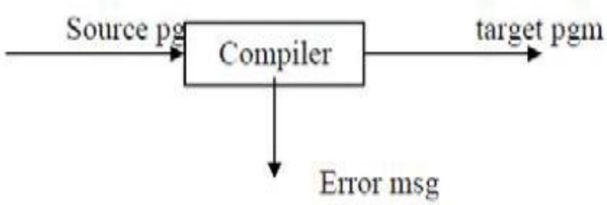
COMPILER

Compiler is a translator program that translates a program written in (HLL) the source program and translate it into an equivalent program in (MLL) the target program. As an important part of a compiler is error showing to the programmer.



STRUCTURE OF THE COMPILER DESIGN

Phases of a compiler: A compiler operates in phases. A phase is a logically interrelated operation that takes source program in one representation and produces output in another representation. The phases of a compiler are shown in below

There are two phases of compilation.

a. Analysis (Machine Independent/Language Dependent)

b. Synthesis(Machine Dependent/Language independent)

Compilation process is partitioned into no-of-sub processes called **'phases'**.

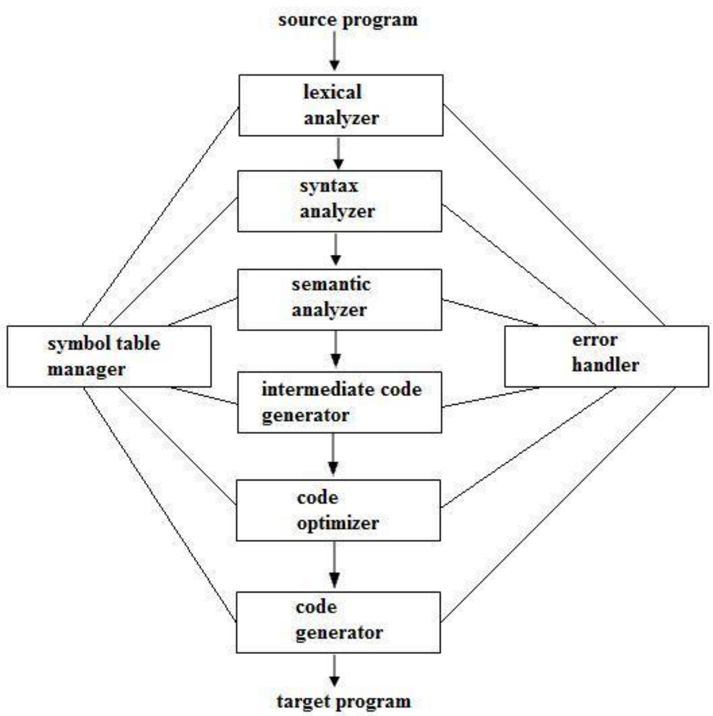


Fig 1.5 Phases of a compiler

Lexical Analysis:-

LA or Scanners reads the source program one character at a time, carving the source program into a sequence of automic units called **tokens.**

Syntax Analysis:-

The second stage of translation is called Syntax analysis or parsing. In this phase expressions, statements, declarations etc… are identified by using the results of lexical analysis. Syntax analysis is aided by using techniques based on formal grammar of the programming language.

Intermediate Code Generations:-

An intermediate representation of the final machine language code is produced. This phase bridges the analysis and synthesis phases of translation.

Code Optimization :-

This is optional phase described to improve the intermediate code so that the output runs faster and takes less space.

Code Generation:-

The last phase of translation is code generation. A number of optimizations to reduce the length of machine language program are carried out during this phase. The output of the code generator is the machine language program of the specified computer.

PROGRAM 1

Design and implement a lexical analyzer for given language using C and the lexical analyzer should ignore redundant spaces, tabs and new lines.

```
#include<stdio.h>
#include<string.h>

FILE  *fp;
int lineno=0;
char c;
char lexbuf[50],symtab[50][20];
int i=0,x;
char
kw[30][20]={"void","int","float","double","short","long","if","else","switch","case","break","ret
urn","main","static","goto"};
char delim[]={'(',')','{','}','[',']',';',','};
char oper[]={'+','=','-','*','/','<','>'};
int isdelim(char);
int isoper(char);
int iskw(char[]);
void main()
{
fp=fopen("sample.c","r");
c=getc(fp);
while(c!=EOF)
{
if(c==' '||c=='\t');
else if(c=='\n')
{
lineno++;
}
else if((x=isdelim(c))!=-1)
{
printf("%c\t\tDelimiter\n",c);
}
else if((x=isoper(c))!=-1)
{
printf("%c\t\tOperator\n",c);
}
else if(isdigit(c))
{
int b=0;
while(isdigit(c))
{
```

```
lexbuf[b++]=c;
c=getc(fp);
}
ungetc(c,fp);
lexbuf[b]='\0';
printf("%s\t\tDigit\n",lexbuf);
}
else if(isalpha(c))
{
int b=0,k;
while(isalpha(c)||isdigit(c)||c=='_')
{
lexbuf[b++]=c;
c=getc(fp);
}
ungetc(c,fp);
lexbuf[b]='\0';
if((!(lookup(lexbuf)))&&(!iskw(lexbuf)))
{
strcpy(symtab[i++],lexbuf);

}
if((k=iskw(lexbuf))!=0)
{
printf("%s\t\t Keyword\n",lexbuf);
}
else
{
printf("%s\t\tIdentifier\n",lexbuf);
}
}
c=getc(fp);
}
fclose(fp);
printf("\nNumber of lines=%d\n",lineno-1);
}
//Is delimiter
int isdelim(char d)
{
int k;
for(k=0;k<8;k++)
{
if(d==delim[k])
{
return k;
}
```

```
}
return -1;
}

//Is operator
int isoper(char op)
{
int k;
//printf("%c\n",op);
for(k=0;k<7;k++)
{
if(op==oper[k])
{
return k;
}

}
return -1;
}

int lookup(char s[])
{
int k;
for(k=0;k<i;k++)
{
if((strcmp(s,symtab[k]))==0)
{
return k+1;
}
return 0;
}
}
int iskw(char s[])
{
int k;
for(k=0;k<15;k++)
{
if(strcmp(s,kw[k])==0)
return k+1;
}
return 0;
}
```

PROGRAM 2

Implementation of Lexical Analyzer using Lex Tool

Structure of Lex Programs

A lex program has the following form:
Declarations
%%
Translation rules
%%
Auxiliary functions
Each section is divided with %%

Declaration Section

It includes declaration of variables used in the code segment and regular definitions .Variable declarations are specified within %{ and %}.

Translation rules

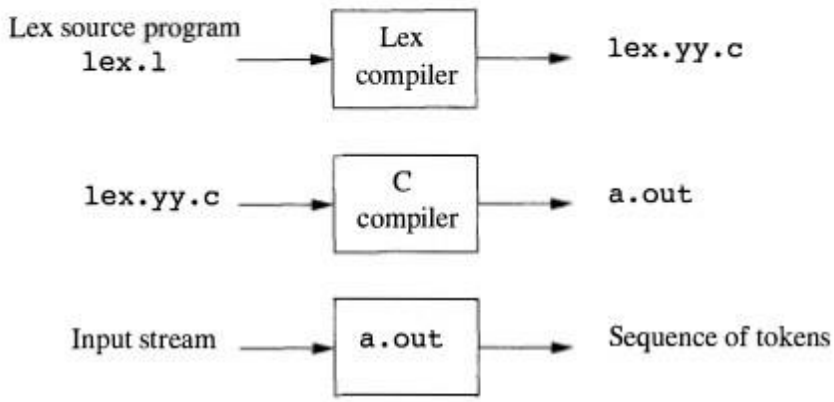
Translation rules each have the form
{Pattern} Action
Each pattern is a regular expression, which may use the regular definitions of the declaration section.

Auxiliary functions

It holds whatever additional functions are used in the actions. The lexical analyzer created by Lex behaves in concert with the parser .When called by the parser; the lexical analyzer begins reading its remaining input, one character at a time, until it finds the longest prefix of the input that matches one of the patterns Pi. It then executes the associated action Ai. The lexical analyzer returns a single value, t he token name to the parser, but uses the shared variable yylavl to pass additional information about the lexeme found, if needed.

LEX-Lexical Analyzer Generator

Lex is a program generator designed for lexical processing of character input streams. It accepts a high-level, problem oriented specification for character string matching, and produces a program in a general purpose language which recognizes regular expressions. The regular expressions are specified by the user in the source specifications given to Lex. The Lex written code recognizes these expressions in an input stream and partitions the input stream into strings matching the expressions .An input file, which we call lex.l, is written in the Lex language and describes the lexical analyzer to be generated. The Lex compiler transforms lex.l to a C program, in a file that is always named lex.yy.c. The latter file is compiled by the C compiler into a file called a.out, as always. The C-compiler output is a working lexical analyzer



Lex program to count the number of characters in a file.

```
%{
int c=0;
%}
%%
[A-Za-z] c++;
. ;
%%
int main()
{
yyin=fopen("b.c","r");
yylex();
printf("count is %d\n",c);
}
int yywrap()
{
return 1;
}
```

Lex program to count the digits in a file.

```
%{
int c=0;
%}
digit [0-9]

%%
{digit} c++;
. ;
%%
int main()
{
yyin=fopen("b.c","r");
```

```
yylex();
printf("count is %d\n",c);
}
int yywrap()
{
return 1;
}
```

Lex program to count number of a’s in a program

```
%{
int c=0,d=0;
%}
digit [0-9]

%%
a c++;
. ;
%%
int main()
{
yyin=fopen("b.c","r");
yylex();
printf("count is %d\n",c);
}
int yywrap()
{
return 1;
}
```

```
%{
int negative=0;
int positive=0;
int positivefraction=0;
%}
%%
[-][0-9]+ {negative=negative+1;}
[+][0-9]+ {positive=positive+1;}
[+][0-9]+[.][0-9]+ {positivefraction=positivefraction+1;}
. ;
%%
int main()
{
yyin=fopen("b.c","r");
```

```
yylex();
printf("count of negative no  is %d\n",negative);
printf("count of positive no  is %d\n",positive);
printf("count of positive fraction is %d\n",positivefraction);
}
int yywrap()
{
return 1;
}
```

Lex program to remove comment line

```
%{
int c=0;
%}


%%
\/\/.* ;
%%
int main()
{
yyin=fopen("b.c","r");
yyout=fopen("c.c","w");
yylex();
}
int yywrap()
{
return 1;
}
```

Lex program to count the number of identifier.

```
%{
int c=0;
%}

%%
[a-z_][a-z_0-9]* {c=c+1;}
.|\n ;
%%
int main()
{
yyin=fopen("b.c","r");
yylex();
printf("count is %d\n",c);
}
```

```
int yywrap()
{
return 1;
}
```

Yacc Yet Another Compiler Compiler(Parser Generator)

Syntax

```
... definitions ...
%%
... rules ...
%%
... subroutines ...
```

Input to yacc is divided into three sections. The definitions section consists of token declarations and C code bracketed by “ %{ “ and “ %} ”. The BNF grammar is placed in the rules section and user subroutines are added in the subroutines section.

```
%{
        //Header file
        //variable declarations
%}

%left            //for left - associative

%right // right associative
%token token_name //defining token

Eg.
%token NUMBER
%left    '+' '-'

%%
        // Grammar for example  expr: expr '+' expr { $$ = $1 + $3; }
                                 |
                                 expr '*' expr { $$ = $1 * $3; }
                                 ;
```

// “$1” for the first term on the right - hand side of the production, “$2 ” for the second, and so on. “$$” designates the top of the stack after reduction has taken place.

%%

E -> E + E
E -> E * E

E -> id

Three productions have been specified. Terms that appear on the left - hand side (LHS) of a production, such as E (expression) are nonterminals. Terms such as id (identifier) are terminals (tokens returned by lex) and only appear on the right - hand side (RHS) of a production. This grammar specifies that an expression may be the sum of two expressions, the product of two expressions, or an identifier.

Lex includes this file and utilizes the definitions for token values. To obtain tokens yacc calls yylex. Function yylex has a return type of int that returns a token. Values associated with the token are returned by lex in variable yylval.
For example,

```
[0-9]+ {yylval = atoi(yytext);
        return INTEGER;
        }
```

would store the value of the integer in yylval, and return token INTEGER to yacc.

Internally yacc maintains two stacks in memory; a parse stack and a value stack. Theparse stack contains terminals and nonterminals that represent the current parsing state. The value stack is an array of YYSTYPE elements and associates a value yylval with each element in the parse stack. For example when lex returns an INTEGER token yacc shifts this token to the parse stack. At the same time the corresponding yylval is shifted to the value stack. The parse and value stacks are always synchronized so finding a value related to a token on the stack is easily accomplished.

When we apply the rule **expr: expr '+' expr { $$ = $1 + $3; }.**We replace the right-hand side of the production in the parse stack with the lef-hand side of the same production. In this case pop "expr '+' expr" and push "expr". We have reduced the stack by popping three terms off the stack nd pushing back one term. We may reference positions in the value stack in our C code by specifying "$1" for the first term on the right - hand side of the production, "$2 " for the second, and so on. "$$" designates the top of the stack after reduction has taken place. The above action adds the value associated with two expressions, pops three terms off the value stack, and pushes back a single sum. As a conse quence the parse and value stacks remain synchronized.

PROGRAM 3

Generate YACC specification for a few syntactic categories.
a) Implementation of Calculator using LEX and YACC
calculator.y

```
%{
#include <stdio.h>
//extern FILE *yyin;
%}
%token NUMBER
%start S
%%

S       : E                   { printf("Expression_value= %d\n", $1); }
          ;
E       : E '+' NUMBER          { $$ = $1 + $3;
                              printf ("Recognized '+' expression.\n");
                              }
          | E '-' NUMBER        { $$ = $1 - $3;
                              printf ("Recognized '-' expression.\n");
                              }
          | E '*' NUMBER { $$ = $1 * $3;
                              printf ("Recognized '*' expression.\n");
                              }
          | E '/' NUMBER { if($3==0)
                              {
                              printf("Cannot divide by 0");
                              break;
                              }
                              else
                              $$ = $1 / $3;
                              printf ("Recognized '/' expression.\n");

                            }
          | NUMBER      { $$ = $1;
                              printf ("Recognized a number.\n");
                              }
          ;
%%
int main ()
          {
          //yyin=fopen("s.txt","r");
          do
          {printf("Enter the expression\n");
           yyparse();
```

```
        }while(1);
        return 1;

        }

int yyerror (char *msg)
        {
                printf("Invalid Expression\n");
        }
yywrap()
{
  return(1);
}
```

calculator.l

```
%{
#include "y.tab.h"
extern int yylval;
%}
%%
[0-9]+  { yylval = atoi (yytext);
        printf ("scanned the number %d\n", yylval);
        return NUMBER; }
[ \t]   { printf ("skipped whitespace\n"); }
\n      { printf ("reached end of line\n");
        return 0;
        }
.       { printf ("found other data \"%s\"\n", yytext);
        return yytext[0];
        /* so yacc can see things like '+', '-', and '=' */
        }
%%
```

How to run

```
yacc -d calculator.y
lex calculator.l
gcc y.tab.c lex.yy.c
./a.out
```

b.Program to recognize a valid variable which starts with a letter followed by any number of letters or digits

valid.y

```
%{
#include<stdio.h>
#include<stdlib.h>
%}
%token DIGIT LETTER
%start S
%%

S        : variable    { printf("Valid Variable\n"); }
   ;
variable         : LETTER alphanumeric
         ;

alphanumeric :LETTER alphanumeric
         |DIGIT alphanumeric
         |LETTER
         |DIGIT
         ;
%%
int main ()
   {
   do
   {printf("Enter the expression\n");
    yyparse();
   }while(1);
   return 1;

   }

int yyerror (char *msg)
   {
         printf("Invalid Expression\n");
   }
yywrap()
{
 return(1);
}
```

valid.l

```
%{
#include "y.tab.h"
extern int yylval;
```

```
%}
%%
[a-zA-Z] {return LETTER;}
[0-9] {return DIGIT;}
\n    { printf ("reached end of line\n");
   return 0;
   }
.    { printf ("found other data \"%s\"\n", yytext);
   return yytext[0];
   /* so yacc can see things like '+', '-', and '=' */
   }
```

c.Program to recognize a valid arithmetic expression that uses operator +,-,*and /

```
arithmetic.y
%{
#include<stdio.h>
%}
%token ID NUMBER
%left '+' '-'
%left '*' '/'
%%
stmt:expr {printf("valid Expression\n");}
         ;
expr: expr '+' expr
         | expr '-' expr
         | expr '*' expr
         | expr '/' expr
         | '(' expr ')'
         | NUMBER
         | ID
         ;
%%
int main ()
   {
   do
   {printf("Enter the expression\n");
    yyparse();
   }while(1);
   return 1;

   }

int yyerror (char *msg)
   {
```

```
            printf("Invalid Expression\n");
    }
yywrap()
{
  return(1);
}
```

arithmetic.l

```
%{
#include "y.tab.h"
extern int yylval;
%}
%%
[a-zA-Z] {return ID;}
[0-9] {return NUMBER;}
\n    { printf ("reached end of line\n");
    return 0;
    }
.    { printf ("found other data \"%s\"\n", yytext);
    return yytext[0];
    /* so yacc can see things like '+', '-', and '=' */
    }
```

PROGRAM 4

Find ε – closure of all states of any given NFA with ε transition.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#define MAX_LEN 100

char NFA_FILE[MAX_LEN];
char buffer[MAX_LEN];
int zz = 0;

// Structure to store DFA states and their
// status ( i.e new entry or already present)
struct DFA {
  char *states;
  int count;
} dfa;

int last_index = 0;
FILE *fp;
int symbols;

/* reset the hash map*/
void reset(int ar[], int size) {
  int i;

  // reset all the values of
  // the mapping array to zero
  for (i = 0; i < size; i++) {
    ar[i] = 0;
  }
}

// Check which States are present in the e-closure

/* map the states of NFA to a hash set*/
void check(int ar[], char S[]) {
  int i, j;

  // To parse the individual states of NFA
  int len = strlen(S);
  for (i = 0; i < len; i++) {

    // Set hash map for the position
    // of the states which is found
```

```
    j = ((int)(S[i]) - 65);
    ar[j]++;
  }
}

// To find new Closure States
void state(int ar[], int size, char S[]) {
  int j, k = 0;

  // Combine multiple states of NFA
  // to create new states of DFA
  for (j = 0; j < size; j++) {
    if (ar[j] != 0)
      S[k++] = (char)(65 + j);
  }

  // mark the end of the state
  S[k] = '\0';
}

// To pick the next closure from closure set
int closure(int ar[], int size) {
  int i;

  // check new closure is present or not
  for (i = 0; i < size; i++) {
    if (ar[i] == 1)
      return i;
  }
  return (100);
}

// Check new DFA states can be
// entered in DFA table or not
int indexing(struct DFA *dfa) {
  int i;

  for (i = 0; i < last_index; i++) {
    if (dfa[i].count == 0)
      return 1;
  }
  return -1;
}

/* To Display epsilon closure*/
void Display_closure(int states, int closure_ar[],
```

```
                    char *closure_table[],
                    char *NFA_TABLE[][symbols + 1],
                    char *DFA_TABLE[][symbols]) {
  int i;
  for (i = 0; i < states; i++) {
    reset(closure_ar, states);
    closure_ar[i] = 2;

    // to neglect blank entry
    if (strcmp(&NFA_TABLE[i][symbols], "-") != 0) {

      // copy the NFA transition state to buffer
      strcpy(buffer, &NFA_TABLE[i][symbols]);
      check(closure_ar, buffer);
      int z = closure(closure_ar, states);

      // till closure get completely saturated
      while (z != 100)
      {
        if (strcmp(&NFA_TABLE[z][symbols], "-") != 0) {
          strcpy(buffer, &NFA_TABLE[z][symbols]);

          // call the check function
          check(closure_ar, buffer);
        }
        closure_ar[z]++;
        z = closure(closure_ar, states);
      }
    }

    // print the e closure for every states of NFA
    printf("\n e-Closure (%c) :\t", (char)(65 + i));

    bzero((void *)buffer, MAX_LEN);
    state(closure_ar, states, buffer);
    strcpy(&closure_table[i], buffer);
    printf("%s\n", &closure_table[i]);
  }
}

/* To check New States in DFA */
int new_states(struct DFA *dfa, char S[]) {

  int i;

  // To check the current state is already
```

```
  // being used as a DFA state or not in
  // DFA transition table
  for (i = 0; i < last_index; i++) {
    if (strcmp(&dfa[i].states, S) == 0)
      return 0;
  }

  // push the new
  strcpy(&dfa[last_index++].states, S);

  // set the count for new states entered
  // to zero
  dfa[last_index - 1].count = 0;
  return 1;
}

// Transition function from NFA to DFA
// (generally union of closure operation )
void trans(char S[], int M, char *clsr_t[], int st,
               char *NFT[][symbols + 1], char TB[]) {
  int len = strlen(S);
  int i, j, k, g;
  int arr[st];
  int sz;
  reset(arr, st);
  char temp[MAX_LEN], temp2[MAX_LEN];
  char *buff;

  // Transition function from NFA to DFA
  for (i = 0; i < len; i++) {

    j = ((int)(S[i] - 65));
    strcpy(temp, &NFT[j][M]);

    if (strcmp(temp, "-") != 0) {
      sz = strlen(temp);
      g = 0;

      while (g < sz) {
        k = ((int)(temp[g] - 65));
        strcpy(temp2, &clsr_t[k]);
        check(arr, temp2);
        g++;
      }
    }
  }
```

```
  bzero((void *)temp, MAX_LEN);
  state(arr, st, temp);
  if (temp[0] != '\0') {
    strcpy(TB, temp);
  } else
    strcpy(TB, "-");
}

/* Display DFA transition state table*/
void Display_DFA(int last_index, struct DFA *dfa_states,
                 char *DFA_TABLE[][symbols]) {
  int i, j;
  printf("\n\n****************************************************************\n\n");
  printf("\t\t DFA TRANSITION STATE TABLE \t\t \n\n");
  printf("\n STATES OF DFA :\t\t");

  for (i = 1; i < last_index; i++)
    printf("%s, ", &dfa_states[i].states);
  printf("\n");
  printf("\n GIVEN SYMBOLS FOR DFA: \t");

  for (i = 0; i < symbols; i++)
    printf("%d, ", i);
  printf("\n\n");
  printf("STATES\t");

  for (i = 0; i < symbols; i++)
    printf("|%d\t", i);
  printf("\n");

  // display the DFA transition state table
  printf("--------+-----------------------\n");
  for (i = 0; i < zz; i++) {
    printf("%s\t", &dfa_states[i + 1].states);
    for (j = 0; j < symbols; j++) {
      printf("|%s \t", &DFA_TABLE[i][j]);
    }
    printf("\n");
  }
}

// Driver Code
int main() {
  int i, j, states;
  char T_buf[MAX_LEN];
```

```
// creating an array dfa structures
struct DFA *dfa_states = malloc(MAX_LEN * (sizeof(dfa)));
states = 6, symbols = 2;

printf("\n STATES OF NFA :\t\t");
for (i = 0; i < states; i++)

  printf("%c, ", (char)(65 + i));
printf("\n");
printf("\n GIVEN SYMBOLS FOR NFA: \t");

for (i = 0; i < symbols; i++)

  printf("%d, ", i);
printf("eps");
printf("\n\n");
char *NFA_TABLE[states][symbols + 1];

// Hard coded input for NFA table
char *DFA_TABLE[MAX_LEN][symbols];
strcpy(&NFA_TABLE[0][0], "FC");
strcpy(&NFA_TABLE[0][1], "-");
strcpy(&NFA_TABLE[0][2], "BF");
strcpy(&NFA_TABLE[1][0], "-");
strcpy(&NFA_TABLE[1][1], "C");
strcpy(&NFA_TABLE[1][2], "-");
strcpy(&NFA_TABLE[2][0], "-");
strcpy(&NFA_TABLE[2][1], "-");
strcpy(&NFA_TABLE[2][2], "D");
strcpy(&NFA_TABLE[3][0], "E");
strcpy(&NFA_TABLE[3][1], "A");
strcpy(&NFA_TABLE[3][2], "-");
strcpy(&NFA_TABLE[4][0], "A");
strcpy(&NFA_TABLE[4][1], "-");
strcpy(&NFA_TABLE[4][2], "BF");
strcpy(&NFA_TABLE[5][0], "-");
strcpy(&NFA_TABLE[5][1], "-");
strcpy(&NFA_TABLE[5][2], "-");
printf("\n NFA STATE TRANSITION TABLE \n\n\n");
printf("STATES\t");

for (i = 0; i < symbols; i++)
  printf("|%d\t", i);
printf("eps\n");
```

```
  // Displaying the matrix of NFA transition table
  printf("--------+-----------------------------------\n");
  for (i = 0; i < states; i++) {
    printf("%c\t", (char)(65 + i));

    for (j = 0; j <= symbols; j++) {
      printf("|%s \t", &NFA_TABLE[i][j]);
    }
    printf("\n");
  }
  int closure_ar[states];
  char *closure_table[states];

  Display_closure(states, closure_ar, closure_table, NFA_TABLE, DFA_TABLE);
  strcpy(&dfa_states[last_index++].states, "-");

  dfa_states[last_index - 1].count = 1;
  bzero((void *)buffer, MAX_LEN);

  strcpy(buffer, &closure_table[0]);
  strcpy(&dfa_states[last_index++].states, buffer);

  int Sm = 1, ind = 1;
  int start_index = 1;

}
```

OUTPUT

```
STATES OF NFA :              A, B, C, D, E, F,

 GIVEN SYMBOLS FOR NFA:       0, 1, eps


 NFA STATE TRANSITION TABLE


STATES          |0        |1        eps
--------+-----------------------------------
A        |FC      |-        |BF
B        |-       |C        |-
C        |-       |-        |D
D        |E       |A        |-
E        |A       |-        |BF
F        |-       |-        |-
```

e-Closure (A) :	ABF
e-Closure (B) :	B
e-Closure (C) :	CD
e-Closure (D) :	D
e-Closure (E) :	BEF
e-Closure (F) :	F

PROGRAM 5

Develop a program to convert NFA to DFA

PROGRAM LOGIC:

Step 1 : Take ∈ closure for the beginning state of NFA as beginning state of DFA.

Step 2 : Find the states that can be traversed from the present for each input symbol (union of transition value and their closures for each states of NFA present in current state of DFA).

Step 3 : If any new state is found take it as current state and repeat step 2.

Step 4 : Do repeat Step 2 and Step 3 until no new state present in DFA transition table.

Step 5 : Mark the states of DFA which contains final state of NFA as final states of DFA.

PROGRAM

```
// C Program to illustrate how to convert e-nfa to DFA

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#define MAX_LEN 100

char NFA_FILE[MAX_LEN];
char buffer[MAX_LEN];
int zz = 0;
// Structure to store DFA states and their
// status ( i.e new entry or already present)
struct DFA {
char *states;
int count;
} dfa;
int last_index = 0;
FILE *fp;
```

```
int symbols;

/* reset the hash map*/
void reset(int ar[], int size) {
int i;
// reset all the values of
// the mapping array to zero
for (i = 0; i < size; i++) {
	ar[i] = 0;
}
}
// Check which States are present in the e-closure
/* map the states of NFA to a hash set*/
void check(int ar[], char S[]) {
int i, j;
// To parse the individual states of NFA
int len = strlen(S);
for (i = 0; i < len; i++) {
	// Set hash map for the position
	// of the states which is found
	j = ((int)(S[i]) - 65);
	ar[j]++;
}
}
// To find new Closure States
void state(int ar[], int size, char S[]) {
int j, k = 0;
// Combine multiple states of NFA
// to create new states of DFA
for (j = 0; j < size; j++) {
	if (ar[j] != 0)
```

```
        S[k++] = (char)(65 + j);
}
// mark the end of the state
S[k] = '\0';
}
// To pick the next closure from closure set
int closure(int ar[], int size) {
int i;
// check new closure is present or not
for (i = 0; i < size; i++) {
        if (ar[i] == 1)
        return i;
}
return (100);
}
// Check new DFA states can be
// entered in DFA table or not
int indexing(struct DFA *dfa) {
int i;
for (i = 0; i < last_index; i++) {
        if (dfa[i].count == 0)
        return 1;
}
return -1;
}
/* To Display epsilon closure*/
void Display_closure(int states, int closure_ar[],
                        char *closure_table[],
                        char *NFA_TABLE[][symbols + 1],
                        char *DFA_TABLE[][symbols]) {
int i;
```

```
for (i = 0; i < states; i++) {
        reset(closure_ar, states);
        closure_ar[i] = 2;
        // to neglect blank entry
        if (strcmp(&NFA_TABLE[i][symbols], "-") != 0) {
        // copy the NFA transition state to buffer
        strcpy(buffer, &NFA_TABLE[i][symbols]);
        check(closure_ar, buffer);
        int z = closure(closure_ar, states);

        // till closure get completely saturated
        while (z != 100)
        {
                if (strcmp(&NFA_TABLE[z][symbols], "-") != 0) {
                strcpy(buffer, &NFA_TABLE[z][symbols]);
                // call the check function
                check(closure_ar, buffer);
                }
                closure_ar[z]++;
                z = closure(closure_ar, states);
        }
        }
        // print the e closure for every states of NFA
        printf("\n e-Closure (%c) :\t", (char)(65 + i));
        bzero((void *)buffer, MAX_LEN);
        state(closure_ar, states, buffer);
        strcpy(&closure_table[i], buffer);
        printf("%s\n", &closure_table[i]);
}
}
/* To check New States in DFA */
```

```
int new_states(struct DFA *dfa, char S[]) {
int i;
// To check the current state is already
// being used as a DFA state or not in
// DFA transition table
for (i = 0; i < last_index; i++) {
	if (strcmp(&dfa[i].states, S) == 0)
	return 0;
}
// push the new
strcpy(&dfa[last_index++].states, S);
// set the count for new states entered
// to zero
dfa[last_index - 1].count = 0;
return 1;
}
// Transition function from NFA to DFA
// (generally union of closure operation )
void trans(char S[], int M, char *clsr_t[], int st,
				char *NFT[][symbols + 1], char TB[]) {
int len = strlen(S);
int i, j, k, g;
int arr[st];
int sz;
reset(arr, st);
char temp[MAX_LEN], temp2[MAX_LEN];
char *buff;
// Transition function from NFA to DFA
for (i = 0; i < len; i++) {
	j = ((int)(S[i] - 65));
	strcpy(temp, &NFT[j][M]);
```

```
            if (strcmp(temp, "-") != 0) {
            sz = strlen(temp);
            g = 0;
            while (g < sz) {
                        k = ((int)(temp[g] - 65));
                        strcpy(temp2, &clsr_t[k]);
                        check(arr, temp2);
                        g++;
            }
            }
}
bzero((void *)temp, MAX_LEN);
state(arr, st, temp);
if (temp[0] != '\0') {
            strcpy(TB, temp);
} else
            strcpy(TB, "-");
}
/* Display DFA transition state table*/
void Display_DFA(int last_index, struct DFA *dfa_states,
                                                char *DFA_TABLE[][symbols]) {
int i, j;
printf("\n\n************************************************************\n\n");
printf("\t\t DFA TRANSITION STATE TABLE \t\t \n\n");
printf("\n STATES OF DFA :\t\t");
for (i = 1; i < last_index; i++)
            printf("%s, ", &dfa_states[i].states);
printf("\n");
printf("\n GIVEN SYMBOLS FOR DFA: \t");
for (i = 0; i < symbols; i++)
            printf("%d, ", i);
```

```
printf("\n\n");
printf("STATES\t");
for (i = 0; i < symbols; i++)
	printf("|%d\t", i);
printf("\n");
// display the DFA transition state table
printf("--------+-----------------------\n");
for (i = 0; i < zz; i++) {
	printf("%s\t", &dfa_states[i + 1].states);
	for (j = 0; j < symbols; j++) {
	printf("|%s \t", &DFA_TABLE[i][j]);
	}
	printf("\n");
}
}
// Driver Code
int main() {
int i, j, states;
char T_buf[MAX_LEN];
// creating an array dfa structures
struct DFA *dfa_states = malloc(MAX_LEN * (sizeof(dfa)));
states = 6, symbols = 2;
printf("\n STATES OF NFA :\t\t");
for (i = 0; i < states; i++)
	printf("%c, ", (char)(65 + i));
printf("\n");
printf("\n GIVEN SYMBOLS FOR NFA: \t");
for (i = 0; i < symbols; i++)
	printf("%d, ", i);
printf("eps");
printf("\n\n");
```

```
char *NFA_TABLE[states][symbols + 1];
// Hard coded input for NFA table
char *DFA_TABLE[MAX_LEN][symbols];
strcpy(&NFA_TABLE[0][0], "FC");
strcpy(&NFA_TABLE[0][1], "-");
strcpy(&NFA_TABLE[0][2], "BF");
strcpy(&NFA_TABLE[1][0], "-");
strcpy(&NFA_TABLE[1][1], "C");
strcpy(&NFA_TABLE[1][2], "-");
strcpy(&NFA_TABLE[2][0], "-");
strcpy(&NFA_TABLE[2][1], "-");
strcpy(&NFA_TABLE[2][2], "D");
strcpy(&NFA_TABLE[3][0], "E");
strcpy(&NFA_TABLE[3][1], "A");
strcpy(&NFA_TABLE[3][2], "-");
strcpy(&NFA_TABLE[4][0], "A");
strcpy(&NFA_TABLE[4][1], "-");
strcpy(&NFA_TABLE[4][2], "BF");
strcpy(&NFA_TABLE[5][0], "-");
strcpy(&NFA_TABLE[5][1], "-");
strcpy(&NFA_TABLE[5][2], "-");
printf("\n NFA STATE TRANSITION TABLE \n\n\n");
printf("STATES\t");
for (i = 0; i < symbols; i++)
        printf("|%d\t", i);
printf("eps\n");
// Displaying the matrix of NFA transition table
printf("--------+------------------------------------\n");
for (i = 0; i < states; i++) {
        printf("%c\t", (char)(65 + i));
        for (j = 0; j <= symbols; j++) {
```

```
            printf("|%s \t", &NFA_TABLE[i][j]);
            }
            printf("\n");
}
int closure_ar[states];
char *closure_table[states];
Display_closure(states, closure_ar, closure_table, NFA_TABLE, DFA_TABLE);
strcpy(&dfa_states[last_index++].states, "-");
dfa_states[last_index - 1].count = 1;
bzero((void *)buffer, MAX_LEN);
strcpy(buffer, &closure_table[0]);
strcpy(&dfa_states[last_index++].states, buffer);
int Sm = 1, ind = 1;
int start_index = 1;
// Filling up the DFA table with transition values
// Till new states can be entered in DFA table
while (ind != -1) {
            dfa_states[start_index].count = 1;
            Sm = 0;
            for (i = 0; i < symbols; i++) {
            trans(buffer, i, closure_table, states, NFA_TABLE, T_buf);
            // storing the new DFA state in buffer
            strcpy(&DFA_TABLE[zz][i], T_buf);
            // parameter to control new states
            Sm = Sm + new_states(dfa_states, T_buf);
            }
            ind = indexing(dfa_states);
            if (ind != -1)
            strcpy(buffer, &dfa_states[++start_index].states);
            zz++;
}
```

```
// display the DFA TABLE
Display_DFA(last_index, dfa_states, DFA_TABLE);
return 0;
}
```

OUTPUT

```
STATES OF NFA :        A, B, C, D, E, F,

 GIVEN SYMBOLS FOR NFA:     0, 1, eps

 NFA STATE TRANSITION TABLE


STATES    |0    |1    eps

--------+------------------------------------

A    |FC     |-     |BF

B    |-     |C     |-

C    |-     |-     |D

D    |E     |A     |-

E    |A     |-     |BF

F    |-     |-     |-

 e-Closure (A) :    ABF

e-Closure (B) :    B

 e-Closure (C) :    CD

 e-Closure (D) :    D

 e-Closure (E) :    BEF

 e-Closure (F) :    F

********************************************************

        DFA TRANSITION STATE TABLE
```

STATES OF DFA : ABF, CDF, CD, BEF,

GIVEN SYMBOLS FOR DFA: 0, 1,

```
STATES   |0    |1
--------+----------------------
ABF   |CDF    |CD
CDF   |BEF    |ABF
CD    |BEF    |ABF
BEF   |ABF    |CD
```

PROGRAM 6

Develop a program to minimize any given DFA.

PROGRAM LOGIC:

Given a deterministic finite state machine A = (T, Q, R, q0, F), this program constructs an equivalent reduced deterministic finite state machine A' = (T, Q', R', q'0, F') as follows:

- Remove all unreachable states from Q (using DFS).
- Construct the states Q' as a partition of states of Q by successive refinement. Initially let there be two groups, F and Q - F. Sets are represents are bitsets in C for efficiency.
- For each group G in Q', partition G into subgroups such that two states q, r of G are in the same subgroup if and only if for all t in T, states q and r have transitions on t to states in the same group of Q', or both don't have transitions on t.
- Replace group G with its subgroups and repeat last step until no group is further refined.

PROGRAM

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int **transitionMap; // 2D array which is used to store state transitions. transitionMap[i][j] is the state reached when state i is given symbol j
int **partitionTransitionMap; // same as transitionMap, except row indices represent partition numbers, not state numbers
int startState; // The starting state. This is used as the root for DFS to eliminate unreachable states
long int reachable; // A bitset to represent states that are reachable
long int allStates; // A bitset to represent all states in the FSM
long int finalStates; // A bitset to represent final states in the FSM
long int nonFinalStates; // A bitset to represent non-final states in the FSM
long int *P; // array of partitions. Each partition is a bitset of states
void dfs(int v)
{
```

```
	reachable |= (1 << v);
	// Try exploring all paths..
	for(int i=0; i<26; i++)
		if((transitionMap[v][i] != -1) && ((reachable & (1 << transitionMap[v][i])) ==
0))
		{
			dfs(transitionMap[v][i]);
		}
}
int main(){
	// We start off with no states
	finalStates = 0;
	allStates = 0;
// Initialize our transition maps. We set transition[i][j] to be -1 in order to indicate that
state/partition i does not transition when given symbol j
	transitionMap = (int**)malloc(64*sizeof(int*));
	for (int i = 0; i < 64; i++){
		transitionMap[i] = (int*) malloc(26*sizeof(int));
		for (int j = 0; j < 26; j++){
			transitionMap[i][j] = -1;
		}
	}
	partitionTransitionMap = (int**)malloc(64*sizeof(int*));
	for (int i = 0; i < 64; i++){
		partitionTransitionMap[i] = (int*) malloc(26*sizeof(int));
		for (int j = 0; j < 26; j++){
			partitionTransitionMap[i][j] = -1;
		}
	}
	// read start state
	char buff[125];
```

```
fgets(buff, sizeof(buff), stdin);
char *p = strtok(buff, " ");
startState = atoi(p);
// read final states
fgets(buff, sizeof(buff), stdin);
p = strtok(buff, " ");
while (p != NULL)
{
        int state = atoi(p);
        finalStates |= 1 << (state);
        p = strtok(NULL, " ");
}
// read transitions
int from;
char symbol;
int to;
while (fscanf(stdin, "%d %c %d", &from, &symbol, &to) != EOF) {
        transitionMap[from][symbol-'a'] = to; // add transition
        // add from and to states to the allStates bitset
        allStates |= (1 << from);
        allStates |= (1 << to);
}
// initialize reachable bitset to 0 and run dfs to determine reachable states
reachable = 0;
dfs(startState);
// filter unreachable states
allStates &= reachable;
finalStates &= reachable;
// initialize array of partitions to include empty bitsets
P =  (long int*) malloc(64*sizeof(long int));
for (int i = 0; i < 64 ; i++){
```

```
        P[i] = 0; // no partition exists
    }
    // P should include two partitions to start: final states and non-final states
    nonFinalStates = allStates & ~finalStates;
    P[0] = finalStates;
    P[1] = nonFinalStates;
    int nextPartitionIndex = 2; // Store how many partitions have been added already
// There will be at most 64 partitions. At each iteration, we operate on a partition and add at most 1 more partition
    for (int i = 0; i < 64; i++){
// A bitset for a new partition. This partition will include all states that are distinct from the state corresponding to the leftmost bit in P[i]
        long int newPartition = 0;
        // Done partitioning
        if (P[i] == 0){
            break;
        }

// Try to find leftmost bit in the bitset. This loop will only run to its entirety once when that bit is found
        for (int j = 63; j >=  0; j--) {
            // Potential leftmost bit. If found, this bit will remain in the bit set.
            long int staticState = (long int) 1 << j;
            // Check if this state is in the current bitset
            if ((P[i] & (staticState)) != 0){
// The lestmost bit state will be associated with this partition. Therefore, we must copy over the transitions for this state to the transitions for
                // the corresponding partition
                partitionTransitionMap[i] = transitionMap[j];
                // Check for states that should be removed from this partition. All states will be bits right of the staticState bit
```

}

```
for (int k = j - 1; k >= 0; k -- ){
    // Potential state to remove
    long int otherState = (long int) 1 << k;
    // Check if this state is in the current bitset
    if ((P[i] & (otherState)) != 0){
        // Iterate across the entire alphabet and check if staticState and otherState can transition to different partitions.
        for (int l  = 0; l < 26; l++){
            int staticNext = -1; // next partition for static
            int otherNext = -1; // next partition for other
            for (int m = 0; m < nextPartitionIndex; m++){
                if ((P[m] & (1 << transitionMap[j][l])) != 0){
                    staticNext = m;        //found static next
                }
            if ((P[m] & (1 << transitionMap[k][l])) != 0){
                otherNext = m; // found other next
                }
            }

// If partitions differ, remove the other state and add it to the new partition. Then break, since we are done with this partition
    if (transitionMap[j][l] != transitionMap[k][l] && (staticNext != otherNext)){
                P[i] &= ~(1 << k);
                newPartition |= (1 << k);
                break;
            }
        }
    }
```

```
                }
                break;
            }
        }
        // New partition exists. Add it to P and increment nextPartitionIndex
        if (newPartition != 0){
            P[nextPartitionIndex] = newPartition;
            nextPartitionIndex++;
        }
}
// find and print start partition
int startPartition = 0;
for (int i = 0; i < nextPartitionIndex; i ++){
        if ((P[i] & (1 << startState)) != 0 ){
            startPartition = i;
            break;
        }
}
printf("%d \n", startPartition);
// find and print final partitions
for (int i = 0; i < nextPartitionIndex; i++){
        if ((P[i] & finalStates) != 0){
            printf("%d ", i);
        }
}
printf("\n");
// find and print all transitions
for (int i = 0; i < nextPartitionIndex; i++){
        for (int j = 0; j < 26; j++) {
            if (partitionTransitionMap[i][j] != -1){
                for (int k = 0; k < nextPartitionIndex; k++){
```

```
                    if ((P[k] & (1 << partitionTransitionMap[i][j])) != 0){
                        printf("%d %c %d\n", i, j + 'a', k);
                    }
                }
            }
        }
    }
    return 0;
}
```

OUTPUT

3
0
1 b 0
2 a 1
3 a 1
3 b 2

PROGRAM 7

Develop an operator precedence parser for a given language.

PROGRAM LOGIC:

An operator precedence parser is a one of the bottom-up parser that interprets an operator-precedence grammar. This parser is only used for operator grammars. Ambiguous grammars are not allowed in case of any parser except operator precedence parser. The operator precedence parsers usually do not store the precedence table with the relations; rather they are implemented in a special way. Operator precedence parsers use precedence functions that map terminal symbols to integers, and so the precedence relations between the symbols are implemented by numerical comparison. The parsing table can be encoded by two precedence functions f and g that map terminal symbols to integers. We select f and g such that:

- $f(a) < g(b)$ whenever a is precedence to b
- $f(a) = g(b)$ whenever a and b having precedence
- $f(a) > g(b)$ whenever a takes precedence over b

PROGRAM

```
#include<stdio.h>
#include<conio.h>
void main(){

/*OPERATOR PRECEDENCE PARSER*/
char stack[20],ip[20],opt[10][10][1],ter[10];
int i,j,k,n,top=0,col,row;
clrscr();
for(i=0;i<10;i++)
{
 stack[i]=NULL;
 ip[i]=NULL;
 for(j=0;j<10;j++)
 {
 opt[i][j][1]=NULL;
 }
}
printf("Enter the no.of terminals :\n");
scanf("%d",&n);
```

```
printf("\nEnter the terminals :\n");
scanf("%s",&ter);
printf("\nEnter the table values :\n");
for(i=0;i<n;i++)
{
 for(j=0;j<n;j++)
 {
 printf("Enter the value for %c %c:",ter[i],ter[j]);
 scanf("%s",opt[i][j]);
 }
}
printf("\n**** OPERATOR PRECEDENCE TABLE ****\n");
for(i=0;i<n;i++)
{
printf("\t%c",ter[i]);
}
printf("\n");
for(i=0;i<n;i++){printf("\n%c",ter[i]);
for(j=0;j<n;j++){printf("\t%c",opt[i][j][0]);}}
stack[top]='$';
printf("\nEnter the input string:");
scanf("%s",ip);
i=0;
printf("\nSTACK\t\t\tINPUT STRING\t\t\tACTION\n");
printf("\n%s\t\t\t%s\t\t\t",stack,ip);
while(i<=strlen(ip))
{
for(k=0;k<n;k++)
{
if(stack[top]==ter[k])
col=k;
if(ip[i]==ter[k])
row=k;
}
if((stack[top]=='$')&&(ip[i]=='$')){
printf("String is accepted\n");
break;}
else if((opt[col][row][0]=='<') ||(opt[col][row][0]=='='))
{ stack[++top]=opt[col][row][0];
stack[++top]=ip[i];
```

```
 printf("Shift %c",ip[i]);
 i++;
  }
else{
 if(opt[col][row][0]=='>')
{
while(stack[top]!='<'){--top;}
top=top-1;
printf("Reduce");
}
else
{
printf("\nString is not accepted");
break;
}
}
printf("\n");
for(k=0;k<=top;k++)
{
printf("%c",stack[k]);
}
printf("\t\t\t");
for(k=i;k<strlen(ip);k++){
printf("%c",ip[k]);
}
printf("\t\t\t");
}
getch();
}
```

OUTPUT:

Enter the value for * *:>

Enter the value for * $:>

Enter the value for $ i:<

Enter the value for $ +:<

Enter the value for $ *:<

Enter the value for $ $:accept

```
**** OPERATOR PRECEDENCE TABLE ****

        i      +      *      $

i       e      >      >      >

+       <      >      <      >

*       <      >      >      >

$       <      <      <      a

*/

Enter the input string:

i*i

STACK               INPUT STRING             ACTION

$                   i*i                     Shift i

$<i                  *i                      Reduce

$                   *i                      Shift *

$<*                  i                       Shift i

$<*<i

String is not accepted
```

PROGRAM 8

To find First and Follow of any given grammar.

PROGRAM LOGIC:

The functions follow and followfirst are both involved in the calculation of the Follow Set of a given Non-Terminal. The follow set of the start symbol will always contain “$”. Now the calculation of Follow falls under three broad cases :

A. If a Non-Terminal on the R.H.S. of any production is followed immediately by a Terminal then it can immediately be included in the Follow set of that Non-Terminal.
B. If a Non-Terminal on the R.H.S. of any production is followed immediately by a Non-Terminal, then the First Set of that new Non-Terminal gets included on the follow set of our original Non-Terminal. In case encountered an epsilon i.e. ” # ” then, move on to the next symbol in the production.
   Note : “#” is never included in the Follow set of any Non-Terminal.
C. If reached the end of a production while calculating follow, then the Follow set of that non-teminal will include the Follow set of the Non-Terminal on the L.H.S. of that production. This can easily be implemented by recursion.

PROGRAM

```
#include<stdio.h>
#include<ctype.h>
#include<string.h>

// Functions to calculate Follow
void followfirst(char, int, int);
void follow(char c);

// Function to calculate First
void findfirst(char, int, int);
```

```
int count, n = 0;

// Stores the final result
// of the First Sets
char calc_first[10][100];

// Stores the final result
// of the Follow Sets
char calc_follow[10][100];
int m = 0;

// Stores the production rules
char production[10][10];
char f[10], first[10];
int k;
char ck;
int e;

int main(int argc, char **argv)
{
        int jm = 0;
        int km = 0;
        int i, choice;
        char c, ch;
        count = 8;

        // The Input grammar
        strcpy(production[0], "E=TR");
        strcpy(production[1], "R=+TR");
        strcpy(production[2], "R=#");
        strcpy(production[3], "T=FY");
```

```
strcpy(production[4], "Y=*FY");
strcpy(production[5], "Y=#");
strcpy(production[6], "F=(E)");
strcpy(production[7], "F=i");

int kay;
char done[count];
int ptr = -1;

// Initializing the calc_first array
for(k = 0; k < count; k++) {
        for(kay = 0; kay < 100; kay++) {
                calc_first[k][kay] = '!';
        }
}
int point1 = 0, point2, xxx;

for(k = 0; k < count; k++)
{
        c = production[k][0];
        point2 = 0;
        xxx = 0;

        // Checking if First of c has
        // already been calculated
        for(kay = 0; kay <= ptr; kay++)
                if(c == done[kay])
                        xxx = 1;

        if (xxx == 1)
                continue;
```

```
// Function call
findfirst(c, 0, 0);
ptr += 1;

// Adding c to the calculated list
done[ptr] = c;
printf("\n First(%c) = { ", c);
calc_first[point1][point2++] = c;

// Printing the First Sets of the grammar
for(i = 0 + jm; i < n; i++) {
        int lark = 0, chk = 0;

        for(lark = 0; lark < point2; lark++) {

                if (first[i] == calc_first[point1][lark])
                {
                        chk = 1;
                        break;
                }
        }
        if(chk == 0)
        {
                printf("%c, ", first[i]);
                calc_first[point1][point2++] = first[i];
        }
}
printf("}\n");
jm = n;
point1++;
```

```
}
printf("\n");
printf("-----------------------------------------------\n\n");
char donee[count];
ptr = -1;

// Initializing the calc_follow array
for(k = 0; k < count; k++) {
	for(kay = 0; kay < 100; kay++) {
		calc_follow[k][kay] = '!';
	}
}
point1 = 0;
int land = 0;
for(e = 0; e < count; e++)
{
	ck = production[e][0];
	point2 = 0;
	xxx = 0;

	// Checking if Follow of ck
	// has alredy been calculated
	for(kay = 0; kay <= ptr; kay++)
		if(ck == donee[kay])
			xxx = 1;

	if (xxx == 1)
		continue;
	land += 1;

	// Function call
```

```
            follow(ck);
            ptr += 1;

            // Adding ck to the calculated list
            donee[ptr] = ck;
            printf(" Follow(%c) = { ", ck);
            calc_follow[point1][point2++] = ck;

            // Printing the Follow Sets of the grammar
            for(i = 0 + km; i < m; i++) {
                int lark = 0, chk = 0;
                for(lark = 0; lark < point2; lark++)
                {
                    if (f[i] == calc_follow[point1][lark])
                    {
                        chk = 1;
                        break;
                    }
                }
                if(chk == 0)
                {
                    printf("%c, ", f[i]);
                    calc_follow[point1][point2++] = f[i];
                }
            }
            printf(" }\n\n");
            km = m;
            point1++;
        }
}
```

```
void follow(char c)
{
	int i, j;

	// Adding "$" to the follow
	// set of the start symbol
	if(production[0][0] == c) {
		f[m++] = '$';
	}
	for(i = 0; i < 10; i++)
	{
		for(j = 2;j < 10; j++)
		{
			if(production[i][j] == c)
			{
				if(production[i][j+1] != '\0')
				{
					// Calculate the first of the next
					// Non-Terminal in the production
					followfirst(production[i][j+1], i, (j+2));
				}

				if(production[i][j+1]=='\0' && c!=production[i][0])
				{
					// Calculate the follow of the Non-Terminal
					// in the L.H.S. of the production
					follow(production[i][0]);
				}
			}
		}
	}
```

```
}

void findfirst(char c, int q1, int q2)
{
	int j;

	// The case where we
	// encounter a Terminal
	if(!(isupper(c))) {
		first[n++] = c;
	}
	for(j = 0; j < count; j++)
	{
		if(production[j][0] == c)
		{
			if(production[j][2] == '#')
			{
				if(production[q1][q2] == '\0')
					first[n++] = '#';
				else if(production[q1][q2] != '\0'
						&& (q1 != 0 || q2 != 0))
				{
					// Recursion to calculate First of New
					// Non-Terminal we encounter after epsilon
					findfirst(production[q1][q2], q1, (q2+1));
				}
				else
					first[n++] = '#';
			}
			else if(!isupper(production[j][2]))
			{
```

```
                    first[n++] = production[j][2];
                }
                else
                {
                    // Recursion to calculate First of
                    // New Non-Terminal we encounter
                    // at the beginning
                    findfirst(production[j][2], j, 3);
                }
            }
        }
}

void followfirst(char c, int c1, int c2)
{
        int k;

        // The case where we encounter
        // a Terminal
        if(!(isupper(c)))
            f[m++] = c;
        else
        {
            int i = 0, j = 1;
            for(i = 0; i < count; i++)
            {
                if(calc_first[i][0] == c)
                    break;
            }

            //Including the First set of the
```

```
                // Non-Terminal in the Follow of
                // the original query
                while(calc_first[i][j] != '!')
                {
                        if(calc_first[i][j] != '#')
                        {
                                f[m++] = calc_first[i][j];
                        }
                        else
                        {
                                if(production[c1][c2] == '\0')
                                {
                                        // Case where we reach the
                                        // end of a production
                                        follow(production[c1][0]);
                                }
                                else
                                {
                                        // Recursion to the next symbol
                                        // in case we encounter a "#"
                                        followfirst(production[c1][c2], c1, c2+1);
                                }
                        }
                        j++;
                }
        }
}
```

OUTPUT

First(E)= { (, i, }

First(R)= { +, #, }

First(T)= { (, i, }

First(Y)= { *, #, }

First(F)= { (, i, }

Follow(E) = { $,), }

Follow(R) = { $,), }

Follow(T) = { +, $,), }

Follow(Y) = { +, $,), }

Follow(F) = { *, +, $,), }

PROGRAM 9

Construct a recursive descent parser for an expression.

PROGRAM LOGIC:

A recursive descent parser is a top-down parser. This is one of the most simple forms of parsing. It is used to build a parse tree from top to bottom and reads the input from left to right. A form of recursive descent parsing that does not require backtracking algorithm is known as a predictive parser. The parsers that use backtracking may require exponential time. This parser is normally used for compiler designing purpose. The parser gets an input and reads it from left to right and checks it. If the source code fails to parse properly, then the parser exits by giving an error (flag) message. If it parses the source code properly then it exits without giving an error message.\

PROGRAM

```
#include<stdio.h>
#include<ctype.h>
#include<string.h>

void Tprime();
void Eprime();
void E();
void check();
void T();


char expression[10];
int count, flag;

int main()
{
    count = 0;
    flag = 0;
    printf("\nEnter an Algebraic Expression:\t");
    scanf("%s", expression);
    E();
```

```
    if((strlen(expression) == count) && (flag == 0))
    {
        printf("\nThe Expression %s is Valid\n", expression);
    }
    else
    {
        printf("\nThe Expression %s is Invalid\n", expression);
    }
}

void E()
{
    T();
    Eprime();
}

void T()
{
    check();
    Tprime();
}

void Tprime()
{
    if(expression[count] == '*')
    {
        count++;
        check();
        Tprime();
    }
}
```

```
void check()
{
    if(isalnum(expression[count]))
    {
        count++;
    }
    else if(expression[count] == '(')
    {
        count++;
        E();
        if(expression[count] == ')')
        {
            count++;
        }
        else
        {
            flag = 1;
        }
    }
    else
    {
        flag = 1;
    }
}

void Eprime()
{
    if(expression[count] == '+')
    {
        count++;
```

```
        T();
        Eprime();
    }
}
```

OUTPUT

Enter an algebraic expression: (a+b)*c

The expression (a+b)*c is Valid

PROGRAM 10

Construct a Shift Reduce Parser for a given language.

PROGRAM LOGIC:

Shift Reduce parser attempts for the construction of parse in a similar manner as done in bottom up parsing i.e. the parse tree is constructed from leaves(bottom) to the root(up). A more general form of shift reduce parser is LR parser.This parser requires some data structures i.e.

- A input buffer for storing the input string.
- A stack for storing and accessing the production rules.

Basic Operations –

A. **Shift:** This involves moving of symbols from input buffer onto the stack.
B. **Reduce**: If the handle appears on top of the stack then, its reduction by using appropriate production rule is done i.e. RHS of production rule is popped out of stack and LHS of production rule is pushed onto the stack.
C. **Accept:** If only start symbol is present in the stack and the input buffer is empty then, the parsing action is called accept. When accept action is obtained, it is means successful parsing is done.
D. **Error:** This is the situation in which the parser can neither perform shift action nor reduce action and not even accept action.

PROGRAM

```
#include<stdio.h>
#include<conio.h>
#include<string.h>
int k=0,z=0,i=0,j=0,c=0;
char a[16],ac[20],stk[15],act[10];
void check();
void main()
  {
    clrscr();
    puts("GRAMMAR is E->E+E \n E->E*E \n E->(E) \n E->id");
```

```
    puts("enter input string ");
    gets(a);
    c=strlen(a);
    strcpy(act,"SHIFT->");
    puts("stack \t input \t action");
    for(k=0,i=0; j<c; k++,i++,j++)
     {
       if(a[j]=='i' && a[j+1]=='d')
         {
            stk[i]=a[j];
            stk[i+1]=a[j+1];
            stk[i+2]='\0';
            a[j]=' ';
            a[j+1]=' ';
            printf("\n$%s\t%s$\t%sid",stk,a,act);
            check();
         }
       else
         {
            stk[i]=a[j];
            stk[i+1]='\0';
            a[j]=' ';
            printf("\n$%s\t%s$\t%ssymbols",stk,a,act);
            check();
         }
     }
     getch();
  }
void check()
  {
    strcpy(ac,"REDUCE TO E");
```

```
for(z=0; z<c; z++)
  if(stk[z]=='i' && stk[z+1]=='d')
    {
      stk[z]='E';
      stk[z+1]='\0';
      printf("\n$%s\t%s$\t%s",stk,a,ac);
      j++;
    }
for(z=0; z<c; z++)
  if(stk[z]=='E' && stk[z+1]=='+' && stk[z+2]=='E')
    {
      stk[z]='E';
      stk[z+1]='\0';
      stk[z+2]='\0';
      printf("\n$%s\t%s$\t%s",stk,a,ac);
      i=i-2;
    }
for(z=0; z<c; z++)
  if(stk[z]=='E' && stk[z+1]=='*' && stk[z+2]=='E')
    {
      stk[z]='E';
      stk[z+1]='\0';
      stk[z+1]='\0';
      printf("\n$%s\t%s$\t%s",stk,a,ac);
      i=i-2;
    }
for(z=0; z<c; z++)
  if(stk[z]=='(' && stk[z+1]=='E' && stk[z+2]==')')
    {
      stk[z]='E';
      stk[z+1]='\0';
```

```
            stk[z+1]='\0';
            printf("\n$%s\t%s$\t%s",stk,a,ac);
            i=i-2;
          }
   }
```

OUTPUT

GRAMMAR IS E=E*E

E=E*E

E=(E)

E=id

input string is

(id*id)+id

stack	input	action
$(	id*id)+id$	SHIFT->symbols
$(id	*id)+id$	SHIFT->id
$(E	*id)+id$	REDUCE TO E
$(E*	id)+id$	SHIFT->symbols
$(E*id	)+id$	SHIFT->id
$(E*E	)+id$	REDUCE TO E
$(E	)+id$	REDUCE TO E
$(E)	+id$	SHIFT->symbols
$E	+id$	REDUCE TO E
$E+	id$	SHIFT->symbols
$E+id	$	SHIFT->id
$E+E	$	REDUCE TO E
$E	$	REDUCE TO E

PROGRAM 11

Write a program to perform loop unrolling.

```
#include<stdio.h>
void main()
{
unsigned int n;
int x;
char ch;
printf("\nEnter N\n");
scanf("%u",&n);
printf("\n1. Loop Roll\n2. Loop UnRoll\n");
printf("\nEnter ur choice\n");
scanf(" %c",&ch);
switch(ch)
{
case '1':
  x=countbit1(n);
  printf("\nLoop Roll: Count of  1's    :  %d" ,x);
  break;
case '2':
  x=countbit2(n);
  printf("\nLoop UnRoll:  Count of 1's  :  %d" ,x);
  break;
default:
  printf("\n Wrong Choice\n");

}
}
int countbit1(unsigned int n)
{
            int bits = 0,i=0;
            while (n != 0)
            {
 if (n & 1) bits++;
 n >>= 1;
 i++;
            }
            printf("\n no of iterations  %d",i);
            return bits;
}
int countbit2(unsigned int n)
{
            int bits = 0,i=0;
            while (n != 0)
```

```
        {
 if (n & 1) bits++;
 if (n & 2) bits++;
 if (n & 4) bits++;
 if (n & 8) bits++;
 n >>= 4;
 i++;
        }
        printf("\n no of iterations  %d",i);
        return bits;
}
```

OUTPUT

1.

2.

Enter ur choice : 1

Enter N: 48

No.of Intersections: 6

PROGRAM 12

Write a program to perform constant propagation.

```
#include<stdio.h>
#include<string.h>
#include<ctype.h>
void input();
void output();
void change(int p,char *res);
void constant();
struct expr
{
char op[2],op1[5],op2[5],res[5];
int flag;
}arr[10];
int n;
void main()
{
input();
constant();
output();
}
void input()
{
int i;
printf("\n\nEnter the maximum number of  expressions : ");
scanf("%d",&n);
printf("\nEnter the input : \n");
for(i=0;i<n;i++)
{
scanf("%s",arr[i].op);
scanf("%s",arr[i].op1);
scanf("%s",arr[i].op2);
scanf("%s",arr[i].res);
arr[i].flag=0;
}
}
void constant()
{
int i;
int op1,op2,res;
char op,res1[5];
for(i=0;i<n;i++)
{
if(isdigit(arr[i].op1[0]) && isdigit(arr[i].op2[0]) || strcmp(arr[i].op,"=")==0) /*if both digits,
store them in variables*/
```

```
{
op1=atoi(arr[i].op1);
op2=atoi(arr[i].op2);
op=arr[i].op[0];
switch(op)
{
case '+':
res=op1+op2;
break;
case '-':
res=op1-op2;
break;
case '*':
res=op1*op2;
break;
case '/':
res=op1/op2;
break;
case '=':
res=op1;
break;
}
sprintf(res1,"%d",res);
arr[i].flag=1; /*eliminate expr and replace any operand below that uses result of this expr */
change(i,res1);
}
}
}
void output()
{
int i=0;
printf("\nOptimized code is : ");
for(i=0;i<n;i++)
{
if(!arr[i].flag)
{
printf("\n%s %s %s %s",arr[i].op,arr[i].op1,arr[i].op2,arr[i].res);
}
}
}
void change(int p,char *res)
{
int i;
for(i=p+1;i<n;i++)
{
if(strcmp(arr[p].res,arr[i].op1)==0)
```

```
strcpy(arr[i].op1,res);
else if(strcmp(arr[p].res,arr[i].op2)==0)
strcpy(arr[i].op2,res);
}
}
```

INPUT

```
Enter the input :
= 3 - a
+ a b t1
+ a c t2
+ t1 t2 t3
```

OUTPUT:

```
Optimized code is :
+ 3 b t1
+ 3 c t2
+ t1 t2 t3
```

PROGRAM 13

Implement Intermediate code generation for simple expressions.

```
#include"stdio.h"
#include"string.h"
int i=1,j=0,no=0,tmpch=90;
char str[100],left[15],right[15];
void findopr();
void explore();
void fleft(int);
void fright(int);
struct exp
{
 int pos;
 char op;
}k[15];
void main()
{
 printf("\t\tINTERMEDIATE CODE GENERATION\n\n");
 printf("Enter the Expression :");
 scanf("%s",str);
 printf("The intermediate code:\t\tExpression\n");
 findopr();
 explore();

}
void findopr()
{
 for(i=0;str[i]!='\0';i++)
  if(str[i]==':')
  {
  k[j].pos=i;
  k[j++].op=':';
  }
 for(i=0;str[i]!='\0';i++)
  if(str[i]=='/')
  {
  k[j].pos=i;
  k[j++].op='/';
  }
 for(i=0;str[i]!='\0';i++)
  if(str[i]=='*')
  {
  k[j].pos=i;
  k[j++].op='*';
  }
```

```
 for(i=0;str[i]!='\0';i++)
  if(str[i]=='+')
  {
  k[j].pos=i;
  k[j++].op='+';
  }
 for(i=0;str[i]!='\0';i++)
  if(str[i]=='-')
  {
  k[j].pos=i;
  k[j++].op='-';
  }
}
void explore()
{
 i=1;
 while(k[i].op!='\0')
 {
  fleft(k[i].pos);
  fright(k[i].pos);
  str[k[i].pos]=tmpch--;
  printf("\t%c := %s%c%s\t\t",str[k[i].pos],left,k[i].op,right);
  for(j=0;j <strlen(str);j++)
   if(str[j]!='$')
           printf("%c",str[j]);
  printf("\n");
  i++;
 }
 printf("\t%c:=  %c",str[0],str[k[--i].pos]);
}
void fleft(int x)
{
 int w=0,flag=0;
 x--;
 while(x!= -1 &&str[x]!= '+' &&str[x]!='*'&&str[x]!='='&&str[x]!='\0'&&str[x]!='-
'&&str[x]!='/'&&str[x]!=':')
 {
  if(str[x]!='$'&& flag==0)
  {
  left[w++]=str[x];
  left[w]='\0';
  str[x]='$';
  flag=1;
  }
  x--;
 }
```

```
}
void fright(int x)
{
 int w=0,flag=0;
 x++;
 while(x!= -1 && str[x]!= '+'&&str[x]!='*'&&str[x]!='\0'&&str[x]!='='&&str[x]!=':'&&str[x]!='-'&&str[x]!='/')
 {
  if(str[x]!='$'&& flag==0)
  {
  right[w++]=str[x];
  right[w]='\0';
  str[x]='$';
  flag=1;
  }
  x++;
 }
}
```

INPUT

d:=a+b*c

The intermediate code:	Expression
Z := b*c	d:=a+Z
Y := a+Z	d:=Y
d := Y	

PROGRAM 14

Implement the back end of the compiler which takes the three address code and produces the 8086 Assembly language instructions that can be assembled and run using an 8086 assembler. The target assembly instructions can be simple move, add, sub, jump etc.

```
#include<stdio.h>
#include<string.h>
struct code
{
char op[2],arg1[5],arg2[5],result[5];
}in[10];
void main()
{
int n,i;
printf("enter the number of instructions\n");
scanf("%d",&n);
for(i=0;i<n;i++)
{
scanf("%s%s%s%s",in[i].op,in[i].arg1,in[i].arg2,in[i].result);
}
for(i=0;i<n;i++)
{
if(strcmp(in[i].op,"+")==0)
        {
        printf("\nMOV R0,%s",in[i].arg1);
        printf("\nADD R0,%s",in[i].arg2);
        printf("\nMOV %s,R0",in[i].result);
        }
        if(strcmp(in[i].op,"*")==0)
        {
        printf("\nMOV R0,%s",in[i].arg1);
        printf("\nMUL R0,%s",in[i].arg2);
        printf("\nMOV %s,R0",in[i].result);
        }
        if(strcmp(in[i].op,"-")==0)
        {
        printf("\nMOV R0,%s",in[i].arg1);
        printf("\nSUB R0,%s",in[i].arg2);
        printf("\nMOV %s,R0",in[i].result);
        }
        if(strcmp(in[i].op,"/")==0)
        {
        printf("\nMOV R0,%s",in[i].arg1);
        printf("\nDIV R0,%s",in[i].arg2);
        printf("\nMOV %s,R0",in[i].result);
        }
```

```
        if(strcmp(in[i].op,"=")==0)
        {
        printf("\nMOV R0,%s",in[i].arg1);
        printf("\nMOV %s,R0",in[i].result);
        }
        }
}
```

INPUT

```
+ a b t1
+ c d t2
```

```
MOV R0,a
ADD R0,b
MOV t1,R0
MOV R0,c
ADD R0,d
MOV t2,R0
```