COMPILER-DESIGN LAB FILE

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Branch: Computer Engineering

Semester: 6th

Subject Code: CEN 692

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SR No	Program	Date	Signature
1	Write a program to implement a Regular expression. The program should read an R.E through a file and should check whether a string given from the console is acceptable by the given R.E. or not.	24th Jan,24	
2	Write a program to implement Mealy & Moore Machines. The program should read the machine from a file and should generate the corresponding output for a string given from the console. An error must be generated for the case where no valid transition is available.	31st Jan,24 7th Feb,24	
3	Write a program to implement the conversion of an NFA to a DFA. The program should read an NFA through a file and should generate the corresponding tabular DFA for the Q same.	14th FEB,24	
4	Write a program to implement a Regular Grammar. The program should read an R.G. through a file and should check whether a string given from the console is acceptable by the given R.G. or not.	21st Feb,24	
5	Write a program to implement a Context Free Grammar. The program should read the C.F.G. through a file and should check whether a string given from the console is acceptable by the given C.F.G. or not.	28th Feb,24	
6	Write a program to find out the FIRST & FOLLOW values for a given Context Free Grammar. The program should read the C.F.G. from a file	20th Mar,24	
7	Write a program that verifies whether a given CFG is suitable for LL(1) parsing or not. If not then the program should convert the given CFG to a form which is suitable for the LL parsing.	27th Mar,24	
8	Write a program that generates LL(1) parsing table for a given CFG and also performs LL(1) Parsing using the same table. The CFG will be given through a	3rd Apr,24	

	tile and the string to be checked will be given through the console.		
9	Write a program to find the Leaders and Basic Blocks for a Three Address Code given through a file.	24th Apr,24	
10	Write a program to find the Flow Graph and the Dominator nodes in a Three Address Code given through a file	24th Apr,24	
11	Write a program that evaluates GEN & KILL Values for a TAC given through a file.	1st May,24	
12	Write a program to find the Natural Loops in a Three Address Code given through a file.	1st May,24	

Program 1

Code: -

```
#include <iostream>
#include <fstream>
#include <string>
#include <regex>
using namespace std;

int main()
{
    ifstream file("regularExpression.txt");
    if (!file.is_open())
    {
        cout << "Error opening file" << endl;
        return 1;
    }

    string line;
    string exp;
    while (getline(file, line))
    {
        exp += line;
    }
    cout << "Regular expression is " << exp << endl;
    regex regexp(exp);
    int type;
    while (1)
    {
        cout << "Enter 1 to check for a string." << endl;
        cout << "Enter 2 to exit." << endl;
        cin >> type;
        if (type == 1)
        {

            cout << "Give input string to check with the given regular expression"
<< endl;
            string input;
            cin >> input;

            if (regex_match(input, regexp))
            {
                cout << input;
                cout << " string accepted by the given regular expression" << endl;
            }

            else
            {
                cout << input;
```

```
                cout << " string not accepted by the given regular expression" <<
endl;
            }
        }
        else if (type == 2)
        {
            cout << "Exit" << endl;
            break;
        }
    }

    return 0;
}
```

Output: -

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab> cd "f:\Whioo\Se
regularExpression } ; if ($?) { .\regularExpression }
Regular expression is [a+b]*
Enter 1 to check for a string.
Enter 2 to exit.
1
Give input string to check with the given regular expression
aab
aab string accepted by the given regular expression
Enter 1 to check for a string.
Enter 2 to exit.
1
Give input string to check with the given regular expression
abc
abc string not accepted by the given regular expression
Enter 1 to check for a string.
Enter 2 to exit.
```

Program 2

Code: -

Moore Machine

```
#include <bits/stdc++.h>
using namespace std;
vector<vector<int>> dfa;
int initialState;
int convertToInt(string s)
{
    int num = 0;
    for (int i = 0; i < s.size(); i++)
    {
        num = num * 10 + (s[i] - '0');
    }
    return num;
}
vector<int> stringToVector(string &line)
{
    int i = 0;
    vector<int> v;
    while (i < line.size())
    {
        if (line[i] == '-')
        {
            int x = -1;
            v.push_back(x);
            i++;
        }
        else if (line[i] != '-' and line[i] != ' ')
        {
            v.push_back(line[i] - '0');
        }
        i++;
    }
    return v;
}
string isAccepted(vector<vector<int>> &dfa, string input)
{
    string ans = "";
    int currentState = initialState;
    int i = 0;
    int n = input.size();
    int size = dfa[0].size();
    for (int i = 0; i < n; i++)
    {
        if (input[i] - '0' >= size)
            return "Invalid Input";
```

```
    }
    cout << "\nTransitions: ";
    cout << "q" << currentState << " ->";
    while (i < input.size() && currentState != -1)
    {
        ans += dfa[currentState][size - 1] + '0';
        currentState = dfa[currentState][input[i] - '0'];
        if (currentState != -1)
            cout << "q" << currentState << " -> ";
        else
            cout << "Dead state";

        i++;
    }
    cout << endl;
    if (currentState == -1)
        return "Not Accepted and the output is " + ans;
    else
    {
        ans += dfa[currentState][size - 1] + '0';
        return "Accepted and the output is  " + ans;
    }
}
int main()
{
    fstream myfile("moore.txt");
    string line;
    if (!myfile.is_open())
        cout << "Error opening file!\n";
    else
        cout << "File opened successfully!\n";
    cout << "Given DFA - \n";
    while (getline(myfile, line))
    {
        cout << line << endl;
    }
    myfile.clear();
    myfile.seekg(0);
    int currentLine = 0;
    while (getline(myfile, line))
    {
        vector<int> temp;
        if (currentLine == 0)
        {
            initialState = convertToInt(line);
        }
        else
        {
            temp = stringToVector(line);
            dfa.push_back(temp);
```

```
        }
        currentLine++;
    }
    string input;
    cout << "\nEnter input consisting of 0's and 1's: ";
    getline(cin, input);
    string ans = isAccepted(dfa, input);
    cout << endl;
    cout << ans << endl;

    return 0;
}
```

Output: -

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2> cd "f:\Whioo\Sem VI\Co
reTry } ; if ($?) { .\mooreTry }
File opened successfully!
Given DFA -
0
0 1 0
-1 2 1
-1 0 1

Enter input consisting of 0's and 1's: 000010

Transitions: q0 ->q0 -> q0 -> q0 -> q0 -> q1 -> Dead state

Not Accepted and the output is 000001
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2>
```

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2> cd "f:\Whioo
reTry } ; if ($?) { .\mooreTry }
File opened successfully!
Given DFA -
0
0 1 0
-1 2 1
-1 0 1

Enter input consisting of 0's and 1's: 0001

Transitions: q0 ->q0 -> q0 -> q0 -> q1 ->

Accepted and the output is  00001
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2>
```

Mealy machine

```
#include <bits/stdc++.h>
using namespace std;
vector<vector<int>> dfa;
```

```
int initialState;
string isAccepted(vector<vector<int>> &dfa, string input)
{
    string ans = "";
    int currentState = initialState;
    int i = 0;
    int n = input.size();
    int size = dfa[0].size();
    for (int i = 0; i < n; i++)
    {
        if (input[i] - '0' >= size)
            return "Invalid Input";
    }
    cout << "\nTransitions: ";
    cout << "q" << currentState << " ->";
    while (i < input.size() && currentState != -1)
    {
        int currentInput = input[i] - '0';
        if (currentInput == 0)
        {
            if (dfa[currentState][currentInput + 1] != -1)
                ans += (dfa[currentState][currentInput + 1]) + '0'; //
dfa[currentState][1]
            currentState = dfa[currentState][currentInput];         //
dfa[currentState][0]
        }
        else if (currentInput == 1)
        {
            if (dfa[currentState][currentInput + 2] != -1)
                ans += (dfa[currentState][currentInput + 2]) + '0'; //
dfa[currentState][3]
            currentState = dfa[currentState][currentInput + 1];     //
dfa[currentState][2]
        }
        if (currentState != -1)
            cout << "q" << currentState << " -> ";
        else
            cout << "Dead state";

        i++;
    }
    cout << endl;
    if (currentState == -1)
        return "Not Accepted and the output is " + ans;
    else
    {
        return "Accepted and the output is  " + ans;
    }
}
int main()
```

```
{
    fstream myfile("mealy.txt");
    string line;
    if (!myfile.is_open())
        cout << "Error opening file!\n";
    else
        cout << "File opened successfully!\n";
    cout << "Given DFA - \n";
    while (getline(myfile, line))
    {
        cout << line << endl;
    }
    myfile.clear();
    myfile.seekg(0);
    int currentLine = 0;
    while (getline(myfile, line))
    {
        if (currentLine == 0)
        {
            initialState = stoi(line);
        }
        else
        {
            int i = 0;
            vector<int> v;
            while (i < line.size())
            {
                if (line[i] == '-')
                {
                    v.push_back(-1);
                    i++;
                }
                else if (line[i] != '-' and line[i] != ' ')
                {
                    v.push_back(line[i] - '0');
                }
                i++;
            }
            dfa.push_back(v);
        }
        currentLine++;
    }
    string input;
    cout << "\nEnter input consisting of 0's and 1's: ";
    getline(cin, input);
    string ans = isAccepted(dfa, input);
    cout << endl;
    cout << ans << endl;

    return 0;}
```

Output: -

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2> cd
cpp -o tempCodeRunnerFile } ; if ($?) { .\tempCodeRunn
File opened successfully!
Given DFA -
0
0 0 1 0
-1 -1 2 1
-1 -1 0 0

Enter input consisting of 0's and 1's: 010101

Transitions: q0 ->q0 -> q1 -> Dead state

Not Accepted and the output is 00
```

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2> cd "f:\Whioo\Se
cpp -o tempCodeRunnerFile } ; if ($?) { .\tempCodeRunnerFile }
File opened successfully!
Given DFA -
0
0 0 1 0
-1 -1 2 1
-1 -1 0 0

Enter input consisting of 0's and 1's: 00001

Transitions: q0 ->q0 -> q0 -> q0 -> q0 -> q1 ->

Accepted and the output is  00000
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q2>
```

Program 3

Code: -

```
#include <bits/stdc++.h>
#include <fstream>

using namespace std;
int convertToInt(string &s)
{
    int i = 0;
    int ans = 0;
    while (i < s.size())
    {
        int t = s[i] - '0';
        ans = ans * 10 + t;
        i++;
    }
    return ans;
}
vector<set<int>> stringToVectorOfSet(string &line)
{
    int i = 0;
    vector<set<int>> v;
    set<int> s;
    while (i < line.size())
    {
        if (line[i] == '-')
        {
            int x = -1;
            s.insert(x);
            v.push_back(s);
            s.clear();
            i++;
        }
        else if (line[i] != '-' and line[i] != ' ')
        {
            string t = "";
            while (line[i] != ' ' and i < line.size())
            {
                t += line[i];
                i++;
            }
            string k = "";
            for (int j = 0; j < t.size(); j++)
            {
                if (t[j] != ',')
                {
                    k += t[j];
                }
```

```
                else
                {
                    int x = convertToInt(k);
                    k = "";
                    s.insert(x);
                }
            }
            if (k != "")
            {
                int x = convertToInt(k);
                k = "";
                s.insert(x);
            }
            v.push_back(s);
            s.clear();
        }
        i++;
    }
    return v;
}
int main()
{
    ifstream myfile("NFA.txt", ios::in);
    int curr_line = 0;
    string line;
    int istate = 0;
    set<int> finalState;
    vector<vector<set<int>>> nfa;
    while (getline(myfile, line))
    {
        int state;
        vector<set<int>> temp;
        if (curr_line == 0)
        {
            istate = convertToInt(line);
        }
        else if (curr_line == 1)
        {
            string t;
            for (int i = 0; i < line.size(); i++)
            {
                if (line[i] != ',')
                {
                    t += line[i];
                }
                else
                {
                    int x = convertToInt(t);
                    t = "";
                    finalState.insert(x);
```

```
            }
        }
        if (t != "")
        {
            int x = convertToInt(t);
            t = "";
            finalState.insert(x);
        }
    }
    else
    {
        vector<set<int>> v = stringToVectorOfSet(line);
        nfa.push_back(v);
    }
    curr_line++;
}
map<int, set<int>> convergeStates;
map<set<int>, int> mapping;
int n = nfa.size();
for (int i = 0; i < nfa.size(); i++)
{
    for (int j = 0; j < nfa[i].size(); j++)
    {
        if (nfa[i][j].size() > 1)
        {
            convergeStates[n] = nfa[i][j];
            mapping[nfa[i][j]] = n;
            n++;
        }
    }
}
int m = nfa[0].size();

for (auto it : convergeStates)
{
    set<int> s;
    vector<set<int>> nS;
    for (int j = 0; j < m; j++)
    {
        set<int> newSet;
        for (auto i : it.second)
        {
            for (auto k : nfa[i][j])
            {
                if (k != -1)
                {
                    newSet.insert(k);
                }
            }
        }
```

```
        if (newSet.size() > 1)
        {
            if (mapping.find(newSet) == mapping.end())
            {
                convergeStates[n] = newSet;
                mapping[newSet] = n;
                n++;
            }
        }
        if (newSet.size() == 0)
            newSet.insert(-1);
        nS.push_back(newSet);
    }
    nfa.push_back(nS);
}

for (int i = 0; i < nfa.size(); i++)
{
    for (int j = 0; j < nfa[i].size(); j++)
    {
        for (auto it : nfa[i][j])
        {
            cout << it;
        }
        cout << " ";
    }
    cout << endl;
}
cout << endl;
cout << endl;
cout << endl;

int count = 0;
vector<vector<int>> dfa;
set<int> newMergeFinal = finalState;
for (int i = 0; i < nfa.size(); i++)
{
    vector<int> v;
    count = 0;
    for (int j = 0; j < nfa[i].size(); j++)
    {
        if (nfa[i][j].size() == 1)
        {
            v.push_back(*nfa[i][j].begin());
            count++;
        }
        else
        {
            for (auto it : nfa[i][j])
            {
```

```
                    if (finalState.find(it) != finalState.end())
                    {
                        //                        finalState.insert(mapping[nfa[i][j
]]);
                        newMergeFinal.insert(mapping[nfa[i][j]]);
                        break;
                    }
                }
                v.push_back(mapping[nfa[i][j]]);
            }
        }
        dfa.push_back(v);
    }
    ofstream fout("convertedDFA.txt", ios::out);
    fout << istate;
    fout << endl;

    for (auto it : newMergeFinal)
    {
        cout << it << " ";
        fout << it << " ";
    }
    fout << endl;

    cout << endl;

    for (int i = 0; i < dfa.size(); i++)
    {
        for (int j = 0; j < dfa[i].size(); j++)
        {
            if (finalState.find(dfa[i][j]) != finalState.end())
                cout << "[" << dfa[i][j] << "]"
                     << " ";
            else
                cout << dfa[i][j] << " ";
            fout << dfa[i][j] << " ";
        }
        fout << endl;
        cout << endl;
    }

    return 0;
}
```

Output: -

```
ToDfa } ; if ($?) { .\nfaToDfa }
0 01 2
2 1 12
2 3 23
3 3 3
02 01 12
2 13 123
23 3 23
02 013 23
23 13 123
23 13 123
023 013 123
023 013 23



2 3 5 6 7 8 9 10 11
0 4 [2]
[2] 1 5
[2] [3] 6
[3] [3] [3]
7 4 5
[2] 8 9
6 [3] 6
7 10 6
6 8 9
6 8 9
11 10 9
11 10 6
```

Program 4

Code: -

```
#include <iostream>
#include <fstream>
#include <string>
#include <set>
#include <map>

using namespace std;
map<char, set<string>> mp;

bool solve(string &s, int idx, string toCheck)
{
    if (s.substr(idx) == toCheck)
        return true;
    else if (toCheck == "")
        return false;
    for (auto t : mp[toCheck[0]])
    {
        int sz = t.size(), i = idx, j = 0;
        while (j < sz && i < s.size() && s[i] == t[j])
        {
            i++, j++;
        }
        if (j == sz && solve(s, i, toCheck.substr(1)))
            return true;
        else if (j < sz && t[j] == '#' && solve(s, i, toCheck.substr(1)))
            return true;
        else if (j < sz && t[j] >= 'A' && t[j] <= 'Z' && solve(s, i, t.substr(j) +
toCheck.substr(1)))
            return true;
    }
    return false;
}
string checkGrammar(string s = "")
{
    if (solve(s, 0, "S"))
        return "Accepted\n";
    return "Not Accepted\n";
}

int main()
{
    ifstream inputF("regularGrammer.txt");
    string t;
    while (getline(inputF, t))
    {
        string x;
```

```
        for (int i = 3; i < t.size(); i++)
        {
            if (t[i] != '|')
                x.push_back(t[i]);
            else
            {
                mp[t[0]].insert(x);
                x = "";
            }
        }
        mp[t[0]].insert(x);
    }
    for (auto ch : mp)
    {
        cout << ch.first << "-> ";
        for (auto t : mp[ch.first])
            cout << t << "| ";
        cout << endl;
    }
    while (true)
    {
        cout << "Enter a string : ";
        string s;
        cin >> s;
        if (s == "exit")
            break;
        cout << checkGrammar(s) << endl;
    }
    return 0;
}
```

Output: -

```
PS F:\Whioo\Sem VI\Complier Design\Compi
cpp -o tempCodeRunnerFile } ; if ($?) {
A-> #| aA|
B-> #| bB|
S-> AB|
Enter a string : abbba
Not Accepted

Enter a string : ab
Accepted
```

Program 5

Code: -

```
#include <iostream>
#include <fstream>
#include <string>
#include <set>
#include <map>

using namespace std;
map<char, set<string>> mp;

bool solve(string &s, int idx, string toCheck)
{
    if (s.substr(idx) == toCheck)
        return true;
    else if (toCheck == "")
        return false;
    for (auto t : mp[toCheck[0]])
    {
        int sz = t.size(), i = idx, j = 0;
        while (j < sz && i < s.size() && s[i] == t[j])
        {
            i++, j++;
        }
        if (j == sz && solve(s, i, toCheck.substr(1)))
            return true;
        else if (j < sz && t[j] == '#' && solve(s, i, toCheck.substr(1)))
            return true;
        else if (j < sz && t[j] >= 'A' && t[j] <= 'Z' && solve(s, i, t.substr(j) +
toCheck.substr(1)))
            return true;
    }
    return false;
}
string checkGrammar(string s = "")
{
    if (solve(s, 0, "S"))
        return "Accepted\n";
    return "Not Accepted\n";
}

int main()
{
    ifstream inputF("cfg.txt");
    string t;
    while (getline(inputF, t))
    {
        string x;
```

```
        for (int i = 3; i < t.size(); i++)
        {
            if (t[i] != '|')
                x.push_back(t[i]);
            else
            {
                mp[t[0]].insert(x);
                x = "";
            }
        }
        mp[t[0]].insert(x);
    }
    for (auto ch : mp)
    {
        cout << ch.first << "-> ";
        for (auto t : mp[ch.first])
            cout << t << "| ";
        cout << endl;
    }
    while (true)
    {
        cout << "Enter a string : ";
        string s;
        cin >> s;
        if (s == "exit")
            break;
        cout << checkGrammar(s) << endl;
    }
    return 0;
}
```

Output: -

```
S-> #| aSb|
Enter a string : abba
Not Accepted

Enter a string : aab
Not Accepted

Enter a string : ab
Accepted
```

Program 6

Code: -

```
#include <bits/stdc++.h>

using namespace std;

void computingFollow(char c, vector<string> &cfg, map<char, string> &first,
map<char, string> &follow)
{
    for (int i = 0; i < cfg.size(); i++)
    {
        for (int j = 1; j < cfg[i].size(); j++)
        {
            if (cfg[i][j] == c)
            {
                for (int k = j + 1; k <= cfg[i].size(); k++)
                {
                    bool flag = false;
                    if (k < cfg[i].size())
                    {
                        if (cfg[i][k] <= 'Z' && cfg[i][k] >= 'A')
                        {
                            for (int l = 0; l < first[cfg[i][k]].size(); l++)
                            {
                                if (first[cfg[i][k]][l] != '#')
                                {
                                    if (follow[c].find(first[cfg[i][k]][l]) >=
follow[c].size())
                                        follow[c].push_back(first[cfg[i][k]][l]);
                                }
                                else
                                    flag = true;
                            }
                        }
                        else
                        {
                            if (follow[c].find(cfg[i][k]) >= follow[c].size())
                                follow[c].push_back(cfg[i][k]);
                            break;
                        }
                    }
                    else
                    {
                        if (cfg[i][0] == c)
                            break;
                        if (follow[cfg[i][0]].empty())
                            computingFollow(cfg[i][0], cfg, first, follow);
                        for (int l = 0; l < follow[cfg[i][0]].size(); l++)
```

```
                        {
                            if (follow[c].find(follow[cfg[i][0]][l]) >=
follow[c].size())
                                follow[c].push_back(follow[cfg[i][0]][l]);
                        }
                    }
                    if (!flag)
                        break;
                }
            }
        }
    }
}

void computingFirst(char c, vector<string> &cfg, map<char, string> &first)
{
    if (!(c <= 'Z' and c >= 'A'))
    {
        if (first[c].find(c) >= first[c].size())
            first[c].push_back(c);
        return;
    }
    for (int i = 0; i < cfg.size(); i++)
    {
        if (cfg[i][0] == c)
        {
            for (int j = 1; j < cfg[i].size(); j++)
            {
                if (cfg[i][j] == c)
                {
                    break;
                }
                bool flag = false;
                if (first[cfg[i][j]].empty())
                    computingFirst(cfg[i][j], cfg, first);
                for (int k = 0; k < first[cfg[i][j]].size(); k++)
                {
                    if (first[cfg[i][j]][k] != '#')
                    {
                        if (first[c].find(first[cfg[i][j]][k]) >= first[c].size())
                            first[c].push_back(first[cfg[i][j]][k]);
                    }
                    else if (j == cfg[i].size() - 1)
                    {
                        if (first[c].find('#') >= first[c].size())
                            first[c].push_back('#');
                    }
                    else
                        flag = true;
                }
```

```
                if (!flag)
                    break;
            }
        }
    }
}
int main()
{
    ifstream myfile("cfgprac2.txt", ios::in);
    int curr_line = 0;
    string line;
    vector<string> cfg;
    while (getline(myfile, line))
    {
        string temp = "";
        for (int i = 0; i < line.size(); i++)
        {
            if (line[i] != ' ')
            {
                temp += line[i];
            }
        }
        cfg.push_back(temp);
    }
    char s = cfg[0][0];
    map<char, string> first;
    map<char, string> follow;
    follow[s].push_back('$');
    for (int i = 0; i < cfg.size(); i++)
    {
        for (int j = 0; j < cfg[i].size(); j++)
        {
            computingFirst(cfg[i][0], cfg, first);
        }
    }
    for (int i = 0; i < cfg.size(); i++)
    {
        for (int j = 0; j < cfg[i].size(); j++)
        {
            computingFollow(cfg[i][0], cfg, first, follow);
        }
    }
    for (auto it : first)
    {
        if ((it.first <= 'Z' and it.first >= 'A'))
        {
            cout << "First(" << it.first << ") :  { ";
            int j = 0;
            for (auto i : it.second)
            {
```

```
                cout << "'" << i << "'";
                if (j < it.second.size() - 1)
                    cout << " , ";
                j++;
            }
            cout << " }" << endl;
        }
    }
    cout << endl
         << endl;
    for (auto it : follow)
    {
        cout << "Follow(" << it.first << ") :  { ";
        int j = 0;
        for (auto i : it.second)
        {
            cout << "'" << i << "'";
            if (j < it.second.size() - 1)
                cout << " , ";
            j++;
        }
        cout << " }" << endl;
    }
    return 0;
}
```

Output: -

```
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q6> cd
esign\CompilerLab\Q6\" ; if ($?) { g++ firstAndFollow
f ($?) { .\firstAndFollow }
First(A) :  { '#' , ',' }
First(L) :  { '(' , 'a' }
First(S) :  { '(' , 'a' }


Follow(A) :  { ')' }
Follow(L) :  { ')' }
Follow(S) :  { '$' , ',' , ')' }
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q6>
```

Program 7

Code: -

```
#include <iostream>
#include <fstream>
#include <vector>
#include <algorithm>
#include <string>
#include <set>
#include <map>

using namespace std;
char start;

map<char, vector<vector<char>>> readGrammar(const string &filename)
{
    ifstream fin(filename);
    int i, j;
    map<char, vector<vector<char>>> grammar;
    string line;

    bool flag = 0;
    cout << "Grammar: " << '\n';
    while (getline(fin, line))
    {
        if (flag == 0)
        {
            start = line[0], flag = 1;
        }
        cout << line << '\n';
        char nonTerminal = line[0];
        vector<char> production;
        for (int i = 3; i < line.size(); i++)
        {
            if (line[i] == '|')
            {
                grammar[nonTerminal].push_back(production);
                production.clear();
            }
            else
            {
                production.push_back(line[i]);
            }
        }
        grammar[nonTerminal].push_back(production);
    }
    return grammar;
}
```

```
void printGrammar(const std::map<char, std::vector<std::vector<char>>> &grammar)
{
    cout << "\nConverted Grammar:" << endl;
    for (const auto &entry : grammar)
    {
        char nonTerminal = entry.first;
        std::string output = "";
        output += nonTerminal;
        output += " -> ";

        bool first = true;

        for (const auto &production : entry.second)
        {
            if (!first)
            {
                output += " | ";
            }
            else
            {
                first = false;
            }

            for (const auto &symbol : production)
            {
                output += symbol;
            }
        }

        std::cout << output << std::endl;
    }
}

void eliminateLeftRecursion(map<char, vector<vector<char>>> &grammar)
{

    map<char, vector<vector<char>>> additionalRules;

    vector<int> usedNonTerminals(26, 0);
    int flag = 0;

    for (auto &entry : grammar)
    {
        char nonTerminal = entry.first;
        vector<vector<char>> nonLeftRecursiveProductions;
        vector<vector<char>> leftRecursiveProductions;

        for (auto &production : entry.second)
        {
            if (production[0] == nonTerminal)
```

```
            {

                vector<char> adjustedProduction(production.begin() + 1,
production.end());
                leftRecursiveProductions.push_back(adjustedProduction);
            }
            else
            {
                nonLeftRecursiveProductions.push_back(production);
            }
        }

        if (!leftRecursiveProductions.empty())
        {
            flag = 1;
            cout << "Given CFG is not suitable for LL(1) parsing as is has Left
Recurssion." << endl;

            char newNonTerminal = 'A';
            while (grammar.count(newNonTerminal) || usedNonTerminals[newNonTerminal
- 'A'])
            {
                newNonTerminal++;
            }
            usedNonTerminals[newNonTerminal - 'A'] = 1;

            for (auto &production : nonLeftRecursiveProductions)
            {
                production.push_back(newNonTerminal);
            }

            for (auto &production : leftRecursiveProductions)
            {
                production.push_back(newNonTerminal);
            }
            leftRecursiveProductions.push_back({'#'});

            grammar[nonTerminal] = nonLeftRecursiveProductions;

            additionalRules[newNonTerminal] = leftRecursiveProductions;
        }
    }
    for (auto &entry : additionalRules)
    {
        grammar[entry.first] = entry.second;
    }

    if (flag)
    {
        printGrammar(grammar);
```

```
    }
}

set<char> getFirstSet(char nonTerminal, const map<char, vector<vector<char>>>
&grammar, map<char, set<char>> &firstSets)
{

    if (firstSets.count(nonTerminal))
    {
        return firstSets[nonTerminal];
    }

    set<char> firstSet;
    bool canDeriveEpsilon = false;

    for (const auto &production : grammar.at(nonTerminal))
    {
        bool canProduceEpsilon = true;

        for (const char &symbol : production)
        {
            if (symbol >= 'A' && symbol <= 'Z')
            {

                set<char> subFirstSet = getFirstSet(symbol, grammar, firstSets);
                firstSet.insert(subFirstSet.begin(), subFirstSet.end());
                firstSet.erase('#');

                if (!subFirstSet.count('#'))
                {
                    canProduceEpsilon = false;
                    break;
                }
            }
            else if (symbol == '#')
            {

                firstSet.insert(symbol);
                break;
            }
            else
            {

                firstSet.insert(symbol);
                canProduceEpsilon = false;
                break;
            }
        }

        if (canProduceEpsilon)
```

```
        {
            canDeriveEpsilon = true;
        }
    }

    if (canDeriveEpsilon)
    {
        firstSet.insert('#');
    }

    firstSets[nonTerminal] = firstSet;
    return firstSet;
}

map<char, set<char>> calculateFollowSets(const map<char, vector<vector<char>>>
&grammar, char startSymbol, map<char, set<char>> &firstSets)
{
    int i;
    map<char, set<char>> followSets;
    followSets[startSymbol].insert('$');

    int iterations = 10;
    while (iterations--)
    {
        for (auto q : grammar)
        {
            for (auto r : q.second)
            {
                for (i = 0; i < r.size() - 1; i++)
                {
                    if (r[i] >= 'A' && r[i] <= 'Z')
                    {
                        if (!(r[i + 1] >= 'A' && r[i + 1] <= 'Z'))
                            followSets[r[i]].insert(r[i + 1]);
                        else
                        {
                            char temp = r[i + 1];
                            int j = i + 1;
                            while (temp >= 'A' && temp <= 'Z')
                            {
                                if (*firstSets[temp].begin() == '#')
                                {
                                    for (auto g : firstSets[temp])
                                    {
                                        if (g == '#')
                                            continue;
                                        followSets[r[i]].insert(g);
                                    }
                                    j++;
                                    if (j < r.size())
```

```
                                    {
                                        temp = r[j];
                                        if (!(temp >= 'A' && temp <= 'Z'))
                                        {
                                            followSets[r[i]].insert(temp);
                                            break;
                                        }
                                    }
                                    else
                                    {
                                        for (auto g : followSets[q.first])
                                            followSets[r[i]].insert(g);
                                        break;
                                    }
                                }
                                else
                                {
                                    for (auto g : firstSets[temp])
                                    {
                                        followSets[r[i]].insert(g);
                                    }
                                    break;
                                }
                            }
                        }
                    }
                }
                if (r[r.size() - 1] >= 'A' && r[r.size() - 1] <= 'Z')
                {
                    for (auto g : followSets[q.first])
                        followSets[r[i]].insert(g);
                }
            }
        }
    }

    return followSets;
}

bool isLL1(const map<char, set<char>> &firstSets, const map<char, set<char>>
&followSets, const map<char, vector<vector<char>>> &grammar)
{
    for (const auto &entry : grammar)
    {
        char nonTerminal = entry.first;
        set<char> firstUnion;

        for (const auto &production : entry.second)
        {
            set<char> currentFirstSet;
```

```
            for (const auto &symbol : production)
            {
                if (symbol >= 'A' && symbol <= 'Z')
                {
                    const auto &subFirstSet = firstSets.at(symbol);
                    currentFirstSet.insert(subFirstSet.begin(), subFirstSet.end());
                    if (!subFirstSet.count('#'))
                    {
                        break;
                    }
                }
                else
                {
                    currentFirstSet.insert(symbol);
                    break;
                }
            }

            set<char> intersection;
            set_intersection(firstUnion.begin(), firstUnion.end(),
currentFirstSet.begin(), currentFirstSet.end(), inserter(intersection,
intersection.begin()));
            if (!intersection.empty())
            {
                return false;
            }

            firstUnion.insert(currentFirstSet.begin(), currentFirstSet.end());
        }

        if (firstUnion.count('#'))
        {
            set<char> intersection;
            set_intersection(firstUnion.begin(), firstUnion.end(),
followSets.at(nonTerminal).begin(), followSets.at(nonTerminal).end(),
inserter(intersection, intersection.begin()));
            if (!intersection.empty())
            {
                return false;
            }
        }
    }

    return true;
}

int main()
{
    map<char, vector<vector<char>>> grammar = readGrammar("ll1.txt");
```

```
    eliminateLeftRecursion(grammar);

    map<char, set<char>> firstSets;
    for (const auto &entry : grammar)
    {
        getFirstSet(entry.first, grammar, firstSets);
    }

    char startSymbol = start;
    map<char, set<char>> followSets = calculateFollowSets(grammar, startSymbol,
firstSets);

    bool ll1Compatible = isLL1(firstSets, followSets, grammar);

    if (ll1Compatible)
    {
        cout << "Given CFG is suitable for LL(1) parsing." << endl;
    }
    else
    {
        cout << "Given CFG is not suitable for LL(1) parsing as First & Follow have
no common elements." << endl;
    }

    cout << "\nFIRST sets:" << endl;
    for (const auto &entry : firstSets)
    {
        cout << entry.first << " = { ";
        for (const auto &s : entry.second)
        {
            cout << s << " ";
        }
        cout << "}" << endl;
    }

    cout << "\nFOLLOW sets:" << endl;
    for (const auto &entry : followSets)
    {
        cout << entry.first << " = { ";
        for (const auto &s : entry.second)
        {
            cout << s << " ";
        }
        cout << "}" << endl;
    }

    return 0;
}
```

Output: -

```
Grammar:
S->A
A->aB|Ad
B->b
C->g
Given CFG is not suitable for LL(1) parsing as is has Left Recurssion.

Converted Grammar:
A -> aBD
B -> b
C -> g
D -> dD | #
S -> A
Given CFG is suitable for LL(1) parsing.

FIRST sets:
A = { a }
B = { b }
C = { g }
D = { # d }
S = { a }

FOLLOW sets:
A = { $ }
B = { $ d }
D = { $ }
S = { $ }
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q7>
```

Program 8

Code: -

```
#include <bits/stdc++.h>
#include <unordered_map>
#include <set>
#include <vector>
#include <fstream>

using namespace std;

unordered_map<char, set<char>> FIRST, FOLLOW;
unordered_map<char, vector<string>> productions;
unordered_map<char, unordered_map<char, string>> parsingTable;
vector<char> terminals;
char startSymbol = '\0';

void readTxt();
void calculateFIRST(char);
void calculateFOLLOW(char);
void printFirstFollow();
void terminalSet();
void constructParsingTable();
void printParsingTable();
void parseInput(string &input);

int main()
{
  readTxt();
  FOLLOW[startSymbol].insert('$'); // Add $ to the FOLLOW of starting symbol
  printFirstFollow();
  terminalSet();
  constructParsingTable();
  printParsingTable();

  string input;
  cout << "\nEnter the input string to parse: ";
  cin >> input;
  parseInput(input);
  return 0;
}

void readTxt()
{
  fstream myfile;
  myfile.open("LL_cfg2.txt", ios::in);
  string line;
  cout << "\nCFG:\n\n";
  while (getline(myfile, line))
```

```
  {
    cout << line << endl;
    int equalPos = line.find("->"); // Find the position of '='
    if (equalPos != string::npos)
    {
      char NT = line[0];
      if (startSymbol == '\0')
      {
        startSymbol = line[0]; // Set the starting symbol
      }
      string production = line.substr(equalPos + 2); // Get the substring after '->'
      int pos = 0;
      string token;
      while (production.find('|') != string::npos)
      {
        pos = production.find('|');
        token = production.substr(0, pos);
        productions[NT].push_back(token);
        production.erase(0, pos + 1);
      }
      productions[NT].push_back(production); // Add the last or only production
    }
  }
  cout << endl;
  myfile.close();
}

void terminalSet()
{
  for (auto prod : productions)
  {
    for (string str : prod.second)
    {
      for (int i = 0; i < str.size(); i++)
      {
        if (!isupper(str[i]))
        {
          terminals.push_back(str[i]);
        }
      }
    }
  }

  sort(terminals.begin(), terminals.end());
  terminals.erase(unique(terminals.begin(), terminals.end()), terminals.end());
  terminals.erase(remove(terminals.begin(), terminals.end(), ' '), terminals.end());
  terminals.push_back('$');
}

void calculateFIRST(char NT)
```

```
{
  if (!FIRST[NT].empty())
    return; // Already calculated
  int flag = 0;

  for (string &prod : productions[NT])
  {
    int len = prod.size();
    int i = 0;
    for (char symbol : prod)
    {
      if (isupper(symbol))
      { // Non-terminal
        len--;
        calculateFIRST(symbol);
        FIRST[NT].insert(FIRST[symbol].begin(), FIRST[symbol].end());
        FIRST[NT].erase('#'); // remove epsilon
        if (FIRST[symbol].find('#') == FIRST[symbol].end())
        {
          flag = 1;
          break;
        }
        if (flag == 0 && len == 0)
        {
          FIRST[NT].insert('#'); // if RHS is all epsilon then add epsilon
        }
      }
      else
      { // Terminal or Epsilon
        FIRST[NT].insert(symbol);
        break;
      }
    }
  }
}

void calculateFOLLOW(char NT)
{
  if (!FOLLOW[NT].empty())
    if (NT != startSymbol)
    {
      return; // Already calculated
    }
  for (auto &prod : productions)
  {
    for (string &str : prod.second)
    {
      for (int i = 0; i < str.size(); ++i)
      {
        if (str[i] == NT)
```

```
        {
          int j = i + 1;
          while (j < str.size())
          {
            char nextSymbol = str[j];
            if (isupper(nextSymbol))
            { // Next is a Non-terminal
              FOLLOW[NT].insert(FIRST[nextSymbol].begin(), FIRST[nextSymbol].end());
              FOLLOW[NT].erase('#'); // Remove Epsilon if it's there
              if (j == str.size() - 1 && FIRST[nextSymbol].find('#') !=
FIRST[nextSymbol].end())
              {
                calculateFOLLOW(prod.first);
                FOLLOW[NT].insert(FOLLOW[prod.first].begin(),
FOLLOW[prod.first].end());
              }
              else if (FIRST[nextSymbol].find('#') == FIRST[nextSymbol].end())
              {
                break;
              }
            }
            else
            { // Next is a Terminal
              FOLLOW[NT].insert(nextSymbol);
            }
            j++;
          }
          if (prod.first != NT && i + 1 >= str.size())
          {
            calculateFOLLOW(prod.first);
            FOLLOW[NT].insert(FOLLOW[prod.first].begin(), FOLLOW[prod.first].end());
          }
        }
      }
    }
  }
}

void printFirstFollow()
{ // Calculate FIRST
  for (auto prod : productions)
  {
    calculateFIRST(prod.first);
  }

  // Calculate FOLLOW
  for (auto prod : productions)
  {
    calculateFOLLOW(prod.first);
  }
```

```
  cout << "FIRST OF NON-TERMINALS: " << endl
       << endl;
  for (auto &prod : productions)
  {
    cout << "FIRST(" << prod.first << ") = { ";
    for (char c : FIRST[prod.first])
    {
      cout << c << " ";
    }
    cout << "}" << endl;
  }
  cout << "\n-----------------------------\n\n";
  cout << "FOLLOW OF NON-TERMINALS: " << endl
       << endl;
  for (auto &prod : productions)
  {
    cout << "FOLLOW(" << prod.first << ") = { ";
    for (char c : FOLLOW[prod.first])
    {
      cout << c << " ";
    }
    cout << "}" << endl;
  }
  cout << endl;
}

void constructParsingTable()
{
  for (auto &prod : productions)
  {
    char nonTerminal = prod.first;
    for (const string &prodStr : prod.second)
    {
      set<char> firstSet;
      for (char symbol : prodStr)
      {
        if (isupper(symbol))
        { // Non-terminal
          firstSet.insert(FIRST[symbol].begin(), FIRST[symbol].end());
          if (FIRST[symbol].find('#') == FIRST[symbol].end())
          {
            break;
          }
        }
        else
        { // Terminal or Epsilon
          firstSet.insert(symbol);
          break;
        }
```

```
      }
      for (char terminal : firstSet)
      {
        if (terminal != '#')
        {
          parsingTable[nonTerminal][terminal] = prodStr;
        }
        else
        {
          for (char follow : FOLLOW[nonTerminal])
          {
            parsingTable[nonTerminal][follow] = prodStr;
          }
        }
      }
    }
  }
}

void printParsingTable()
{
  cout << "LL(1) Parsing Table:\n\n";
  cout << "NT" << setw(15);
  for (const auto t : terminals)
  {
    if (t != '#')
    {
      cout << t << setw(17);
    }
  }
  cout << endl;
  cout << setw(0) << "------------------------------------------------------------------
-----------------------------------------" << endl;
  for (const auto &nonTerminalEntry : parsingTable)
  {
    char nonTerminal = nonTerminalEntry.first;
    const auto &terminalMap = nonTerminalEntry.second;
    cout << nonTerminal;
    for (const auto t : terminals)
    {
      // char terminal = terminalEntry.first;
      if (t != '#')
      {

        if (terminalMap.count(t))
        {
          const string &production = terminalMap.at(t);
          cout << setw(15) << nonTerminal << "->" << production;
        }
        else
```

```
        {
          cout << setw(15) << "-";
        }
      }
    }
    cout << endl;
  }
}

void parseInput(string &input)
{
  input += '$';
  stack<char> symbolStack;
  symbolStack.push('$');          // Push end of input marker
  symbolStack.push(startSymbol); // Push starting symbol

  cout << "\nParsing Steps:" << endl;

  int inputIndex = 0;
  char currentInput = input[inputIndex];

  cout << "\nStack: ";
  stack<char> printStack = symbolStack;
  while (!printStack.empty())
  {
    cout << printStack.top();
    printStack.pop();
  }

  cout << "\t\tInput: " << input.substr(inputIndex) << endl;

  while (!symbolStack.empty())
  {
    char stackTop = symbolStack.top();

    if (stackTop == currentInput && currentInput == '$')
    {
      cout << "\nString Parsed Successfully." << endl;
      return;
    }

    if (!isupper(stackTop))
    { // Terminal symbol
      if (stackTop == currentInput)
      {
        symbolStack.pop();
        inputIndex++;
        currentInput = input[inputIndex];
      }
      else
```

```
      {
        cout << "\nError: Mismatched terminal symbol." << endl;
        return;
      }
    }
    else
    { // Non-terminal symbol
      auto it = parsingTable.find(stackTop);
      if (it != parsingTable.end())
      {
        auto &row = it->second;
        auto colIt = row.find(currentInput);
        if (colIt != row.end())
        {
          const string &production = colIt->second;
          cout << "\nUsing production rule: " << stackTop << " -> " << production <<
endl;

          // Pop the non-terminal from the stack
          symbolStack.pop();

          // Push the production rule in reverse order onto the stack
          for (auto rit = production.rbegin(); rit != production.rend(); ++rit)
          {
            if (*rit != '#')
            { // Skip epsilon
              symbolStack.push(*rit);
            }
          }
        }
        else
        {
          cout << "\nError: No production rule found." << endl;
          break;
        }
      }
      else
      {
        cout << "\nError: No production rule found." << endl;
        break;
      }
    }

    // Print current stack and input
    cout << "Stack: ";
    stack<char> printStack = symbolStack;
    while (!printStack.empty())
    {
      cout << printStack.top();
      printStack.pop();
```

```
    }
    cout << "\t\tInput: " << input.substr(inputIndex) << endl;
  }

  cout << "\nError: Parsing Failed." << endl;
}
```

Output: -

```
CFG:

S->AB
A->a
A->e
B->b
B->e

FIRST OF NON-TERMINALS:

FIRST(B) = { b e }
FIRST(A) = { a e }
FIRST(S) = { a e }

-----------------------------

FOLLOW OF NON-TERMINALS:

FOLLOW(B) = { $ }
FOLLOW(A) = { b e }
FOLLOW(S) = { $ }

LL(1) Parsing Table:

NT              a               b               e               $
-------------------------------------------------------------------------------------------------------
S             S->AB             -             S->AB             -
A             A->a              -             A->e              -
B             -              B->b             B->e              -
```

```
Enter the input string to parse: abe

Parsing Steps:

Stack: S$               Input: abe$

Using production rule: S -> AB
Stack: AB$              Input: abe$

Using production rule: A -> a
Stack: aB$              Input: abe$
Stack: B$               Input: be$

Using production rule: B -> b
Stack: b$               Input: be$
Stack: $                Input: e$

Error: Mismatched terminal symbol.
PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q8>
```

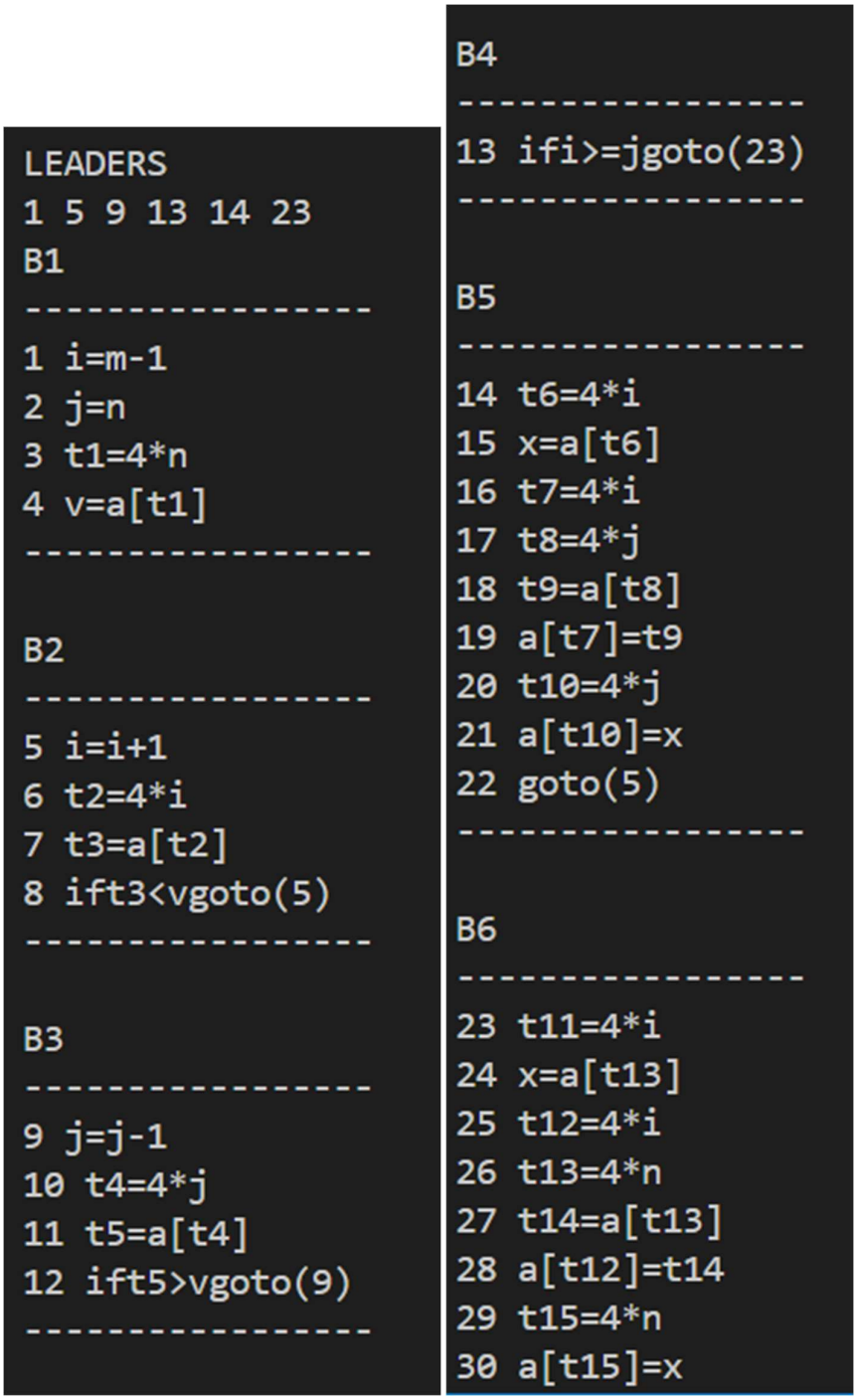
Program 9

Code: -

```
#include <bits/stdc++.h>

using namespace std;

int stoi(string &num)
{
    int ans = 0;
    for (int i = 0; i < num.size(); i++)
    {
        ans = ans * 10 + num[i] - '0';
    }
    return ans;
}

int main()
{
    ifstream myfile("TAC.txt", ios::in);
    int curr_line = 1;
    string line;
    vector<string> tac;
    set<int> leaders;
    leaders.insert(1);
    while (getline(myfile, line))
    {
        string temp;
        int sz = line.size();
        for (int i = 0; i < sz; i++)
        {
            if (line[i] != ' ')
                temp += line[i];
        }
        tac.push_back(temp);
        sz = temp.size();
        int pos = temp.find("goto");
        string num = "";
        if (pos != -1)
        {
            for (int i = pos + 5; temp[i] <= '9' and temp[i] >= '0'; i++)
            {
                num += temp[i];
            }
            int n = stoi(num);
            leaders.insert(n);
            leaders.insert(curr_line + 1);
        }
        curr_line++;
```

```
    }
    curr_line--;
    cout << "\nLEADERS\n";
    for (auto i : leaders)
    {
        if (i == curr_line + 1)
            leaders.erase(i);
        cout << i << " ";
    }
    cout << endl;
    vector<pair<int, int>> blocks;
    int p = -1;
    for (int i : leaders)
    {
        if (p != -1)
        {
            blocks.push_back({p, i - 1});
        }
        p = i;
    }
    blocks.push_back({p, curr_line});
    cout << "B1" << endl;
    cout << "-----------------" << endl;
    int count = 1;
    for (int i = 0; i < blocks.size(); i++)
    {
        for (int j = blocks[i].first - 1; j < blocks[i].second; j++)
        {
            cout << j + 1 << " " << tac[j] << endl;
        }
        cout << "-----------------" << endl;
        count++;
        if (i < blocks.size() - 1)
        {
            cout << endl
                 << "B" << count << endl;
            cout << "-----------------" << endl;
        }
    }
    return 0;
}
```

Output: -


LEADERS
1 5 9 13 14 23
B1
1 i=m-1
2 j=n
3 t1=4*n
4 v=a[t1]
B2
5 i=i+1
6 t2=4*i
7 t3=a[t2]
8 ift3<vgoto(5)
B3
9 j=j-1
10 t4=4*j
11 t5=a[t4]
12 ift5>vgoto(9)
B4
13 ifi>=jgoto(23)
B5
14 t6=4*i
15 x=a[t6]
16 t7=4*i
17 t8=4*j
18 t9=a[t8]
19 a[t7]=t9
20 t10=4*j
21 a[t10]=x
22 goto(5)
B6
23 t11=4*i
24 x=a[t13]
25 t12=4*i
26 t13=4*n
27 t14=a[t13]
28 a[t12]=t14
29 t15=4*n
30 a[t15]=x

Program 10

Code: -

```
#include <bits/stdc++.h>
using namespace std;
int stoi(string &num)
{
    int ans = 0;
    for (int i = 0; i < num.size(); i++)
    {
        ans = ans * 10 + num[i] - '0';
    }
    return ans;
}
int findblock(int j, vector<pair<int, int>> &blocks)
{
    int ans = 0;
    for (int i = 0; i < blocks.size(); i++)
    {
        if (blocks[i].second == j)
        {
            ans = i + 1;
            break;
        }
    }
    return ans;
}
int main()
{
    ifstream myfile("TAC.txt", ios::in);
    int curr_line = 1;
    string line;
    vector<string> tac;
    set<int> leaders;
    leaders.insert(1);
    while (getline(myfile, line))
    {
        string temp;
        int sz = line.size();
        for (int i = 0; i < sz; i++)
        {
            if (line[i] != ' ')
                temp += line[i];
        }
        tac.push_back(temp);
        sz = temp.size();
        int pos = temp.find("goto");
        string num = "";
```

```
    if (pos != -1)
    {
        for (int i = pos + 5; temp[i] <= '9' and temp[i] >= '0'; i++)
        {
            num += temp[i];
        }
        int n = stoi(num);
        leaders.insert(n);
        leaders.insert(curr_line + 1);
    }
    curr_line++;
}
curr_line--;
cout << "Leaders - \n";
for (auto i : leaders)
{
    if (i == curr_line + 1)
        leaders.erase(i);
    cout << i << " ";
}
cout << endl;
vector<pair<int, int>> blocks;
int p = -1;

for (int i : leaders)
{
    if (p != -1)
    {
        blocks.push_back({p, i - 1});
    }
    p = i;
}
blocks.push_back({p, curr_line});
// cout << "B1" << endl;
// cout << "-----------------" << endl;
int count = 1;
for (int i = 0; i < blocks.size(); i++)
{
    for (int j = blocks[i].first - 1; j < blocks[i].second; j++)
    {
        // cout << j + 1 << " " << tac[j] << endl;
    }
    // cout << "-----------------" << endl;
    count++;
    if (i < blocks.size() - 1)
    {
        // cout << endl
        //  << "B" << count << endl;
        // cout << "-----------------" << endl;
    }
```

```
}
count--;
vector<vector<int>> adj(count + 1, vector<int>(count + 1, 0));
vector<vector<int>> adjWithoutBackEdges(count + 1, vector<int>(count + 1, 0));
for (int i = 0; i < tac.size(); i++)
{
    if (leaders.find(i + 1 + 1) != leaders.end())
    {
        int po = tac[i].find("if");
        int go = tac[i].find("goto");
        int b = findblock(i + 1, blocks);
        if (po == -1 and go == -1)
        {
            adj[b][b + 1] = 1;
        }
        else if (po != -1 and go != -1)
        {
            adj[b][b + 1] = 1;
            string num = "";
            for (int j = go + 5; tac[i][j] <= '9' and tac[i][j] >= '0'; j++)
            {
                num += tac[i][j];
            }
            int n = stoi(num);
            int c = findblock(n - 1, blocks);
            adj[b][c + 1] = 1;
        }
        else if (go != -1 and po == -1)
        {
            string num = "";
            for (int j = go + 5; tac[i][j] <= '9' and tac[i][j] >= '0'; j++)
            {
                num += tac[i][j];
            }
            int n = stoi(num);
            int c = findblock(n - 1, blocks);
            adj[b][c + 1] = 1;
        }
    }
}
cout << "Displaying control flow graph -\n";
ofstream fout("adj.txt", ios::out);
fout << "adj" << endl;
for (int i = 1; i < adj.size(); i++)
{
    for (int j = 1; j < adj[i].size(); j++)
    {
        cout << adj[i][j] << " ";
        fout << adj[i][j] << " ";
        if (j >= i && adj[i][j] == 1)
```

```
        {
            adjWithoutBackEdges[i][j] = 1;
        }
    }
    cout << endl;
    fout << endl;
}
cout << "\nDisplaying contol flow graph without backward loops\n";
for (int i = 1; i <= count; i++)
{
    for (int j = 1; j <= count; j++)
    {
        cout << adjWithoutBackEdges[i][j] << " ";
    }
    cout << endl;
}

// vector<vector<int>> adj2 = {
//     {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0},
//     {0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0},
//     {0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1},
//     {0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0},
// };
// vector<vector<int>> adj3 = {
//     {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1},
//     {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
//     {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
// };
vector<int> indegree(count + 1);
vector<pair<int, int>> edges;
for (int i = 1; i < adjWithoutBackEdges.size(); i++)
{
    for (int j = 1; j < adjWithoutBackEdges[i].size(); j++)
    {
        if (adjWithoutBackEdges[i][j] == 1)
```

```
        {
            edges.push_back({i, j});
            indegree[j]++;
        }
    }
}
// cout << "\nDisplaying Indegree\n";
// for (int i = 1; i <= 10; i++)
// {
//     cout << i << " " << indegree[i] << " \n";
// }
unordered_map<int, int> parent;
parent[1] = -1;
for (int i = 1; i < adjWithoutBackEdges.size(); i++)
{
    for (int j = i; j < adjWithoutBackEdges[i].size(); j++)
    {
        if (adjWithoutBackEdges[i][j] == 1)
        {
            bool flag = true;
            if (parent.find(j) == parent.end())
            {
                parent[j] = i;
            }
            else
            {
                if (parent[j] > i)
                {
                    parent[j] = i;
                }
            }
        }
    }
}
// cout << "\nDisplaing map\n";
// for (auto &it : parent)
// {
//     cout << it.first << " " << it.second << "\n";
// }
unordered_map<int, set<int>> dom;
for (int i = 1; i <= count; i++)
{
    int temp = i;
    // cout << i << " - " << i << " , ";
    dom[i].insert(i);
    while (temp != -1)
    {
        if ((indegree[temp] <= 1 || parent[temp] == 1) && parent[temp] != -1)
        {
            // cout << parent[temp] << " , ";
```

```
                dom[i].insert(parent[temp]);
            }
            temp = parent[temp];
        }
        // cout << endl;
    }
    cout << "\nDisplaying dominator -\n";
    for (auto a : dom)
    {
        cout << a.first << " : {";
        for (auto b : a.second)
        {
            cout << b << " , ";
        }
        cout << " }\n";
    }
    return 0;
}
```

Output: -

```
Leaders -
1 5 9 13 14 23
Displaying control flow graph -
0 1 0 0 0 0
0 1 1 0 0 0
0 0 1 1 0 0
0 0 0 0 1 1
0 1 0 0 0 0
0 0 0 0 0 0
```

```
Displaying dominator -
6 : {1 , 3 , 4 , 6 ,  }
5 : {1 , 3 , 4 , 5 ,  }
1 : {1 ,  }
2 : {1 , 2 ,  }
3 : {1 , 3 ,  }
4 : {1 , 3 , 4 ,  }
PS F:\Whioo\Sem VI\Complier
```

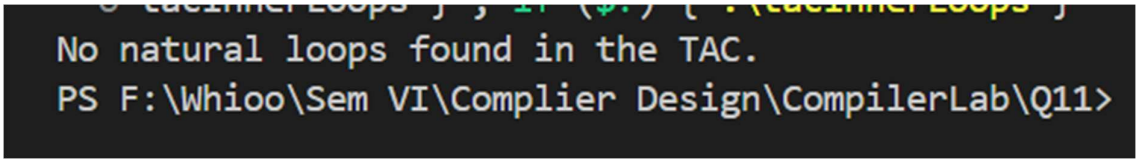
Program 11

Code: -

```
#include <iostream>
#include <fstream>
#include <vector>
#include <set>
#include <sstream>
using namespace std;
int getJumpTarget(const string &instruction, const vector<string> &tac)
{
    stringstream ss(instruction);
    string op, arg1, arg2;
    ss >> op >> arg1;
    if (op == "goto" || op == "if")
    {
        ss >> arg2;
        try
        {
            return stoi(arg2) - 1;
        }
        catch (const invalid_argument &e)
        {
        }
    }
    return -1;
}
vector<vector<int>> findNaturalLoops(vector<string> &tac)
{
    vector<vector<int>> loops;
    set<int> visited;
    for (int i = 0; i < tac.size(); ++i)
    {
        if (visited.count(i) == 0)
        {
            visited.insert(i);
            vector<int> potentialLoop(i);
            int j = getJumpTarget(tac[i], tac);
            while (j != -1 && visited.count(j) == 0)
            {
                visited.insert(j);
                potentialLoop.push_back(j);
                j = getJumpTarget(tac[j], tac);
            }
            if (
                j == i)
            {
                loops.push_back(potentialLoop);
            }
```

```
        }
    }
    return loops;
}
int main()
{
    string filename = "TAC.txt";
    ifstream inputFile(filename);
    if (!inputFile.is_open())
    {
        cerr << "Error: Could not open file " << filename << endl;
        return 1;
    }
    vector<string> tac;
    string line;
    while (getline(inputFile, line))
    {
        tac.push_back(line);
    }
    inputFile.close();
    vector<vector<int>> loops = findNaturalLoops(tac);
    if (loops.empty())
    {
        cout << "No natural loops found in the TAC." << endl;
    }
    else
    {
        cout << "Natural loops found:" << endl;
        for (const vector<int> &loop : loops)
        {
            cout << " - Instructions: ";
            for (int instruction : loop)
            {
                cout << instruction + 1 << " ";
            }
            cout << endl;
        }
    }
    return 0;
}
```

Output: -



Program 12

Code: -

```
#include <bits/stdc++.h>
#include <fstream>
#include <vector>
#include <set>
#include <string>
#include <algorithm>
#include <unordered_map>
using namespace std;

struct BasicBlock
{
  vector<string> instructions;
  unordered_set<string> genSet;
  unordered_set<string> killSet;
};

unordered_map<int, BasicBlock> basicBlocks;

void findLeaders(vector<int> &leaders)
{
  fstream myfile;
  myfile.open("tac_file.txt", ios::in);
  string line;
  int i = 1;
  while (getline(myfile, line))
  {
    size_t gotoPos = line.find("goto");
    if (gotoPos != string::npos)
    {
      leaders.push_back(stoi(line.substr(gotoPos + 6))); // Assuming the "goto"
keyword is followed by line number without space
      leaders.push_back(i + 1);
    }
    i++;
  }
  sort(leaders.begin(), leaders.end());
  auto uniqueEnd = unique(leaders.begin(), leaders.end());
  leaders.erase(uniqueEnd, leaders.end());
  sort(leaders.begin(), leaders.end());
  myfile.close();
}

void printBlocks(vector<int> &leaders)
```

```
{
  fstream myfile;
  myfile.open("tac_file.txt", ios::in);
  string line;
  int j = 0, i = 0;
  while (getline(myfile, line))
  {
    if (find(leaders.begin(), leaders.end(), j + 1) != leaders.end())
    {
      // cout << "\nBlock " << j + 1 << ":" << endl;
      ++i;
    }
    basicBlocks[i].instructions.push_back(line);
    // cout << j + 1 << ": " << line << endl;
    ++j;
  }
  myfile.close();
}

void computeGen()
{
  // Iterate over each basic block
  for (auto &block : basicBlocks)
  {
    BasicBlock &currentBlock = block.second;

    // Initialize GEN set for the block
    unordered_set<string> genSet;

    // Iterate over each instruction in the block
    for (const string &instruction : currentBlock.instructions)
    {
      // Extract defined variable
      size_t equalPos = instruction.find('=');
      if (equalPos != string::npos)
      {
        string definedVar = instruction.substr(0, equalPos);
        if (definedVar.find("if") != string::npos)
        {
          break;
        }
        // Add definedVar to GEN set
        genSet.insert(definedVar);
      }
    }
    // Update GEN set for the block
    currentBlock.genSet = genSet;
  }
}
```

```
void computeKill()
{
  // Iterate over each basic block
  for (auto &block : basicBlocks)
  {
    BasicBlock &currentBlock = block.second;

    // Iterate over each variable in the current block's GEN set
    for (const string &var : currentBlock.genSet)
    {
      // Check if the variable is defined in another block
      for (const auto &otherBlock : basicBlocks)
      {
        if (&otherBlock != &block)
        {
          const BasicBlock &other = otherBlock.second;
          if (other.genSet.find(var) != other.genSet.end())
          {
            // If the variable is defined in another block, add it to the KILL set
            currentBlock.killSet.insert(var);
            break;
          }
        }
      }
    }
  }
}

int main()
{
  vector<int> leaders = {1};
  findLeaders(leaders);
  cout << "Leaders:\n"
       << endl;
  for (int i = 0; i < leaders.size(); i++)
  {
    cout << leaders[i] << " ";
  }
  cout << endl;
  printBlocks(leaders);

  for (int i = 1; i <= basicBlocks.size(); ++i)
  {
    auto it = basicBlocks.find(i);
    if (it != basicBlocks.end())
    {
      cout << "\nBlock " << it->first << " Instructions:" << endl;
      cout << "---------------------\n";
      for (const auto &instruction : it->second.instructions)
      {
```

```
        cout << instruction << endl;
      }
    }
  }
  cout << endl;

  computeGen();
  computeKill();

  // Print GEN and KILL sets for each block
  for (int i = 1; i <= basicBlocks.size(); ++i)
  {
    auto it = basicBlocks.find(i);
    if (it != basicBlocks.end())
    {
      cout << "Block " << it->first << " GEN Set:";
      for (const string &var : it->second.genSet)
      {
        cout << " " << var;
      }
      cout << endl;

      cout << "Block " << it->first << " KILL Set:";
      for (const string &var : it->second.killSet)
      {
        cout << " " << var;
      }
      cout << endl
           << endl;
    }
  }
}
```

Output: -

```
Block 1 GEN Set: v t1 j i
Block 1 KILL Set: i j

Block 2 GEN Set: t2 t3 i
Block 2 KILL Set: i

Block 3 GEN Set: t5 t4 j
Block 3 KILL Set: j

Block 4 GEN Set:
Block 4 KILL Set:

Block 5 GEN Set: t10 a[t7] t9 t6 a[t10] x t7 t8
Block 5 KILL Set: x

Block 6 GEN Set: a[t12] t14 t11 a[t15] x t12 t15 t13
Block 6 KILL Set: x

PS F:\Whioo\Sem VI\Complier Design\CompilerLab\Q12>
```