replace True/False with string "True"/"False"
        kb_result_str = "True" if kb_result else "False"
        query_result_str = "True" if query_result else "False"

        # Convert boolean values of a, b, c to "True"/"False"
        a_str = "True" if a else "False"
        b_str = "True" if b else "False"
        c_str = "True" if c else "False"

        # Print the results for the knowledge base and the query
        print(f"{a_str:<5} {b_str:<5} {c_str:<5} {kb_result_str:<20} {query_result_str:<20}")

    # Additional output for combinations where both KB and query are true
    print("\nCombinations where both KB and Query are True:")
    print(f"{'a':<5} {'b':<5} {'c':<5} {'KB':<20}{'Query':<20}")

    # Print only the rows where both KB and Query are True
    for combination in combinations:
        a, b, c = combination

        # Evaluate the knowledge base (KB) and query expressions
        kb_result = evaluate_expression(a, b, c, kb)
        query_result = evaluate_expression(a, b, c, query)

        # If both KB and query are True, print the combination
        if kb_result and query_result:
            a_str = "True" if a else "False"
            b_str = "True" if b else "False"
            c_str = "True" if c else "False"
            kb_result_str = "True" if kb_result else "False"
            query_result_str = "True" if query_result else "False"
            print(f"{a_str:<5} {b_str:<5} {c_str:<5} {kb_result_str:<20} {query_result_str:<20}")

# Define the logical expressions as strings
kb = "(a or c) and (b or not c)" # Knowledge Base
query = "a or b" # Query to evaluate

# Generate the truth table and evaluate the knowledge base and query
truth_table_and_evaluation(kb, query)
```

```
a       b      c      KB                  Query
False False False False                 False
False False True  False                 False
False True  False False                 True
False True  True  True                  True
True  False False True                  True
True  False True  False                 True
True  True  False True                  True
True  True  True  True                  True

Combinations where both KB and Query are True:
a       b      c      KB                  Query
False True  True  True                  True
True  False False True                  True
True  True  False True                  True
True  True  True  True                  True
```

Program 7
Implement unification in first order logic

Algorithm

$\cdot$ 2.2.

b. SUBST = APPEND(S, SUBST)

Return SUBST

P(x, F(y)) → ①
P(a, F(g(x))) → ②

① & ② are identical if x is replaced with a, in ①

a / x

P(a, F(y)) → ①

g(x) / y

⇒ P(a, F(g(x))) → ②

Eg: Unify(P(x, h(y)), P(a, f(z)))

Eg: P(f(a), g(Y)) = P(X, X)

Eg: Unify(knows (John, x), knows (x, Elizabeth))

Eg: Unify (Eats (x, Apple), Eats (Riya, y))

Q. Ψ_1 = P(f(a), g(y))
Ψ_2 = P(X, X)

Q. Ψ_1 = P(b, x, f(g(z)))
Ψ_2 = P(z, f(y), f(y)))

Both are failure due to different predicates & argument length

1st one is fail
2nd one is pass

Iteration 1: to unify: P(f(a), g(y
attempting & P(X, X)
substitution: empty

Code:
```
import re

def occurs_check(var, x):
    """Checks if var occurs in x (to prevent circular substitutions)."""
    if var == x:
        return True
    elif isinstance(x, list): # If x is a compound expression (like a function or predicate)
        return any(occurs_check(var, xi) for xi in x)
    return False

def unify_var(var, x, subst):
    """Handles unification of a variable with another term."""


    if var in subst: # If var is already substituted
        return unify(subst[var], x, subst)
    elif isinstance(x, (list, tuple)) and tuple(x) in subst: # Handle compound expressions
        return unify(var, subst[tuple(x)], subst)
    elif occurs_check(var, x): # Check for circular references
        return "FAILURE"
    else:
        # Add the substitution to the set (convert list to tuple for hashability)
        subst[var] = tuple(x) if isinstance(x, list) else x
        return subst

def unify(x, y, subst=None):
    """
    Unifies two expressions x and y and returns the substitution set if they can be unified.
    Returns 'FAILURE' if unification is not possible.
    """
    if subst is None:
        subst = {} # Initialize an empty substitution set

    # Step 1: Handle cases where x or y is a variable or constant
    if x == y: # If x and y are identical
        return subst
    elif isinstance(x, str) and x.islower(): # If x is a variable
        return unify_var(x, y, subst)
    elif isinstance(y, str) and y.islower(): # If y is a variable
        return unify_var(y, x, subst)
    elif isinstance(x, list) and isinstance(y, list): # If x and y are compound expressions (lists)
        if len(x) != len(y): # Step 3: Different number of arguments
            return "FAILURE"

        # Step 2: Check if the predicate symbols (the first element) match
        if x[0] != y[0]: # If the predicates/functions are different
            return "FAILURE"
```

```
        # Step 5: Recursively unify each argument
        for xi, yi in zip(x[1:], y[1:]): # Skip the predicate (first element)
            subst = unify(xi, yi, subst)
            if subst == "FAILURE":
                return "FAILURE"
        return subst
    else: # If x and y are different constants or non-unifiable structures
        return "FAILURE"

def unify_and_check(expr1, expr2):
    """
    Attempts to unify two expressions and returns a tuple:
    (is_unified: bool, substitutions: dict or None)


    """
    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):
    """Parses a string input into a structure that can be processed by the unification algorithm."""
   # Remove spaces and handle parentheses
    input_str = input_str.replace(" ", "")

    # Handle compound terms (like p(x, f(y)) -> ['p', 'x', ['f', 'y']])
    def parse_term(term):
        # Handle the compound 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)

# Main function to interact with the user
def main():
    while True:
        # Get the first and second terms from the user
        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))): ")

        # Parse the input strings into the appropriate structures
        expr1 = parse_input(expr1_input)
        expr2 = parse_input(expr2_input)

        # Perform unification
        is_unified, result = unify_and_check(expr1, expr2)


 # Display the results
 display_result(expr1, expr2, is_unified, result)

 # Ask the user if they want to run another test
 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()
```

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

Program 8

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

Algorithm:

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22.

4. SUBST = APPEND(S, SUBST)

Return SUBST

$P(x, F(y)) \rightarrow$ ①

$P(a, F(g(x))) \rightarrow$ ②

① & ② are identical if x is replaced with a in ①

a / x

$\therefore P(a, F(y))$: ①

$g(x) / y$

$\Rightarrow P(a, F(g(x))) \rightarrow$ ②

Quick Work

Eg: Unify(P(x, h(y)), P(a, f(z)))

Eg: P(f(a), g(Y)) = P(X, X)

Eg: Unify(knows(John, x), knows(x, Elizabeth))

Eg: Unify(Eats(x, Apple), Eats(Riya, y))

Q. $\psi_1 = P(f(a), g(y))$
$\psi_2 = P(x, x)$

Q. $\psi_1 = P(b, x, f(g(z)))$
$\psi_2 = P(z, f(y), f(y))$

Both are failure due to different predicates & argument length

1st one is fail
2nd one is pass

Iteration 1: attempting to unify: P(f(a), g(y) & P(x, x)
substitution: empty

Code:

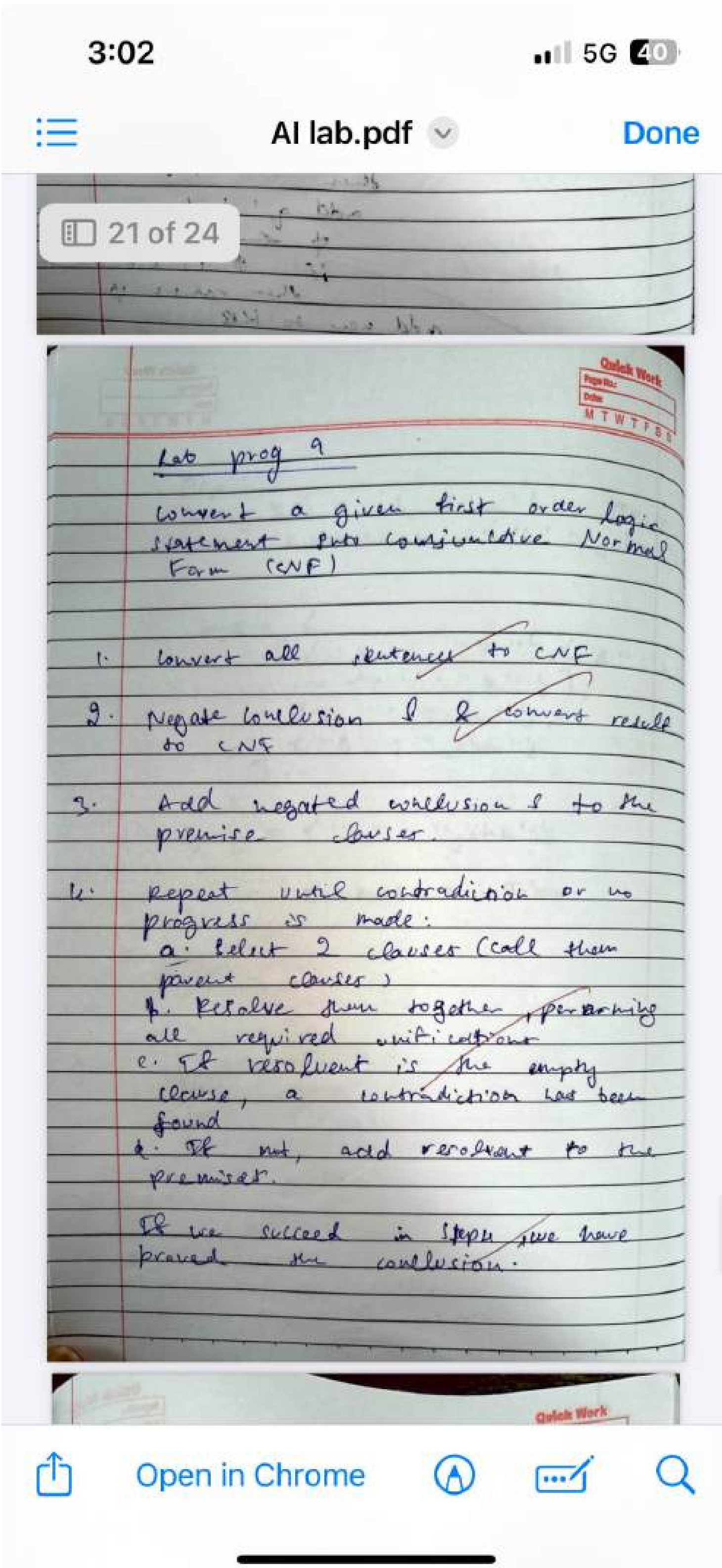
```
# Define the knowledge base (KB) as a set of facts
KB = set()

# Premises based on the provided FOL problem
KB.add('American(Robert)')
KB.add('Enemy(America, A)')
KB.add('Missile(T1)')
KB.add('Owns(A, T1)')

# Define inference rules
def modus_ponens(fact1, fact2, conclusion):
   """ Apply modus ponens inference rule: if fact1 and fact2 are true, then conclude conclusion """
  if fact1 in KB and fact2 in KB:
      KB.add(conclusion)
      print(f"Inferred: {conclusion}")

def forward_chaining():
   """ Perform forward chaining to infer new facts until no more inferences can be made """
  # 1. Apply: Missile(x) → Weapon(x)
   if 'Missile(T1)' in KB:
      KB.add('Weapon(T1)')
      print(f"Inferred: Weapon(T1)")

   # 2. Apply: Sells(Robert, T1, A) from Owns(A, T1) and 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)")

   # 3. Apply: Hostile(A) from Enemy(A, America)
   if 'Enemy(America, A)' in KB:
      KB.add('Hostile(A)')
      print(f"Inferred: Hostile(A)")

   # 4. Now, check if the goal is reached (i.e., if 'Criminal(Robert)' can be inferred)  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)")

   # Check if we've reached our goal
   if 'Criminal(Robert)' in KB:
      print("Robert is a criminal!")
   else:
      print("No more inferences can be made.")
```

```
# Run forward chaining to attempt to derive the conclusion
forward_chaining()
```

Program 9

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

Algorithm:



Lab prog 9

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

1. Convert all sentences to CNF
2. Negate conclusion S & convert result to CNF
3. Add negated conclusion S to the premise clauses.
4. Repeat until contradiction or no progress is made:
   a. Select 2 clauses (call them parent clauses)
   b. Resolve them together, performing all required unifications
   c. If resolvent is the empty clause, a contradiction has been found
   d. If not, add resolvent to the premises.

If we succeed in step 4, we have proved the conclusion.

parent clauses)

b. Resolve them together, performing all required unifications

c. If resolvent is the empty [illegible] a contradiction has been [illegible]

d. If not, add resolvent to the premises.

If we succeed in steps we have proved the conclusion.

Quick Work
Page No.:
Date:
M T W T F S S

$\neg$ likes (John, Peanuts) $\qquad$ $\neg$ food(x) v likes (John, x)

$\neg$ food (Peanuts) $\qquad$ $\neg$ eats (y, z) v killed (y) v food(z)

$\neg$ eats (y, Peanuts) v killed (y) $\qquad$ eats (Anil, Peanuts) {Anil / y}

killed (Anil) $\qquad$ $\neg$ alive (k) v $\neg$ killed (k) {Anil / k}

$\neg$ alive (Anil) $\qquad$ alive (Anil)

{ } Hence proved

3-12-24

Quick Work
Page No.:
Date:
M T W T F S S

Code:

```
# Define the knowledge base (KB)
KB = {
    "food(Apple)": True,
    "food(vegetables)": True,
    "eats(Anil, Peanuts)": True,
    "alive(Anil)": True,
    "likes(John, X)": "food(X)", # Rule: John likes all food
    "food(X)": "eats(Y, X) and not killed(Y)", # Rule: Anything eaten and not killed is food
   "eats(Harry, X)": "eats(Anil, X)", # Rule: Harry eats what Anil eats
    "alive(X)": "not killed(X)", # Rule: Alive implies not killed
    "not killed(X)": "alive(X)", # Rule: Not killed implies alive
}

# Function to evaluate if a predicate is true 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 is a specific query (e.g., likes(John, Peanuts))
    if "(" in predicate:
        func, args = predicate.split("(")
        args = args.strip(")").split(", ")
        if func == "food" and args[0] == "Peanuts":
            return resolve("eats(Anil, Peanuts)") and not resolve("killed(Anil)")
        if func == "likes" and args[0] == "John" and args[1] == "Peanuts":
            return resolve("food(Peanuts)")

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

```
# Query to prove: John likes Peanuts
query = "likes(John, Peanuts)"
result = resolve(query)

# Print the result
print(f"Does John like peanuts? {'Yes' if result else 'No'}")
```

```
Does John like peanuts? Yes
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:

Lab prog 10

Alpha - Beta pruning

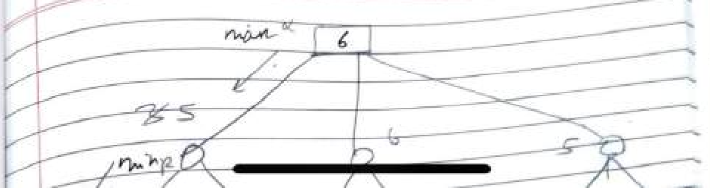
α-β proposes to compute find the optimal path without looking at every node in the game tree.

Max contains α & Min contains β bound during the calc.

In both Min & Max, we return when $\alpha \geq \beta$ which compares with its parent node only.

Both minimax & α-β cut off the same path.

α-β gives optimal solution as it takes less time to get the value for the root node.



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both min & max, we ... when $\alpha \geq \beta$ which compared with its parent node only.

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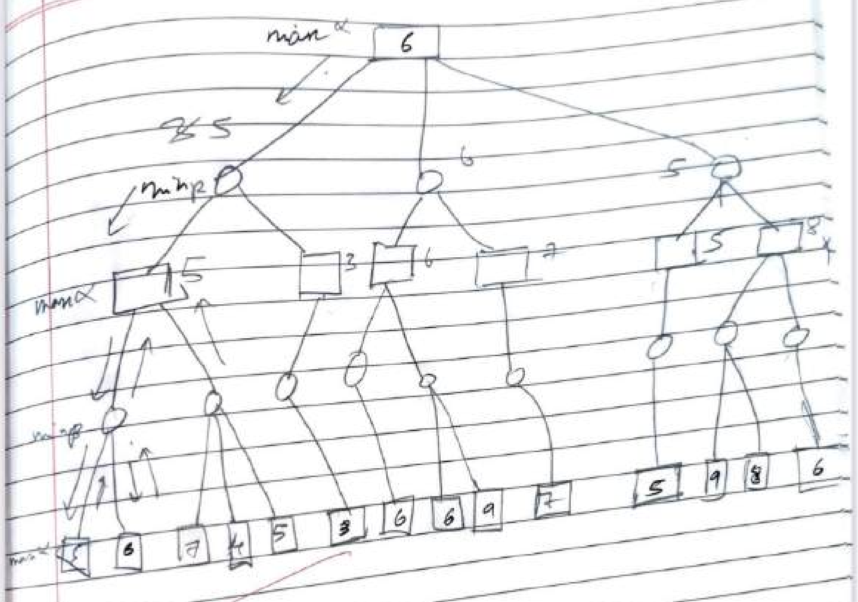

Code:

```
# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(node, alpha, beta, maximizing_player):
    # Base case: If it's a leaf node, return its value (simulating evaluation of the node)
    if type(node) is int:
        return node

    # If not a leaf node, explore the children
    if maximizing_player:
        max_eval = -float('inf')
        for child in node: # Iterate over children of the maximizer node
            eval = alpha_beta_pruning(child, alpha, beta, False)
            max_eval = max(max_eval, eval)
            alpha = max(alpha, eval) # Maximize alpha
            if beta <= alpha: # Prune the branch
                break
        return max_eval
    else:
        min_eval = float('inf')
        for child in node: # Iterate over children of the minimizer node
            eval = alpha_beta_pruning(child, alpha, beta, True)
            min_eval = min(min_eval, eval)
            beta = min(beta, eval) # Minimize beta
            if beta <= alpha: # Prune the branch
                break
        return min_eval

# Function to build the tree from a list of numbers
def build_tree(numbers):
    # We need to build a tree with alternating levels of maximizers and minimizers
    # Start from the leaf nodes and work up
    current_level = [[n] for n in numbers]

    while len(current_level) > 1:
        next_level = []
        for i in range(0, len(current_level), 2):
            if i + 1 < len(current_level):
                next_level.append(current_level[i] + current_level[i + 1]) # Combine two nodes
            else:
                next_level.append(current_level[i]) # Odd number of elements, just carry forward
        current_level = next_level

    return current_level[0] # Return the root node, which is a maximizer

# Main function to run alpha-beta pruning
```

```python
def main():

    # Input: User provides a list of numbers
    numbers = list(map(int, input("Enter numbers for the game tree (space-separated): ").split()))

    # Build the tree with the given numbers
    tree = build_tree(numbers)

    # Parameters: Tree, initial alpha, beta, and the root node is a maximizing player
   alpha = -float('inf')
    beta = float('inf')
    maximizing_player = True # The root node is a maximizing player

    # Perform alpha-beta pruning and get the final result
    result = alpha_beta_pruning(tree, alpha, beta, maximizing_player)

    print("Final Result of Alpha-Beta Pruning:", result)

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

```
Enter numbers for the game tree (space-separated): 10 9 14 18 5 4 50 3
Final Result of Alpha-Beta Pruning: 50
```