VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

ANNAMSETTI SARAN TEJ (1BM24CS040)

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

B.M.S. COLLEGE OF ENGINEERING
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B.M.S. College of Engineering,
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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 **ANNAMSETTI SARAN TEJ (1BM24CS040),** 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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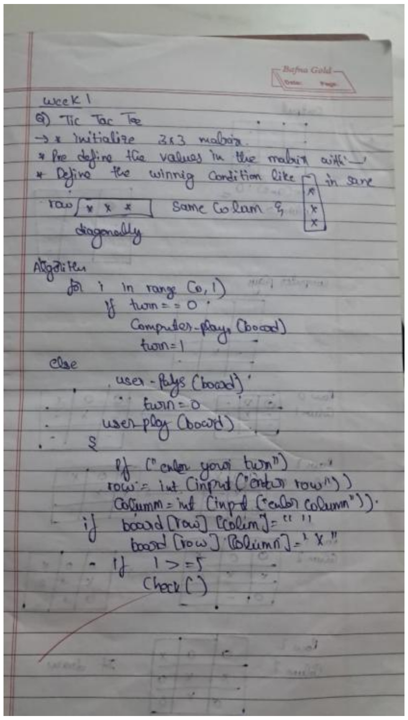
Github Link: https://github.com/Sarantej555/AI-lab

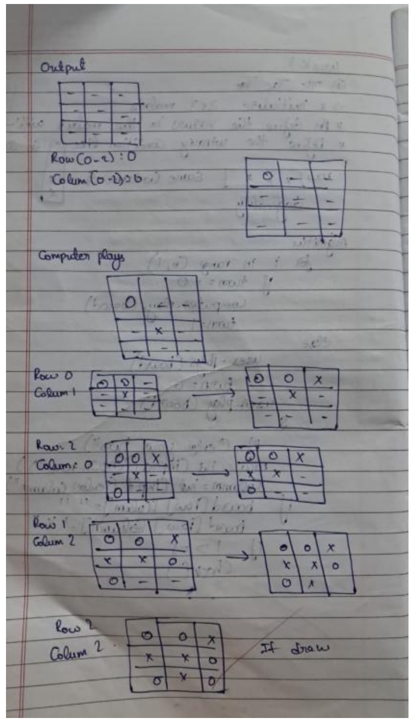
PROGRAM 1:

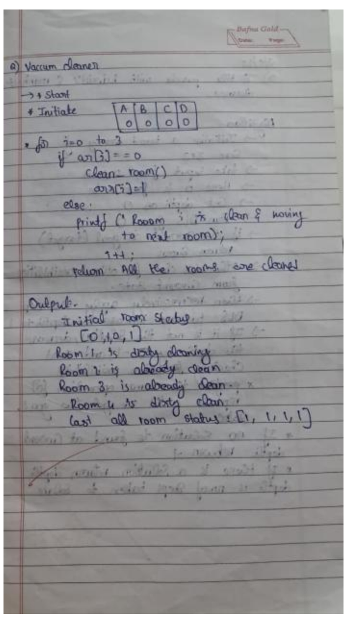
Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

ALGORITHM:



week 1
Q) Tic Tac Toe
→ * Initialize 3x3 matrix.
* Pre define the values in the matrix with '–'
* Define the winnig Condition like in same row [x x x] Same Colam & diagonally
Algorithm
for i in range (0, 1)
if turn = = 0
Computer-plays (board)
turn = 1
else
user - plays (board)
turn = 0
user-play (board)
{
if ("enter your turn")
row = int (input ("enter row"))
Column = int (input ("enter column")).
if board [row] [colim] = " "
board [row] [column] = "X"
if i >= 5
Check ( )





Q) Vaccum cleaner
→ * Start
* Initiate

A	B	C	D
0	0	0	0

* for i=0 to 3
if arr[i] = = 0
clean_room()
arr[i] = 1
else
printf (" Room i is clean & moving to next room);
i++;
return All the rooms are cleaned

Output.
Initial room status
: [0, 1, 0, 1]
Room 1 is dirty cleaning
Room 2 is already clean
Room 3 is already clean.
Room 4 is dirty clean
last all room status : [1, 1, 1, 1]

CODE:

#TicTacToe

```
import math

def check_win(boar
wins = [(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 a,b,c in wins:
        if board[a] == board[b] == board[c] != 0:
            return board[a]
    return 0 if 0 not in board else None

def selection(board, player):
    result = check_win(board)
    if result is not None: return result
    scores = []
    for i in range(9): if
        board[i] == 0:
            board[i] = player
            scores.append(selection(board, -player))
            board[i] = 0
    return max(scores) if player == 1 else min(scores)

def best_move(board):
    return max((selection(board[:i]+[1]+board[i+1:], -1), i)
               for i in range(9) if board[i]==0)[1]

def print_board(board):
    s = {1:'X', -1:'O', 0:' '}
    for i in range(0,9,3):
        print(f"{s[board[i]]}|{s[board[i+1]]}|{s[board[i+2]]}"
        ) if i<6: print(" ")

board=[0]*9; player=1
while True:
    print_board(board)
    res = check_win(board)
    if res is not None:
        print("X wins!" if res==1 else "O wins!" if res==-1 else "Tie!")
        break
    if player==1:
        print("AI thinking. ")
        board[best_move(board)] = 1
    else:
        move=int(input("Move (0-8): "))
        if 0<=move<=8 and board[move]==0: board[move]=-1
        else: print("Invalid"); continue
    player*=-1


#Vaccum Cleaner:
```

```
def isclean(list,place):
 if(list[place]==1):
   list[place] = 0
 return False
 else:
   return True

list = [1,1]
place = 0
count = 2

while(count!=0):
 if(place==0):
 if(isclean(list,place)):
     print("Location A is already cleaned")
    else:
     print("Location A is not clean")
     print("cleaning Location A")
     print("Locatin A has been cleaned")

    count = count-1
   place = 1

 if(isclean(list,place)):
   print("Location B is already cleaned")
 else:
print("Location B is not clean") print("cleaning Location B") print("Locatin B has been cleaned") count
= count-1
```

<u>OUTPUT:</u>

```
 0 | 1 | 2
---+---+---
 3 | 4 | 5
---+---+---
 6 | 7 | 8
AI thinking...
 0 | 1 | 2
---+---+---
 3 | 4 | 5
---+---+---
 6 | 7 | X
Your move (0-8): 2
 0 | 1 | O
---+---+---
 3 | 4 | 5
---+---+---
 6 | 7 | X
AI thinking...
 0 | 1 | O
---+---+---
 3 | 4 | 5
---+---+---
 6 | X | X
Your move (0-8): 6
 0 | 1 | O
---+---+---
 3 | 4 | 5
---+---+---
 O | X | X
AI thinking...
 0 | 1 | O
---+---+---
 3 | X | 5
---+---+---
 O | X | X
Your move (0-8): 0
 O | 1 | O
---+---+---
 3 | X | 5
```

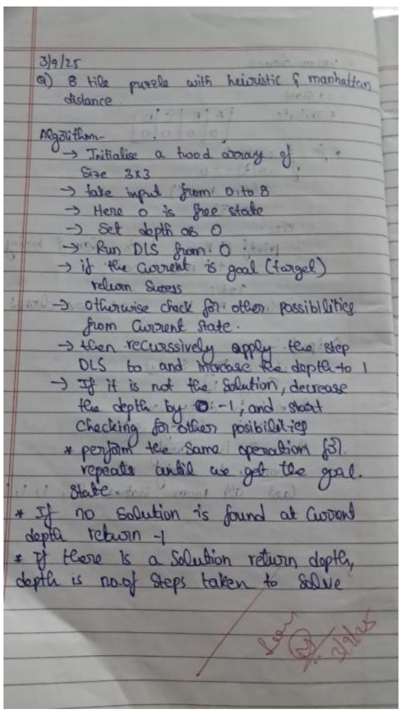
```
Your move (0-8): 0
 O | 1 | O
---+---+---
 3 | X | 5
---+---+---
 O | X | X
AI thinking...
 O | X | O
---+---+---
 3 | X | 5
---+---+---
 O | X | X
X wins!
```

```
Location A is not clean
cleaning Location A
Locatin A has been cleaned
Location B is not clean
cleaning Location B
Locatin B has been cleaned
```

PROGRAM 2:

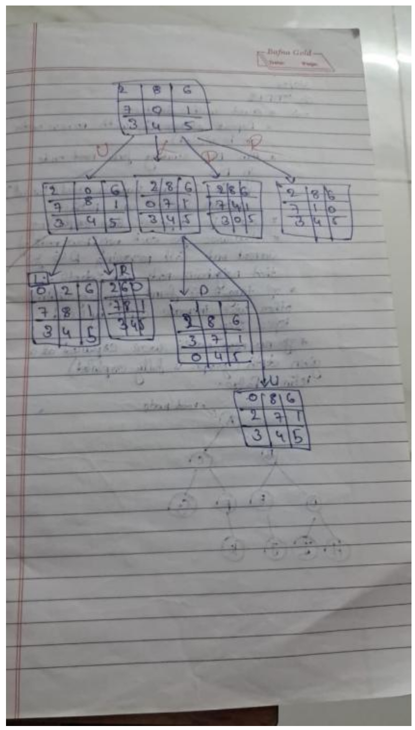
Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

ALGORITHM:



3/9/25
a) 8 tile puzzle with heiuristic & manhattan distance

Algorithm-
→ Initialise a twod array of Size 3x3
→ take input from 0 to 8
→ Here 0 is free state
→ Set depth as 0
→ Run DLS from 0
→ if the current is goal (target) return Sucess
→ otherwise check for other possibilities from current state.
→ then recurssively apply the step DLS to and increase the depth to 1
→ If it is not the Solution, decrease the depth by -1, and start checking for other posibilities
* perform the same operation [3] repeats until we get the goal. State.
* If no solution is found at current depth return -1
* If there is a solution return depth, depth is no.of steps taken to solve



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Q) IDDFS

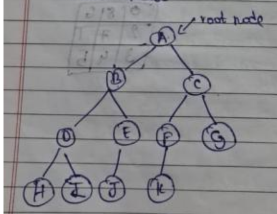
→ * Start with depth = 0

* Repeat forever (or with no new nodes can be visited)
* Run DLS strating from root node

In DLS

if the current node is goal (target) return Success and path.

* else if depth = 0 stop exploring.
* otherwise for each neighbour node of current node call recursing DLS for that neighbour node with depth - 1
* If target is found stop algorithm other wise increase depth by 1 and repeat step 2.
* If no new nodes were explored at a given depth (graph is fully explored) return "False".



depth = 0 A

depth = 1 A B C

depth 2 A B D E C F G

depth 3 A B D H I E J C F K

Path A → C → F → K

CODE:

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

moves = [(-1,0),(1,0),(0,-1),(0,1)]

def find_zero(s):
    for i in range(3):
        for j in range(3):
            if s[i][j] == 0:
                return i, j


def get_neighbors(s):
    x, y = find_zero(s)
    out = []
    for dx, dy in moves:
        nx, ny = x+dx, y+dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            t = [r[:] for r in s]
            t[x][y], t[nx][ny] = t[nx][ny], t[x][y]
            out.append(t)
    return out


def dfs(s, visited):
    if s == goal:
        return [s]
    visited.add(str(s))
    for nxt in get_neighbors(s):
```

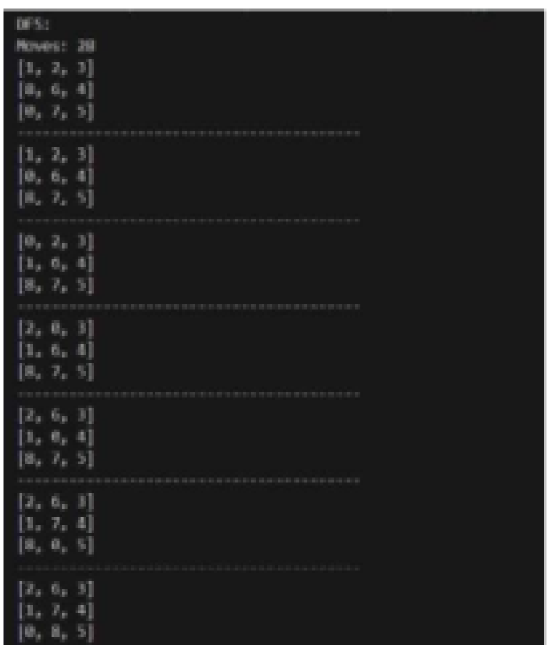
```
        if str(nxt) not in visited:
            p = dfs(nxt, visited)
            if p:
                return [s] + p
    return None


def dls(s, goal, depth, path, visited):
    if s == goal:
        return path
    if depth == 0:
        return None
    visited.add(str(s))
    for nxt in get_neighbors(s):
        if str(nxt) not in visited:
            res = dls(nxt, goal, depth-1, path+[nxt], visited)
            if res:
                return res
    return None


def ids(start, goal, limit=20):
    for d in range(limit+1):
        visited = set()
        r = dls(start, goal, d, [start], visited)
        if r:
            return r
    return None
```

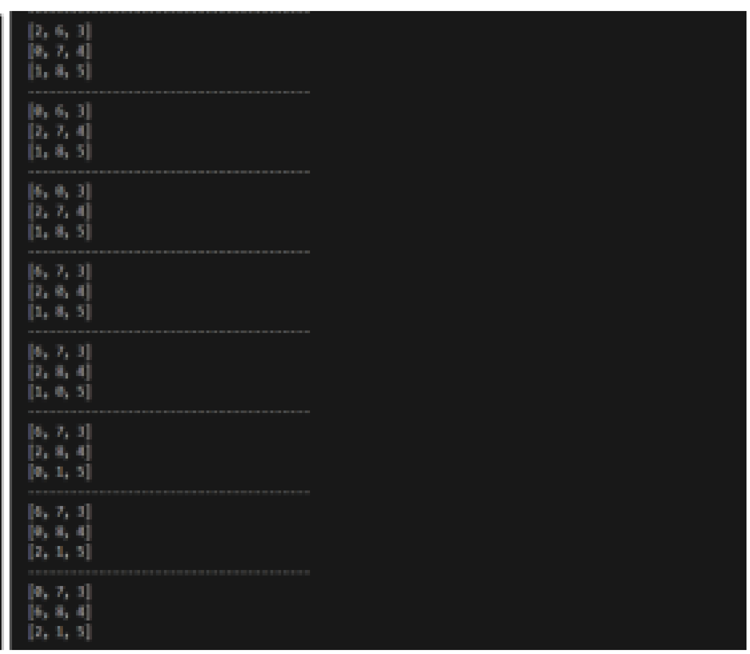
if **name** == "**main**":

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


print("DFS:")

    sol1 = dfs(start, set())

    if sol1:

        print("Moves:", len(sol1)-1)

        for st in sol1:

            for r in st:

                print(r)

            print("-"*40)

    else:
```

```
        print("No solution.")


print("\nIDS:")

    sol2 = ids(start, goal, 20)
    if sol2:

        print("Moves:", len(sol2)-1)

        for st in sol2:

            for r in st:

                print(r)

            print("-"*40)

    else:

        print("No solution.")
```

Output:





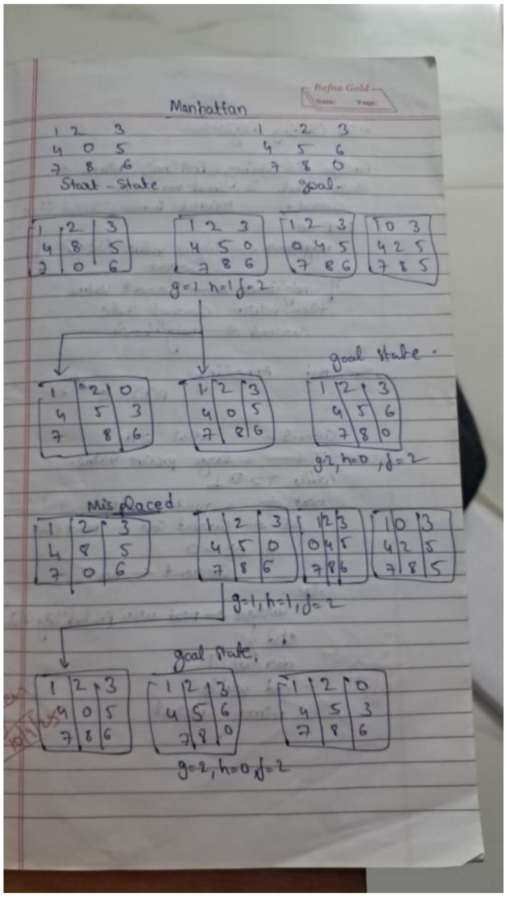
PROGRAM 3:

Implement A* search algorithm

ALGORITHM:

8 puzzle using A* algorithm:

```
A star function (Start-state, goal-state)
    if not issolvable (Start-state)
        return "unsolvable"

Start key = Start-key (Start-state)
goal-key = goal-key (goal-state)

    if Start-key = goal-key
        return start-key

    g. Score [Start-key] = 0
    f. score [start-key] = manhattan
                          (Start_state,
                           goal-state)

    open = priority queue()
    open = push (f, score, g. score, start-key)

    closed = Set()
    while open is not empty.
    (f-current, h-current, current-state)
        if current-key = goal-key
            return path (current key, Parent)
for neighbour in neighbour-key.

tentative-g = g-score. get (current.score)

closed.add (neighbour-state)
    if tentative-g >= g-score.get (neighbour)
        Continue

    if tentative-g < g-score.get (neighbour)
        g-score (current-key) = tentative-g.

    f.score (current-key) = tentative-g + manhattan
                           (neighbour key,
                            goal-key.

    open-push (f.score, manhattan. current key, goal key.
               current-key)

return "failure"
```



2

CODE:

```
import heapq
class PuzzleState:
    def __init__(self, board, parent=None, move="", depth=0, cost=0):
        self.board = board
        self.parent = parent
        self.move = move
        self.depth = depth
        self.cost = cost

    def __lt__(self, other):
        return self.cost < other.cost

    def blank_pos(self):
        return self.board.index(0)

    def expand(self):
        b = self.blank_pos()
        row, col = divmod(b, 3)
        dirs = {
            "Up": (row - 1, col),
            "Down": (row + 1, col),
            "Left": (row, col - 1),
            "Right": (row, col + 1)
        }
        nxt = []
        for mv, (r, c) in dirs.items():
            if 0 <= r < 3 and 0 <= c < 3:
                idx = r * 3 + c
```

```
            nb = self.board[:]
            nb[b], nb[idx] = nb[idx], nb[b]
            nxt.append(PuzzleState(nb, self, mv, self.depth + 1))
        return nxt

    def build_path(self):
        p, node = [], self
        while node:
            p.append((node.move, node.board, node.depth))
            node = node.parent
        return list(reversed(p))


def misplaced_tiles(state, goal):
    return sum(1 for i in range(9) if state.board[i] not in (0, goal[i]))
def manhattan_distance(state, goal):
    d = 0
    for i, v in enumerate(state.board):
        if v != 0:
            r1, c1 = divmod(i, 3)
            r2, c2 = divmod(goal.index(v), 3)
            d += abs(r1 - r2) + abs(c1 - c2)
    return d


def a_star(start, goal, h):
    opened = []
    closed = set()
    nodes = 0
    s = PuzzleState(start)
    s.cost = h(s, goal)
    heapq.heappush(opened, s)

    while opened:
        cur = heapq.heappop(opened)
        nodes += 1

        if cur.board == goal:
            return cur.build_path(), nodes

        closed.add(tuple(cur.board))

        for nxt in cur.expand():
            if tuple(nxt.board) in closed:
                continue
            nxt.cost = nxt.depth + h(nxt, goal)
            heapq.heappush(opened, nxt)

    return None, nodes


def print_solution(path, total_nodes):
    print("Steps:\n")
    for mv, st, d in path:
```

```
        label = "Start" if mv == "" else f"Move {mv}"
        print(f"{label} | Depth {d}")
        for i in range(0, 9, 3):
            print(" ".join(str(x) if x != 0 else " " for x in st[i:i+3]))
        print()
    print(f"Total Moves: {len(path)-1}")
    print(f"Nodes Expanded: {total_nodes}")


if __name__ == "__main__":
    start = [1, 2, 3,
             4, 0, 6,
             7, 5, 8]

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

    print("A* (Misplaced Tiles)\n")
    sol1, n1 = a_star(start, goal, misplaced_tiles)
    if sol1:
        print_solution(sol1, n1)
    else:
        print("No solution.")

    print("\nA* (Manhattan Distance)\n")
    sol2, n2 = a_star(start, goal, manhattan_distance)
    if sol2:
        print_solution(sol2, n2)
    else:
        print("No solution.")
```

OutPut:

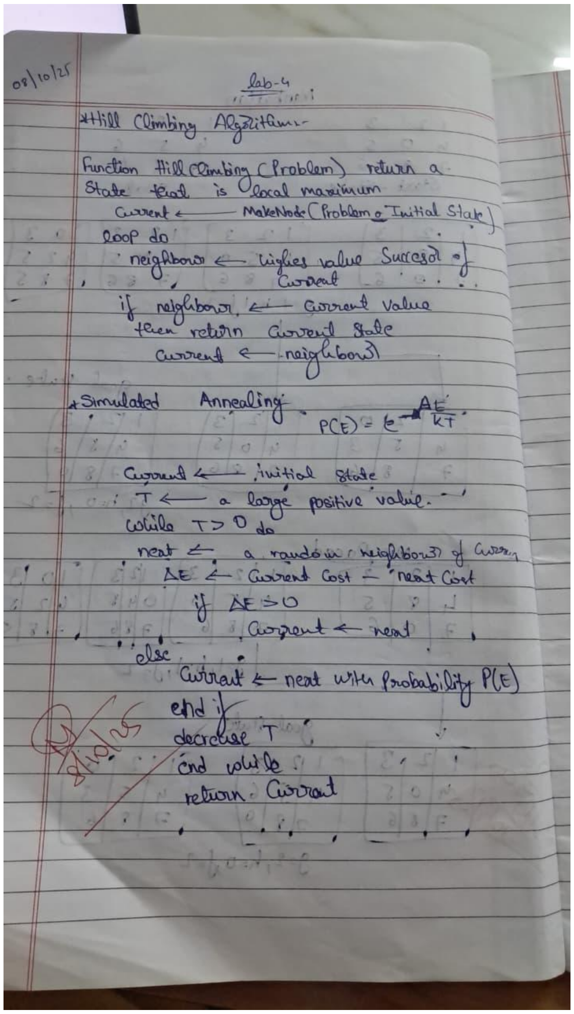
```
A* (Manhattan Distance)

Steps:

Start | Depth 0
1 2 3
4   6
7 5 8

Move Down | Depth 1
1 2 3
4 5 6
7   8

Move Right | Depth 2
1 2 3
4 5 6
7 8

Total Moves: 2
Nodes Expanded: 3
```

```
A* (Misplaced Tiles)

Steps:

Start | Depth 0
1 2 3
4   6
7 5 8

Move Down | Depth 1
1 2 3
4 5 6
7   8

Move Right | Depth 2
1 2 3
4 5 6
7 8

Total Moves: 2
Nodes Expanded: 3
```

PROGRAM 4:

Implement Hill Climbing search algorithm to solve N-Queens problem

ALGORITHM:



08/10/25

lab-4

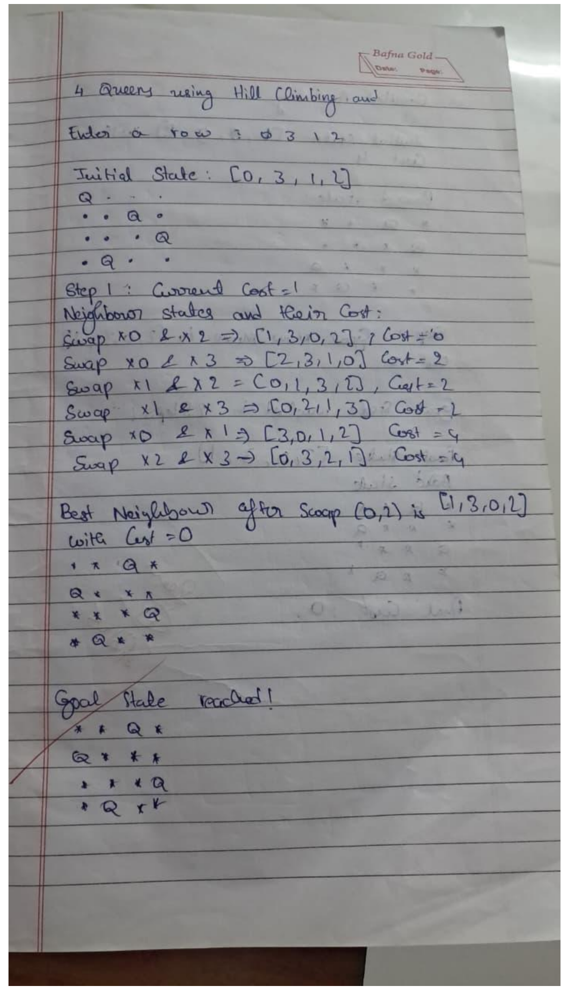
*Hill Climbing Algorithm:-

Function Hill Climbing (Problem) return a State that is local maximum
Current ← MakeNode (Problem. Initial State)
loop do
neighbour ← highes value Successor of Current
if neighbour ← Current Value
then return Current State
Current ← neighbour

*Simulated Annealing: $P(E) = e^{-\frac{\Delta E}{kT}}$

Current ← initial State
T ← a large positive value.
while T > 0 do
next ← a random neighbour of Current
ΔE ← Current Cost − next Cost
if ΔE > 0
Current ← next
else
Current ← next with Probability P(E)
end if
decrease T
end while
return Current

8/10/25



Bafna Gold

Date: Page:

4 Queens using Hill Climbing and

Enter a row : 0 3 1 2

Initial State : [0, 3, 1, 2]

```
Q . . .
. . Q .
. . . Q
. Q . .
```

Step 1 : Current Cost = 1
Neighbour states and their Cost:
Swap x0 & x2 ⇒ [1, 3, 0, 2] ; Cost = 0
Swap x0 & x3 ⇒ [2, 3, 1, 0] Cost = 2
Swap x1 & x2 = [0, 1, 3, 2] , Cost = 2
Swap x1 & x3 ⇒ [0, 2, 1, 3] Cost = 2
Swap x0 & x1 ⇒ [3, 0, 1, 2] Cost = 4
Swap x2 & x3 → [0, 3, 2, 1] Cost = 4

Best Neighbour after Swap (0,2) is [1, 3, 0, 2] with Cost = 0

```
* * Q *
Q * * *
* * * Q
* Q * *
```

Goal State reached!

```
* * Q *
Q * * *
* * * Q
* Q * *
```

CODE:

```
import random
import time

def print_board(b):
    n = len(b)
    for i in range(n):
        row = ["Q" if b[i] == j else "." for j in range(n)]
        print(" ".join(row))
    print()

def cost(b):
    n = len(b)
    c = 0
    for i in range(n):
        for j in range(i + 1, n):
            if b[i] == b[j] or abs(b[i] - b[j]) == abs(i - j):
                c += 1
    return c

def best_neighbor(b):
    n = len(b)
    best_b = list(b)
```

```
    best_c = cost(b)
    for r in range(n):
        for c in range(n):
            if b[r] != c:
                temp = list(b)
                temp[r] = c
                k = cost(temp)
                if k < best_c:
                    best_c = k
                    best_b = temp
    return best_b, best_c

def hill(n):
    state = [random.randint(0, n - 1) for _ in range(n)]
    c = cost(state)

    print("Initial Board:")
    print_board(state)
    print("Initial Cost:", c, "\n")

    step = 1
    while True:
        print("Step", step)
        print("Current Board:")
        print_board(state)
        print("Current Cost:", c)
        time.sleep(0.2)

        nxt, nxt_c = best_neighbor(state)
        print("Best Neighbor Cost:", nxt_c, "\n")
        time.sleep(0.25)

        if nxt_c >= c:
            break

        state = nxt
        c = nxt_c
        step += 1

    print("Final Board:")
    print_board(state)
    print("Final Cost:", c)

    if c == 0:
        print("Solution Found")
    else:
        print("Local Minimum Reached")

hill(6)
```

<u>OutPut:</u>

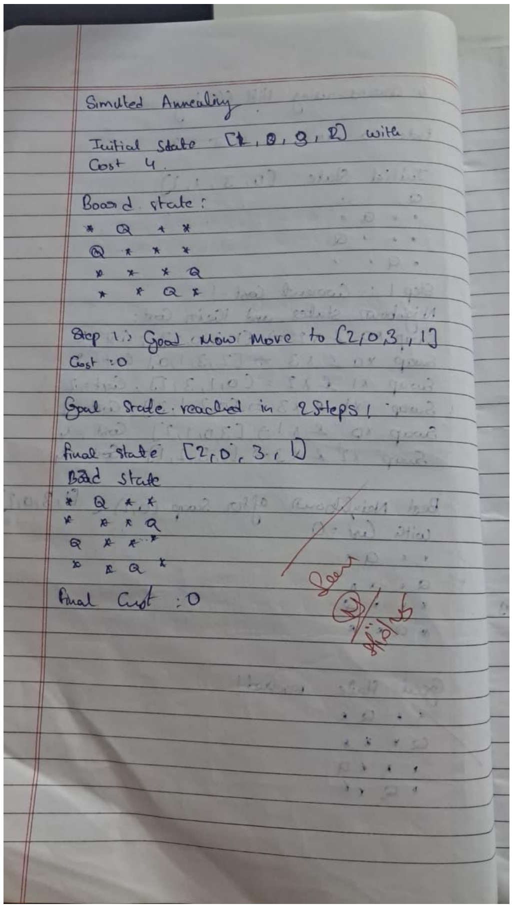
```
Initial Board:
. . . . . Q
Q . . . . .
Q . . . . .
. . . Q . .
. . . Q . .
. . Q . . .

Initial Cost: 4

Step 1
Current Board:
. . . . . Q
Q . . . . .
Q . . . . .
. . . Q . .
. . . Q . .
. . Q . . .

Current Cost: 4
Best Neighbor Cost: 2

Step 2
Current Board:
. . . . . Q
Q . . . . .
Q . . . . .
. . . Q . .
. . . . Q .
. . Q . . .

Current Cost: 2
Best Neighbor Cost: 2
```

```
Current Cost: 2
Best Neighbor Cost: 2

Final Board:
. . . . . Q
Q . . . . .
Q . . . . .
. . . Q . .
. . . . Q .
. . Q . . .

Final Cost: 2
Local Minimum Reached
```

PROGRAM 5:

Simulated Annealing to Solve 8-Queens problem

ALGORITHM:


Simulated Annealing

Initial State [1, 0, 3, 2] with
Cost 4.

Board state:
* Q * *
Q * * *
* * * Q
* * Q *

Step 1: Good Now Move to [2,0,3,1]
Cost : 0

Goal State reached in 2 Steps!

final state [2, 0, 3, 1]
Board State
* Q * *
* * * Q
Q * * *
* * Q *

Final Cost : 0

Seen

CODE:

```
import random
import math

def print_board(board):
    n = len(board)
    for i in range(n):
        row = ["Q" if board[i] == j else "." for j in range(n)]
        print(" ".join(row))
    print()

def calculate_cost(board):
    n = len(board)
    cost = 0
    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):
                cost += 1
    return cost

def random_neighbor(board):
    n = len(board)
    neighbor = list(board)
    row = random.randint(0, n - 1)
    col = random.randint(0, n - 1)
    neighbor[row] = col
    return neighbor
```

```
def simulated_annealing(n, initial_temp=100.0, cooling_rate=0.95, stopping_temp=1.0,
max_steps=20):
    current_board = [random.randint(0, n - 1) for _ in range(n)]
    current_cost = calculate_cost(current_board)
    temperature = initial_temp
    step = 1

    print("Initial Board:")
    print_board(current_board)
    print(f"Initial Cost: {current_cost}\n")

    while temperature > stopping_temp and current_cost > 0 and step <= max_steps:
        neighbor = random_neighbor(current_board)
        neighbor_cost = calculate_cost(neighbor)
        delta = neighbor_cost - current_cost

        if delta < 0 or random.random() < math.exp(-delta / temperature):
            current_board = neighbor
            current_cost = neighbor_cost

        print(f"Step {step}: Temp={temperature:.3f}, Cost={current_cost}")
        step += 1
        temperature *= cooling_rate

    print("\nFinal Board:")
    print_board(current_board)
    print(f"Final Cost: {current_cost}")

    if current_cost == 0:
        print("Goal State Reached!")
    else:
        print("Terminated before reaching goal.")

if __name__ == "__main__":
    simulated_annealing(8, initial_temp=100.0, cooling_rate=0.95, stopping_temp=1.0,
max_steps=20)
```

OutPut:

PROGRAM 6:

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

ALGORITHM:

Create a knowledge based using propositional logic and show that the given entails the knowledge based or not

function TT Entails ? (KB, α) return True or false
inputs: KB, the knowledge base, a sentence in Propositional logic
α, the query a sentence in propositional logic

Symbols ← a list of the proposition symbol in KB and α return TT-CHECK ALL (KB, α, Symbols, {})

function TT_CHECK_ALL(KB, α, Symbols, model) return true or false
if Empty? (Symbols):
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})

a) Q → P
P → ¬Q
Q v R

i) Construct Truth Table
ii) Does KB entail R
iii) Does KB entail R → P?
iv) Does KB entail Q → R?

i)

P	Q	R	Q→P	P→¬Q	QvR
T	T	T	T	F	T
T	T	F	T	F	T
T	F	T	T	T	T
T	F	F	T	T	F
F	T	T	F	T	T
F	T	F	F	T	T
F	F	T	T	T	T
F	F	F	T	T	F

ii) R
Consider rows 3 and 7 the KB Q→P, P→¬Q and QvR is true and R is true for both ro
Therefore, KB entails R

iii) In Row 7, the models of the KB are true But R→P is false Therefor R→P is not entailed.

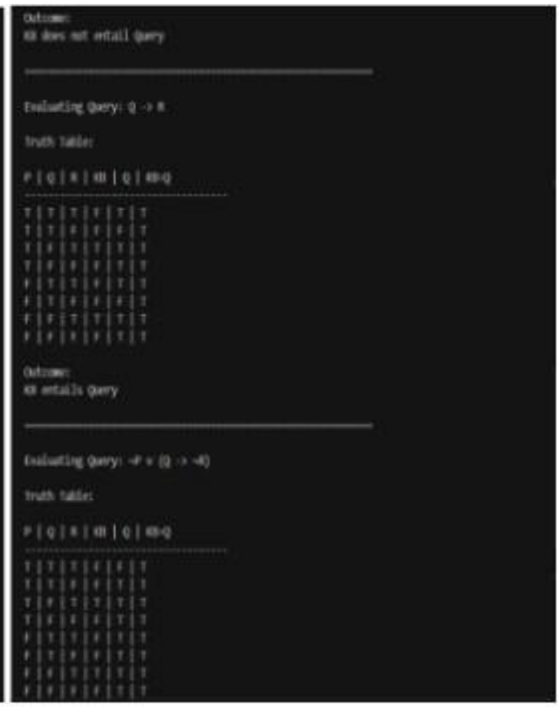
iv) In rows 3 and 7, all models are true and Q→R is true.
Therefore, the KB entails Q→R

CODE:

```
import itertools
import re

def interpret(expr, model):
    expr = expr.replace("<->", " == ")
    expr = expr.replace("->", " <= ")
    expr = re.sub(r'~(\w+)', r'(not \1)', expr)
    expr = re.sub(r'~\(([^)]+)\)', r'(not (\1))', expr)
    expr = expr.replace("^", " and ")
    expr = expr.replace("v", " or ")
    for s, v in model.items():
        expr = re.sub(r'\b' + re.escape(s) + r'\b', str(v), expr)
    return eval(expr)

def truth_table(kb, query, symbols):
    all_models = list(itertools.product([True, False], repeat=len(symbols)))
    ent = True

    print("Truth Table:\n")
    head = " | ".join(symbols) + " | KB | Q | KB⇒Q"
    print(head)
    print("-" * (len(head) + 10))

    for vals in all_models:
        model = dict(zip(symbols, vals))
        kb_v = interpret(kb, model)
        q_v = interpret(query, model)
        impl = (not kb_v) or q_v
```

```
        if kb_v and not q_v:
            ent = False

        row = " | ".join(["T" if v else "F" for v in vals])
        row += f" | {'T' if kb_v else 'F'} | {'T' if q_v else 'F'} | {'T' if impl else 'F'}"
        print(row)

    print("\nOutcome:")
    if ent:
        print("KB entails Query")
    else:
        print("KB does not entail Query")

def run_evaluation(kb, queries, symbols):
    print("\nKnowledge Base:", kb)
    print("Symbols:", ", ".join(symbols))
    print("\n" + "="*60 + "\n")
    for q in queries:
        print("Evaluating Query:", q)
        print()
        truth_table(kb, q, symbols)
        print("\n" + "="*60 + "\n")

kb = "(Q -> P) ^ (P -> ~Q) ^ (Q v R)"
symbols = ["P", "Q", "R"]
queries = ["R", "R -> P", "Q -> R", "~P v (Q -> ~R)"]

run_evaluation(kb, queries, symbols)
```

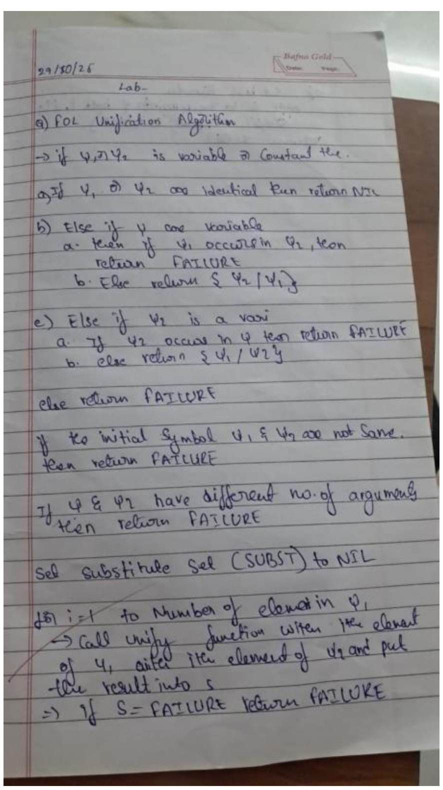
Output:



PROGRAM 7:

Implement unification in first order logic

ALGORITHM:



24/10/25

Lab-

a) FOL Unification Algorithm

-> if ψ_1 or ψ_2 is variable or Constant then.

a) If ψ_1 or ψ_2 are identical then return NIL

b) Else if ψ are variable

a. then if ψ_1 occurs in ψ_2, then return FAILURE

b. Else return $\{\psi_2 / \psi_1\}$

c) Else if ψ_2 is a vari

a. If ψ_2 occurs in ψ then return FAILURE

b. else return $\{\psi_1 / \psi_2\}$

else return FAILURE

If the initial Symbol ψ_1 & ψ_2 are not Same. then return FAILURE

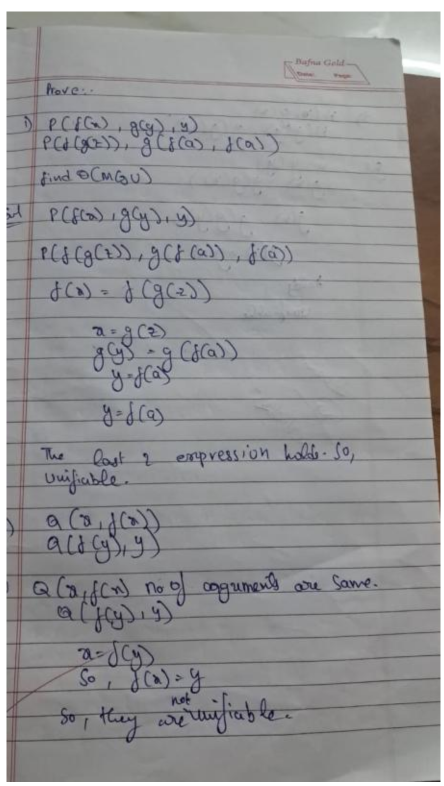
If ψ & ψ_2 have different no. of arguments then return FAILURE

Set Substitute Set (SUBST) to NIL

for i=1 to Number of element in ψ_1

-> Call unify function with the element of ψ_1 and the element of ψ_2 and put the result into S

=> If S = FAILURE return FAILURE



Prove:

1) $P(f(x), g(y), y)$

$P(f(g(z)), g(f(a), f(a))$

find θ(MGU)

Sol $P(f(x), g(y), y)$

$P(f(g(z)), g(f(a)), f(a))$

$f(x) = f(g(z))$

$x = g(z)$

$g(y) = g(f(a))$

$y = f(a)$

$y = f(a)$

The last 2 expression holds. So, unifiable.

2) $Q(x, f(x))$

$Q(f(y), y)$

$Q(x, f(x))$ no of arguments are Same.

$Q(f(y), y)$

$x = f(y)$

So, $f(x) = y$

So, they are not unifiable.

CODE:

```
import time
class Term:
    def __init__(self, value):
        self.value = value
    def __eq__(self, other):
        return isinstance(other, Term) and self.value == other.value
    def __hash__(self):
        return hash(self.value)
    def __repr__(self):
        return str(self.value)

class Constant(Term):
    pass

class Variable(Term):
    pass

class Function(Term):
    def __init__(self, symbol, args):
        self.value = symbol
        self.arguments = list(args)
    def __eq__(self, other):
        return isinstance(other, Function) and self.value == other.value and self.arguments ==
other.arguments
    def __hash__(self):
        return hash((self.value, tuple(self.arguments)))
    def __repr__(self):
        return f"{self.value}({', '.join(map(str, self.arguments))})"

FAILURE = "FAILURE"

def occurs_in(v, t):
    if v == t:
        return True
    if isinstance(t, Function):
        return any(occurs_in(v, a) for a in t.arguments)
    return False

def substitute(subst, t):
    if not subst:
        return t
    if isinstance(t, Variable):
        return subst.get(t, t)
    if isinstance(t, Function):
        return Function(t.value, [substitute(subst, a) for a in t.arguments])
    return t

def compose(s1, s2):
    if not s1:
        return s2 or {}
    if not s2:
        return dict(s1)
    r = {v: substitute(s1, t) for v, t in s2.items()}
    for v, t in s1.items():
```

```
        if v not in r:
            r[v] = t
    return r

def unify_core(a, b):
    if a == b:
        return {}
    if isinstance(a, Variable):
        if occurs_in(a, b):
            return FAILURE
        return {a: b}
    if isinstance(b, Variable):
        if occurs_in(b, a):
            return FAILURE
        return {b: a}
    if isinstance(a, Function) and isinstance(b, Function) and a.value == b.value and len(a.arguments)
== len(b.arguments):
        s = {}
        for x, y in zip(a.arguments, b.arguments):
            x2 = substitute(s, x)
            y2 = substitute(s, y)
            r = unify_core(x2, y2)
            if r == FAILURE:
                return FAILURE
            if r:
                s = compose(r, s)
        return s
    return FAILURE

def unify(a, b):
    return unify_core(a, b)

def pretty(s):
    if not s:
        return "{}"
    return "{" + ", ".join([f"{k}->{v}" for k, v in s.items()]) + "}"
def trace_unify(a, b):
    print("Unify:")
    print("A =", a)
    print("B =", b)
    print()
    steps = [(a,
    b)] subst = {}
    step = 1
    while steps:
        x, y = steps.pop(0)
        x = substitute(subst, x)
        y = substitute(subst, y)
        print("Step", step)
        print("Compare:", x, "and", y)
        if x == y:
            print("Equal\n")
            step += 1
            time.sleep(0.1)
```

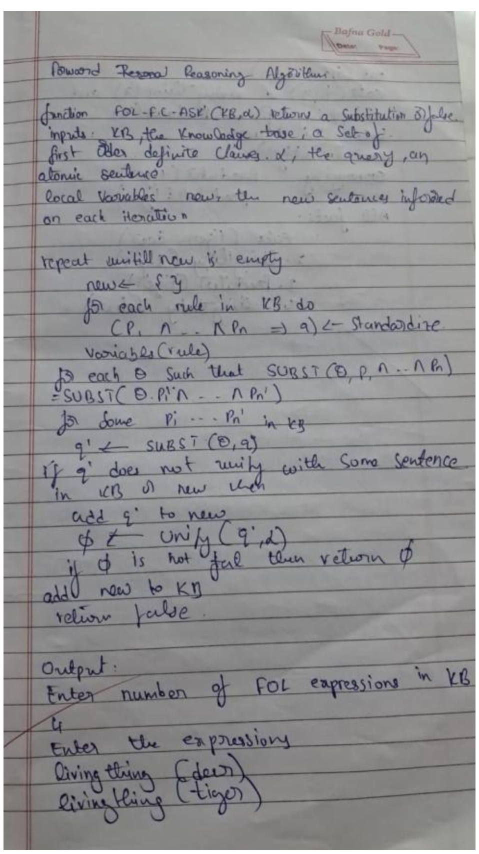
```
            continue
        if isinstance(x, Variable):
            if occurs_in(x, y):
                print("Failure\n")
                return FAILURE
            s = {x: y}
            subst = compose(s, subst)
            print("Bind:", pretty(s))
            print("Now:", pretty(subst), "\n")
            step += 1
            time.sleep(0.1)
            continue
        if isinstance(y, Variable):
            if occurs_in(y, x):
                print("Failure\n")
                return FAILURE
            s = {y: x}
            subst = compose(s, subst)
            print("Bind:", pretty(s))
            print("Now:", pretty(subst), "\n")
            step += 1
            time.sleep(0.1)
            continue
        if isinstance(x, Function) and isinstance(y, Function) and x.value == y.value:
            for a1, a2 in zip(x.arguments, y.arguments):
                steps.insert(0, (a1, a2))
            print("Expand arguments\n")
            step += 1
            time.sleep(0.1)
            continue
        print("Failure\n")
        return FAILURE
    print("Final substitution:", pretty(subst), "\n")
    return subst

X = Variable("X")
Y = Variable("Y")
A = Constant("a")
B = Constant("b")

t1 = Function("P", [X, A])
t2 = Function("P", [B, Y])

t3 = Function("R", [X, Function("f", [X])])
t4 = Function("R", [A, Function("f", [B])])

print("\n=== Example 1 ===\n")
trace_unify(t1, t2)

print("\n=== Example 2 ===\n")
trace_unify(t3, t4)
```

OutPut:

PROGRAM 8:

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

ALOGRITHM:



Forward Reasonal Reasoning Algorithm.

function FOL-F.C-ASK (KB, α) returns a Substitution or false.
inputs: KB, the Knowledge base; a Set of first Order definite Clauses. α; the query, an atomic sentence
local Variables: new, the new sentences inferred on each iteration

repeat untill new is empty:
new $\leftarrow$ { }
for each rule in KB do
($P_1 \wedge \ldots \wedge P_n \Rightarrow q$) $\leftarrow$ Standardize variables(rule)
for each θ Such that SUBST (θ, $P_1 \wedge \ldots \wedge P_n$)
= SUBST (θ. $P_1' \wedge \ldots \wedge P_n'$)
for some $P_1' \ldots P_n'$ in KB
$q' \leftarrow$ SUBST (θ, q)
if q' does not unify with Some sentence in KB or new then
add q' to new
$\phi \leftarrow$ unify (q', α)
if ϕ is not fail then return ϕ
add new to KB
return false.

Output:
Enter number of FOL expressions in KB
4
Enter the expressions
Living thing (deer)
living thing (tiger)

CODE:

```
class Predicate:
    def init (self, name, args):
        self.name = name
        self.args = args

    def repr (self):
        return f"{self.name}({', '.join(map(str, self.args))})"

    def eq (self, other):
        return isinstance(other, Predicate) and self.name == other.name and self.args == other.args

    def hash (self):
        return hash((self.name, tuple(self.args)))

class Var:
    def init (self, name):
        self.name = name

    def repr (self): return
        self.name

    def eq (self, other):
        return isinstance(other, Var) and self.name == other.name

    def hash (self): return
        hash(self.name)

class Const:
    def init (self, name):
        self.name = name

    def repr (self): return
        self.name

    def eq (self, other):
        return isinstance(other, Const) and self.name == other.name

    def hash (self): return
        hash(self.name)

def is_variable(x):
    return isinstance(x, Var)

def unify(x, y, subst={}):
    if subst is None:
        return None
    elif x == y:
        return subst
    elif is_variable(x):
        return unify_var(x, y, subst)
    elif is_variable(y):
        return unify_var(y, x, subst)
    elif isinstance(x, Predicate) and isinstance(y, Predicate):
```

```
        if x.name != y.name or len(x.args) != len(y.args):
            return None
        for a, b in zip(x.args, y.args):
            subst = unify(a, b, subst)
            if subst is None:
                return None
        return subst
    else:
        return None

def unify_var(var, x, subst):
    if var in subst:
        return unify(subst[var], x, subst)
    elif is_variable(x) and x in subst:
        return unify(var, subst[x], subst)
    elif occurs_check(var, x, subst):
        return None
    else:
        subst_copy = subst.copy()
        subst_copy[var] = x
        return subst_copy

def occurs_check(var, x, subst):
    if var == x:
        return True
    elif is_variable(x) and x in subst:
        return occurs_check(var, subst[x], subst)
    elif isinstance(x, Predicate):
        return any(occurs_check(var, arg, subst) for arg in x.args)
    else:
        return False

def substitute(predicate, subst):
    new_args = []
    for arg in predicate.args:
        val = arg
        while is_variable(val) and val in subst:
            val = subst[val]
        new_args.append(val)
    return Predicate(predicate.name, new_args)

class Rule:
    def __init__(self, premises, conclusion):
        self.premises = premises
        self.conclusion = conclusion

    def __repr__(self):
        return f"{' ∧ '.join(map(str, self.premises))} => {self.conclusion}"

def forward_chain(kb_facts, kb_rules, query):
    inferred = set(kb_facts)
    print("Initial Facts:")
    for f in inferred:
```

```
        print(f"  {f}")
    print("\nStarting inference steps:\n")

    new_inferred = True

    while new_inferred:
        new_inferred = False
        for rule in kb_rules:
            possible_substs = [{}]

            for premise in rule.premises:
                temp_substs = []
                for fact in inferred:
                    for subst in possible_substs:
                        subst_try = unify(premise, fact, subst)
                        if subst_try is not None:
                            temp_substs.append(subst_try)
                possible_substs = temp_substs

            for subst in possible_substs:
                concluded_fact = substitute(rule.conclusion, subst)
                if concluded_fact not in inferred:
                    print(f"Inferred: {concluded_fact} from rule {rule} using substitution {subst}")
                    inferred.add(concluded_fact)
                    new_inferred = True
                    if unify(concluded_fact, query) is not None:
                        print(f"\nQuery {query} proved!")
                        return True

    print(f"\nQuery {query} not proved.")
    return False

if __name__ == "__main__":
    a = Const('a')
    b = Const('b')
    c = Const('c')
    x = Var('x')
    y = Var('y')
    z = Var('z')

    kb_facts = {
        Predicate('Parent', [a, b]),
        Predicate('Parent', [b, c]),
    }

    kb_rules = [
        Rule([Predicate('Parent', [x, y])], Predicate('Ancestor', [x, y])),
        Rule([Predicate('Parent', [x, y]), Predicate('Ancestor', [y, z])], Predicate('Ancestor', [x, z])),
    ]

    query = Predicate('Ancestor', [a, c])

    print("Running forward chaining...\n")
    forward_chain(kb_facts, kb_rules, query)
```

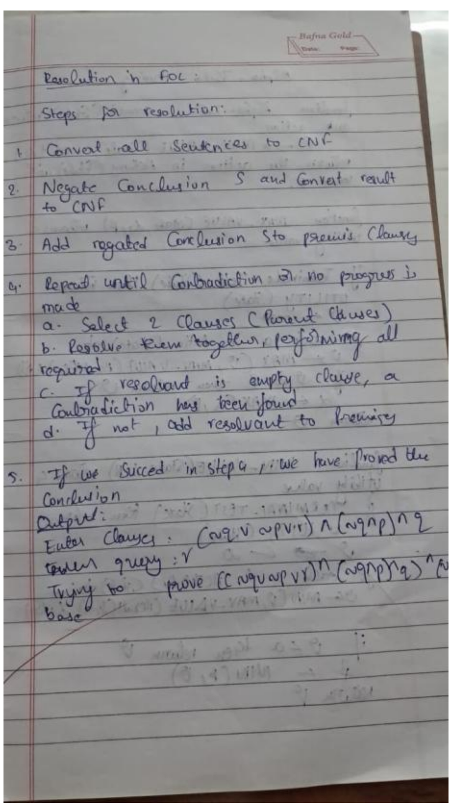
Output:

```
Running forward chaining...

Initial Facts:
  Parent(a, b)
  Parent(b, c)

Starting inference steps:

Inferred: Ancestor(a, b) from rule Parent(x, y) -> Ancestor(x, y) using substitution {x: a,
 y: b}
Inferred: Ancestor(b, c) from rule Parent(x, y) -> Ancestor(x, y) using substitution {x: b,
 y: c}
Inferred: Ancestor(a, c) from rule Parent(x, y) ∧ Ancestor(y, z) -> Ancestor(x, z) using su
bstitution {x: a, y: b, z: c}

Query Ancestor(a, c) proved!
```

PROGRAM 9:

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

ALGORITHM:



Bafna Gold

Resolution in FOL:

Steps for resolution:

1. Convert all sentences to CNF
2. Negate Conclusion S and Convert result to CNF
3. Add negated Conclusion S to premise Clauses
4. Repeat until Contradiction or no progress is made
   a. Select 2 Clauses (Parent Clauses)
   b. Resolve them together, performing all required;
   c. If resolvant is empty clause, a Contradiction has been found
   d. If not, add resolvant to Premises
5. If we Succeed in step 4, we have Proved the Conclusion

Output:

Enter Clauses: (~q v ~p v r) ∧ (~q ∧ p) ∧ q

Enter query: r

Trying to prove ((~q v ~p v r) ∧ (~q ∧ p) ∧ q) ∧ (~

base

CODE:

```
def is_variable(x):
    return x[0].islower() and len(x) == 1

def unify(x, y, subs=None):
    if subs is None:
        subs = {}
    if x == y:
        return subs
    if is_variable(x):
        return unify_var(x, y, subs)
    if is_variable(y):
        return unify_var(y, x, subs)
    if isinstance(x, list) and isinstance(y, list) and len(x) == len(y):
        for a, b in zip(x, y):
            subs = unify(a, b, subs)
            if subs is None:
                return None
        return subs
    return None

def unify_var(var, x, subs):
    if var in subs:
        return unify(subs[var], x, subs)
    if x in subs:
        return unify(var, subs[x], subs)
    if occurs_check(var, x, subs):
        return None
    subs[var] = x
    return subs

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

def negate(literal):
    return literal[1:] if literal.startswith("¬") else "¬" + literal

def parse_predicate(pred):
    name, args = pred.split("(")
    args = args[:-1].split(",")
    args = [a.strip() for a in args]
    return name.strip(), args

def substitute(literal, subs):
```

```
    name, args = parse_predicate(literal.replace("¬", ""))
    new_args = [subs.get(a, a) for a in args]
    new_lit = name + "(" + ", ".join(new_args) + ")" return
    "¬" + new_lit if literal.startswith("¬") else new_lit

def unify_predicates(p1, p2):
    p1_clean = p1.replace("¬", "")
    p2_clean = p2.replace("¬", "")
    n1, a1 = parse_predicate(p1_clean)
    n2, a2 = parse_predicate(p2_clean)
    if n1 != n2 or len(a1) != len(a2):
        return None
    return unify(a1, a2)

def resolve(ci, cj):
    for li in ci:
        for lj in cj:
            if lj == negate(li):
                subs = unify_predicates(li, lj)
                if subs is not None:
                    new_clause = set()
                    for l in ci.union(cj):
                        if l != li and l != lj:
                            new_clause.add(substitute(l, subs))
                    return new_clause, (li, lj), subs
    return None, None, None


KB = [
    {"¬food(x)", "likes(John,x)"},
    {"food(Apple)"},
    {"food(vegetables)"},
    {"¬eats(y,z)", "killed(y)", "food(z)"},
    {"eats(Anil,Peanuts)"},
    {"alive(Anil)"},
    {"¬eats(Anil,w)", "eats(Harry,w)"},
    {"killed(g)", "alive(g)"},
    {"¬alive(k)", "¬killed(k)"},
    {"likes(John,Peanuts)"}
]

def resolution_tree(KB, query):

    print(" PROOF BY RESOLUTION (FOL) ")
    print(f"Goal: Prove that {query}\n")
    print("Converting to CNF and negating the query...\n")

    clauses = [c.copy() for c in KB]
    negated_query = negate(query)
    clauses.append({negated_query})
    print(f"Negated query added to KB: {negated_query}\n")
    new = []
    step = 1
    proof_steps = []
```

```
    tree_nodes = []

    while True:
        pairs = [(clauses[i], clauses[j]) for i in range(len(clauses))
                 for j in range(i + 1, len(clauses))]

        for (ci, cj) in pairs:
            resolvent, used, subs = resolve(ci, cj)
            if resolvent is not None:
                proof_steps.append({
                    "step": step,
                    "parents": (ci, cj),
                    "used": used,
                    "subs": subs,
                    "resolvent": resolvent
                })

                print(f"Step {step}: Resolving {ci} and {cj}")
                print(f" Used literals: {used}")
                if subs:
                    print(f" Substitution: {subs}")
                print(f" ⇒ New Clause:
                 {resolvent}\n")
                tree_nodes.append((ci, cj, resolvent))

                if not resolvent:

                    print(" Empty clause derived — Query is PROVED!\n")
                    print("\n============ PROOF TREE ============\n")
                    print_tree(tree_nodes)
                    return True

                if resolvent not in clauses:
                    new.append(resolvent)
                step += 1
        if not new:
            print(" No new clauses can be derived — Query cannot be proven.\n")
            print("\n============ PROOF TREE (Partial) ============\n")
            print_tree(tree_nodes)

            return False

        clauses.extend(new)
        new = []

def print_tree(nodes):
    def print_branch(node, level=0):
        indent = " " * level
        c1, c2, result = node
        print(f"{indent} ├─ Derived {result} from:")
        print(f"{indent} │   {c1}")
        print(f"{indent} │   {c2}")
```

```
    for n in nodes:
        print_branch(n)
        print("")

if __name__ == "__main__": query
     = "likes(John,Peanuts)"
    result = resolution_tree(KB, query)
    print("Result:", " PROVED" if result else " NOT PROVED")
```

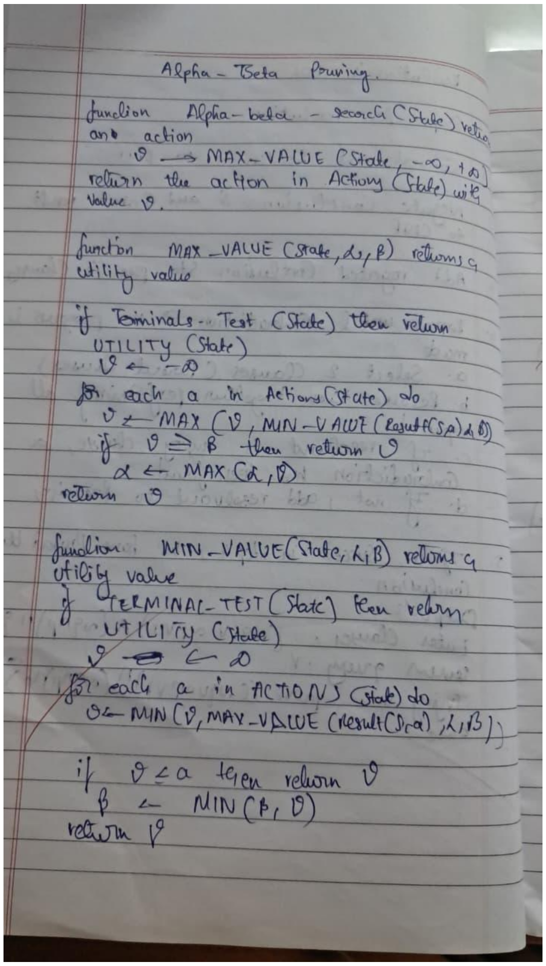
OutPut:

```
        PROOF BY RESOLUTION (FOL)
Goal: Prove that likes(John,Peanuts)

Converting to CNF and negating the query...

Negated query added to KB: ¬likes(John,Peanuts)

Step 1: Resolving {'likes(John,Peanuts)'} and {'¬likes(John,Peanuts)'}
       Used literals: ('likes(John,Peanuts)', '¬likes(John,Peanuts)')
       ⇒ New Clause: set()

 Empty clause derived — Query is PROVED!


============ PROOF TREE ============

├─ Derived set() from:
│     {'likes(John,Peanuts)'}
│     {'¬likes(John,Peanuts)'}

Result:  PROVED
```

PROGRAM 10:

Implement Alpha-Beta Pruning.

ALGORITHM:



Alpha - Beta Pruning.

function Alpha-beta-search(State) returns an action
v → MAX-VALUE(State, -∞, +∞)
return the action in Actions(State) with value v.

function MAX_VALUE(State, α, β) returns a utility value
if Terminals-Test(State) then return UTILITY(State)
v ← -∞
for each a in Actions(State) do
v ← MAX(v, MIN-VALUE(Result(S,a), α, β))
if v ≥ β then return v
α ← MAX(α, β)
return v

function MIN-VALUE(State, α, β) returns a utility value
if TERMINAL-TEST(State) then return UTILITY(State)
v ← ∞
for each a in ACTIONS(State) do
v ← MIN(v, MAX-VALUE(Result(S,a), α, β))
if v ≤ α then return v
β ← MIN(β, v)
return v

CODE:

```
import math


tree = {
    'A': ['B', 'C'],
    'B': ['D', 'E'],
    'C': ['F', 'G'],
    'D': ['H', 'I'],
    'E': ['J', 'K'],
    'F': ['L', 'M'],
    'G': ['N', 'O'],
    'H': [], 'I': [], 'J': [], 'K': [],
    'L': [], 'M': [], 'N': [], 'O': []
}

values = {
    'H': 3, 'I':
    5,
    'J': 6, 'K': 9,
    'L': 1, 'M': 2,
    'N': 0, 'O': -1
}

def get_children(node):
```

```
    return tree.get(node, [])

def evaluate(node):
    return values.get(node, 0)

def alphabeta(node, depth, alpha, beta, maximizingPlayer):
    if not get_children(node) or depth == 0:
        return evaluate(node)

    if maximizingPlayer:
        value = -math.inf
        print(f"MAX Node {node}: α={alpha}, β={beta}")
        for child in get_children(node):
            value = max(value, alphabeta(child, depth - 1, alpha, beta, False))
            alpha = max(alpha, value)
            print(f" MAX updating α={alpha} after visiting {child}")
            if alpha >= beta:
                print(f" Pruned remaining children of {node} (α={alpha}, β={beta})")
                break
        return value
    else:
        value = math.inf
        print(f"MIN Node {node}: α={alpha}, β={beta}")
        for child in get_children(node):
            value = min(value, alphabeta(child, depth - 1, alpha, beta, True))
            beta = min(beta, value)
            print(f" MIN updating β={beta} after visiting {child}")
            if beta <= alpha:
                print(f" Pruned remaining children of {node} (α={alpha}, β={beta})")
                break
        return value


print("\n--- Running Alpha–Beta Pruning on Minimax Tree ---\n")
optimal_value = alphabeta('A', depth=4, alpha=-math.inf, beta=math.inf, maximizingPlayer=True)
print("\nOptimal value at the root (A):", optimal_value)
```

OutPut:

```
--- Running Alpha-Beta Pruning on Minimax Tree ---

MAX Node A: α=-inf, β=inf
MIN Node B: α=-inf, β=inf
MAX Node D: α=-inf, β=inf
  MAX updating α=3 after visiting H
  MAX updating α=5 after visiting I
  MIN updating β=5 after visiting D
MAX Node E: α=-inf, β=5
  MAX updating α=6 after visiting J
   Pruned remaining children of E (α=6, β=5)
  MIN updating β=5 after visiting E
  MAX updating α=5 after visiting B
MIN Node C: α=5, β=inf
MAX Node F: α=5, β=inf
  MAX updating α=5 after visiting L
  MAX updating α=5 after visiting M
  MIN updating β=2 after visiting F
   Pruned remaining children of C (α=5, β=2)
  MAX updating α=5 after visiting C

Optimal value at the root (A): 5
```