/* B9: Write a program to design CLR parsing. */

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

/*
      CLR parser
*/

// @ is null symbol

// structure for representing grammer rules (eg. S -> A)
struct Rules
{
      char var;
      char der[10];
};

// structure for representing CLR items
struct Item
{
      int dotposition;
      struct Rules r;
      int lookahead[255];
      int f;
};

// structure for representing states
struct State
{
      int len;
      struct Item itm[20];
      int transition[255];
};

// Structure for storing a list of states
struct list
{
      struct State data;
      struct list* next;
};

int variables[26] = {0};
int terminals[255] = {0};

int nullable[26] = {0};

char first[26][255] = {{0}}; // Array to store first of each variable
char follow[26][255] = {{0}};// Array to store follow of each variable
char *var,*term;
```

```
char start;

int n,n_var = 0,n_term = 0;
struct Rules* a;

struct list* head,*tail;

// Given a character(variable or terminal) check if its nullable or
not
int is_nullable(char* s)
{
      char* p;
      p = s;
      while(*p!='\0')
      {
            if(*p<'A'||*p>'Z'||!nullable[*p-'A'])
                  return 0;
            p++;
      }
      return 1;
}

// Check if a item is in a given state
int is_item_in(struct State* l,struct Rules r,int dot)
{
      for(int i=0;i<l->len;i++)
      {
            if((l->itm[i].dotposition==dot)&&(l-
>itm[i].r.var==r.var)&&(strcmp(l->itm[i].r.der,r.der)==0))
                  return i;
      }
      return -1;
}

int is_item_in_advanced(struct State* l,struct Rules r,int dot,int*
bit)
{
      int f = 0;
      for(int i=0;i<l->len;i++)
      {
            f = 1;
            for(int j=0;j<255;j++)
            {
                  if(bit[j]!=l->itm[i].lookahead[j])
                  {
                        f = 0;break;
                  }
            }
            if(f&&(l->itm[i].dotposition==dot)&&(l-
>itm[i].r.var==r.var)&&(strcmp(l->itm[i].r.der,r.der)==0))
                  return 1;
```

```
	}
	return 0;
}

// Fill the look aheads in a gievn item
void fill_lookaheads(int* bit,struct Item* l)
{
	//printf("fill\n");
	int length = strlen(l->r.der+l->dotposition+1);
	char sto;int f = 0;
	for(int i=l->dotposition+1;i<l->dotposition+length+1;i++)
	{
		//printf("+\n");
		if(l->r.der[i]=='\0')
			continue;
		if(l->r.der[i]<'A'||l->r.der[i]>'Z')
		{
			//printf("c = %c\n",l->r.der[i]);
			bit[l->r.der[i]] = 1;
			return;
		}
		for(int j=0;j<255;j++)
		{
			if(first[l->r.der[i]-'A'][j])
			{
				bit[j] = 1;
			}
		}
		sto = l->r.der[i];
		l->r.der[i] = '\0';
		if(!is_nullable(l->r.der+l->dotposition+1))
		{
			l->r.der[i] = sto;
		}
		else
		{
			l->r.der[i] = sto;f = 1;break;
		}
	}
	if(!f)
	{
		for(int i=0;i<255;i++)
		{
			if(l->lookahead[i])
			bit[i] = 1;
		}
	}
	//printf("fill_end\n");
}

// Fill the dot position, look ahead and item of a given state
void build_state(struct State* l)
```

```
{
	int s;
	//printf("start\n");
	for(int i=0;i<l->len;i++)
	{
		//printf("*\n");
		if(l->itm[i].r.der[l->itm[i].dotposition]>='A'&&l-
>itm[i].r.der[l->itm[i].dotposition]<='Z')
		{
			//printf("yes\n");
			for(int j=0;j<n;j++)
			{
				if((a[j].var==l->itm[i].r.der[l-
>itm[i].dotposition]))
				{
					if((s = is_item_in(l,a[j],0))==-1)
					{
						//printf("yeah\n");
						l->itm[l->len].dotposition = 0;
						l->itm[l->len].r = a[j];
						l->itm[l->len].f = 0;
						memset(l->itm[l-
>len].lookahead,0,255);
						fill_lookaheads(l->itm[l-
>len].lookahead,&l->itm[i]);
						//printf("finish\n");
						l->len++;
					}
					else
					{
						//printf("Nope\n");
						// code to be added
						fill_lookaheads(l-
>itm[s].lookahead,&l->itm[i]);
					}

				}
			}
		}
	}
}

// Check if a state is already in the list of states
int state_already_included(struct list* l,struct State* s)
{
	struct list* q;
	q = l;
	int f,rtn = -1;int ind = 0;
	while(q!=NULL)
	{
		f = 0;
		if(q->data.len!=s->len)
```

```
            {
                  q = q->next;
                  ind++;
                  continue;
            }
            for(int i=0;i<s->len;i++)
            {
                  if(!is_item_in_advanced(&q->data,s->itm[i].r,s-
>itm[i].dotposition,s->itm[i].lookahead))
                  {
                        f = 1;break;
                  }
            }
            if(!f)
                  return ind;
            ind++;q = q->next;
      }
      return -1;
}

// Print a given list of states
void print_state(struct list* q)
{
      for(int i=0;i<q->data.len;i++)
            {
                  printf("%c :: ",q->data.itm[i].r.var);
                  if(q->data.itm[i].r.der[0]=='@')
                        q->data.itm[i].r.der[0] = '\0';
                  char sto = q->data.itm[i].r.der[q-
>data.itm[i].dotposition];
                  q->data.itm[i].r.der[q->data.itm[i].dotposition] =
'\0';
                  printf("%s.",q->data.itm[i].r.der);
                  q->data.itm[i].r.der[q->data.itm[i].dotposition] =
sto;
                  printf("%s",q->data.itm[i].r.der+q-
>data.itm[i].dotposition);

                  printf(" { ");
                  for(int j=0;j<255;j++)
                  {
                        if(q->data.itm[i].lookahead[j])
                              printf("%c,",(char)j);
                  }
                  printf(" }\n");
            }
}
int num=0;

// Find out all the states and the their transitions
void find_out_states(struct list* l)
{
```

```
	if(l==NULL)
		return;
	for(int i=0;i<l->data.len;i++)
	{
		if(l->data.itm[i].f)
			continue;
		else if(l->data.itm[i].dotposition==strlen(l-
>data.itm[i].r.der))
		{
			l->data.itm[i].f = 1;
			continue;
		}
		//printf("here\n");
		struct list* t;
		t = (struct list*)malloc(sizeof(struct list));
		for(int ind=0;ind<255;ind++)
		{
			t->data.transition[ind] = -1;
		}
		t->data.len = 1;
		t->data.itm[0].dotposition = l->data.itm[i].dotposition+1;
		t->data.itm[0].r =  l->data.itm[i].r;
		for(int ind=0;ind<255;ind++)
				t->data.itm[0].lookahead[ind] = l-
>data.itm[i].lookahead[ind];
		l->data.itm[i].f = 1;
		for(int j=i+1;j<l->data.len;j++)
		{
			if(l->data.itm[j].r.der[l-
>data.itm[j].dotposition]==l->data.itm[i].r.der[l-
>data.itm[i].dotposition])
			{
				//t->data.len = 1;
				t->data.itm[t->data.len].dotposition = l-
>data.itm[j].dotposition+1;
				t->data.itm[t->data.len].r =  l->data.itm[j].r;
				memset(t->data.itm[t->data.len].lookahead,0,255);
				for(int ind=0;ind<255;ind++)
					t->data.itm[t->data.len].lookahead[ind] =
l->data.itm[j].lookahead[ind];
				l->data.itm[j].f = 1;
				t->data.len++;

			}
		}
		build_state(&t->data);
		int s;
		if((s = state_already_included(head,&t->data))==-1)
		{
			tail->next = t;
			tail = t;
			tail->next = NULL;
```

```
                l->data.transition[l->data.itm[i].r.der[l-
>data.itm[i].dotposition]] = num;
                num++;
                for(int ii=0;ii<t->data.len;ii++)
                {
                      if(t->data.itm[i].r.der[0]=='@')
                            t->data.itm[i].r.der[0] = '\0';
                }

           }
           else
           {
                l->data.transition[l->data.itm[i].r.der[l-
>data.itm[i].dotposition]] = s;
           }
     }
     find_out_states(l->next);
}

struct Table
{
      char op;
      int state_no;
};

// Given a character find if it is terminal or variable
int find(char c)
{
     for(int i=0;i<n_term;i++)
          if(term[i]==c)
                return i;
     for(int i=0;i<n_var;i++)
          if(var[i]==c)
                return n_term+i;
}

// Find a gievn rule in the grammer
int find_rule(struct Rules r)
{
     for(int i=0;i<n;i++)
     {
          if(a[i].var==r.var&&strcmp(a[i].der,r.der)==0)
                return i+1;
     }
     return -1;
}

// Construct CLR table
void construct_table(struct Table** tab,int num)
{
     struct list* q;int k;
     q = head;
```

```
	for(int i=0;i<num;i++)
	{
		for(int j=0;j<255;j++)
		{
			if(q->data.transition[j]!=-1)
			{
				k = find(j);
				if(j>='A'&&j<='Z')
				{
					tab[i][k].state_no = q->data.transition[j];
				}
				else
				{
					tab[i][k].op = 'S';
					tab[i][k].state_no = q->data.transition[j];
				}
			}
		}

		for(int j=0;j<q->data.len;j++)
		{

			if(q->data.itm[j].dotposition==strlen(q-
>data.itm[j].r.der))
			{
				if(q->data.itm[j].r.var=='#')
				{
					//printf("hey!!!!\n");

					k = find('$');
					//printf("state: %d Column: %d\n",i,k);
					tab[i][k].op = 'A';
					tab[i][k].state_no = 0;continue;
				}
				int nn = find_rule(q->data.itm[j].r);
				for(int l=0;l<255;l++)
				{
					if(q-
>data.itm[j].lookahead[l])//if(follow[q->data.itm[j].r.var-'A'][l])
					{
						k = find(l);
						if(tab[i][k].state_no==-1)
						{
							tab[i][k].op = 'R';
							tab[i][k].state_no = nn;
						}
						else
						{
							printf("A Shift-Reduce
conflict has taken place in state: %d\n",i);
```

```
                                                printf("The operators
involved are: %c (for shift), %c (for reduce)\n",term[k],a[nn-
1].der[1]);
                                                printf("Press 1. for shift
2. for reduce\n");
                                                int d;

      scanf("%d",&d);while(getchar()!='\n');
                                                if(d==2)
                                                {
                                                      tab[i][k].op = 'R';
                                                      tab[i][k].state_no =
nn;
                                                }
                                          }
                                    }
                              }
                        }
                  }
                  q = q->next;
      }


}


int main(int argc, char const *argv[])
{
      // Input
      if(argc<2)
      {
            printf("Usage: %s [STARTING SYMBOL]\n",argv[0]);
            exit(0);
      }
      printf("Enter the no of rules\n");
      scanf("%d",&n);
      while(getchar()!='\n');
      a = (struct Rules*)malloc(sizeof(struct Rules)*n);
      for(int i=0;i<n;i++)
      {
            printf("Enter the variable\n");
            scanf("%c",&a[i].var);
            if(variables[a[i].var-'A'] != 1)
            {
                  //printf("%d\n",a[i].var-'A');
                  variables[a[i].var-'A'] = 1;n_var++;
            }
            while(getchar()!='\n');
            printf("Enter the derivation\n");
            scanf("%s",a[i].der);
            for(int j=0;j<strlen(a[i].der);j++)
            {
```

```
      if(a[i].der[j]!='@'&&(a[i].der[j]<'A'||a[i].der[j]>'Z')&&terminal
s[a[i].der[j]] != 1)
                  {
                        terminals[a[i].der[j]] = 1;n_term++;
                  }
            }
            while(getchar()!='\n');
      }



      var = (char*)malloc(sizeof(char)*n_var);int ind = 0;
      for(int i=0;i<26;i++)
      {
            if(variables[i])
            var[ind++] = 'A'+i;
      }
      n_term++;
      term = (char*)malloc(sizeof(char)*(n_term));ind = 0;
      for(int i=0;i<255;i++)
      {
            if(terminals[i])
            term[ind++] = (char)i;
      }

      term[ind++] = '$';


      // # is the starting dummy symbol for S'

      // calculating the nullable
      // for the derivation S -> A, S is nullable if either S gives a
null directly(in some other derivation) or if A is nullable
      int no_change = 0;

      do
      {
            no_change = 0;
            for(int i=0;i<n;i++)
            {
                  // Check if it is directly nullable
                  if(strlen(a[i].der)==1&&a[i].der[0]=='@')
                  {
                        if(!nullable[a[i].var-'A'])
                        {
                              no_change = 1;
                              nullable[a[i].var-'A'] = 1;
                        }
                  }
                  // Else check if the RHS is nullable
                  else if(is_nullable(a[i].der))
```

```
                {
                        if(!nullable[a[i].var-'A'])
                        {
                                no_change = 1;
                                nullable[a[i].var-'A'] = 1;
                        }
                }
        }
    }while(no_change);

    // calculating the first
    // if the first character of a derivation is a terminal then we
have found our first, else we find first of the first non-nullable
variable which will the first of the lhs also
    do
    {
        no_change = 0;
        for(int i=0;i<n;i++)
        {
            if(a[i].der[0]!='@')
            {
                if(a[i].der[0]>='A'&&a[i].der[0]<='Z')
                {
                    char sto;
                    for(int j=0;j<strlen(a[i].der);j++)
                    {
                        sto = a[i].der[j];
                        a[i].der[j] = '\0';
                        if(is_nullable(a[i].der))
                        {
                            //printf("*\n");
                            a[i].der[j] = sto;
                            if(sto>='A'&&sto<='Z')
                            {
                                for(int k=0;k<255;k++)
                                {
                                    if(first[sto-
'A'][k]&&!first[a[i].var-'A'][k])
                                    {
                                        no_change = 1;
                                        first[a[i].var-
'A'][k] = 1;
                                    }
                                }
                            }
                            else if(!first[a[i].var-
'A'][sto])
                            {
                                no_change = 1;
                                first[a[i].var-'A'][sto] =
1;
                                break;
```

```
                                    }
                              }
                              else
                              {
                                    a[i].der[j] = sto;
                                    break;
                              }
                        }
                  }
                  else if(!first[a[i].var-'A'][a[i].der[0]])
                  {
                        no_change = 1;
                        first[a[i].var-'A'][a[i].der[0]] = 1;
                        break;
                  }
            }
      }
}while(no_change);


// finding the follow

start = 'S';//argv[1][0];

follow[start-'A']['$'] = 1; //sentinel

do
{
      no_change = 0;

      for(int i=0;i<n;i++)
      {
            if(a[i].der[0]!='@')
            {
                  for(int j=strlen(a[i].der)-1;j>=0;j--)
                  {
                        // if the suffix is nullable


if(a[i].der[j]>='A'&&a[i].der[j]<='Z'&&is_nullable(a[i].der+j+1))
                        {
                              //printf("%c :
%s\n",a[i].var,a[i].der);
                              for(int k=0;k<255;k++)
                              {
                                    if(follow[a[i].var-
'A'][k]&&!follow[a[i].der[j]-'A'][k])
                                    {
                                          //printf("k = %c",(char)k);
                                          no_change = 1;
                                          follow[a[i].der[j]-'A'][k]
= 1;
```

```
                                    }
                              }
                        }
                        if(a[i].der[j]>='A'&&a[i].der[j]<='Z')
                        for(int k=j+1;k<strlen(a[i].der);k++)
                        {
                              char sto = a[i].der[k];
                              a[i].der[k] = '\0';

                              if(is_nullable(a[i].der+j+1))
                              {
                                    a[i].der[k] = sto;
                                    if(sto>='A'&&sto<='Z')
                                    {
                                          for(int l=0;l<255;l++)
                                          {
                                                if(first[sto-
'A'][l]&&!follow[a[i].der[j]-'A'][l])
                                                {
                                                      //printf("l =
%c",(char)l);
                                                      no_change = 1;
      follow[a[i].der[j]-'A'][l] = 1;
                                                }
                                          }
                                    }
                                    else
                                    {
                                          if(!follow[a[i].der[j]-
'A'][sto])
                                          {
                                                //printf("sto =
%c\n",sto);
                                                no_change = 1;
                                                follow[a[i].der[j]-
'A'][sto] = 1;
                                                break;
                                          }
                                    }
                              }
                              else
                              {
                                    a[i].der[k] = sto;break;
                              }
                        }
                  }
            }
      }while(no_change);
```

```
	// all prerocessing done!! now the actual part
	// Creating a state diagram from the clr items
	head = (struct list*)malloc(sizeof(struct list));
	tail = head;
	head->data.len = 1;
	//head->data.itm = (struct Item*)malloc(sizeof(struct
Item)*(n+1));

	head->data.itm[0].r.var = '#';

	head->data.itm[0].r.der[0] = start;
	head->data.itm[0].r.der[1] = '\0';

	head->data.itm[0].dotposition = 0;
	head->data.itm[0].f = 0;
	memset(head->data.itm[0].lookahead,0,255);
	head->data.itm[0].lookahead['$'] = 1;



	// Create initial state
	for(int i=0;i<255;i++)
	{
		head->data.transition[i] = -1;
	}
	build_state(&head->data);

	struct list* q;
	q = head;
	for(int i=0;i<q->data.len;i++)
		{
			//printf("%c :: ",q->data.itm[i].r.var);
			if(q->data.itm[i].r.der[0]=='@')
				q->data.itm[i].r.der[0] = '\0';
		}


	head->next = NULL;

	// Find out all the states and print them
	tail = head;num++;
	find_out_states(head);
	q = head;int num1 = 0;
	while(q!=NULL)
	{
		printf("********  I%d *********\n",num1);
		print_state(q);
		q = q->next;
		num1++;
	}

	// From the states create the CLR table
```

```
	struct Table** tab;
	tab = (struct Table**)malloc(sizeof(struct Table*)*num);
	for(int i=0;i<num;i++)
	{
		tab[i] = (struct Table*)malloc(sizeof(struct
Table)*(n_var+n_term));
		for(int j=0;j<n_var+n_term;j++)
		{
			tab[i][j].state_no = -1;
		}
	}
	for(int i=0;i<n;i++)
		if(a[i].der[0]=='@')
			a[i].der[0] = '\0';
	construct_table(tab,num);

	printf("%8s"," ");
	for(int i=0;i<n_term;i++)
	{
		printf("%8c",term[i]);
	}
	//printf("\n");
	for(int i=0;i<n_var;i++)
		printf("%8c",var[i]);
	printf("\n");
	for(int i=0;i<num;i++)
	{
		printf("%7d:",i);
		for(int j=0;j<n_term+n_var;j++)
		{
			if(tab[i][j].state_no!=-1)
			{
				printf("%7c%d",tab[i][j].op,tab[i][j].state_no);
			}
			else
				printf("%8s","-");
		}
		printf("\n");
	}


	// for(int i=0;i<n;i++)
	// {
	//   printf("%c :: %s\n",a[i].var,a[i].der);
	// }

	// for(int i=0;i<26;i++)
	// {
	//   if(variables[i]==1)
	//   {
	//     printf("%c: ",(char)(i+'A'));
	//     for(int j=0;j<255;j++)
```

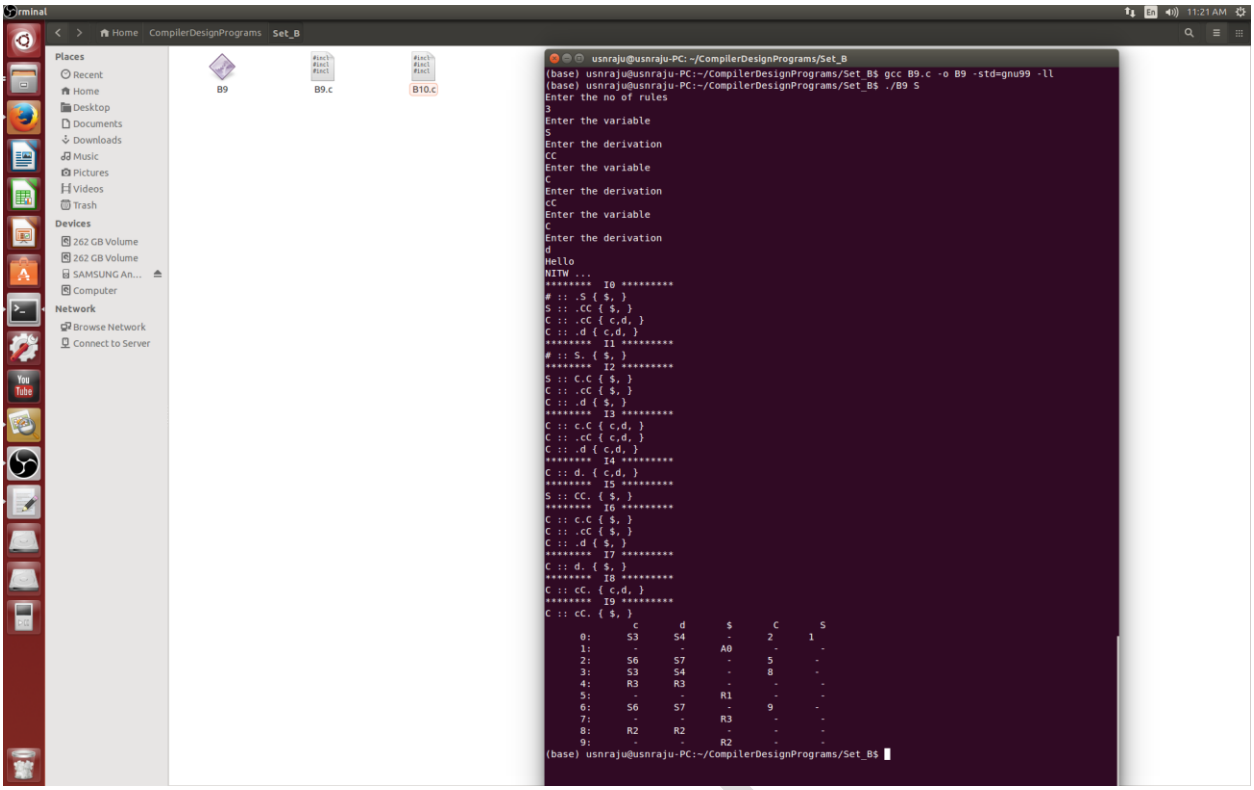
```
      //      {
      //        if(first[i][j])
      //        printf("%c, ",(char)(j));
      //      }
      //      printf("\n");
      //    }
      // }


      // for(int i=0;i<26;i++)
      // {
      //   if(variables[i]==1)
      //   {
      //     printf("%c: ",(char)(i+'A'));
      //     for(int j=0;j<255;j++)
      //     {
      //       if(follow[i][j])
      //       printf("%c, ",(char)(j));
      //     }
      //     printf("\n");
      //   }
      // }

      return 0;
}

/*


---------------------------------------------------------------------
```



```
/*

3
S
CC
C
cC
C
d

4
S
S+S
S
S*S
S
(S)
S
d



5
S
```

```
AB
A
@
A
a
B
@
B
b

4
E
E+E
E
E*E
E
(E)
E
i

10
E
TA
E
T
A
+TA
A
@
T
FR
T
F
R
*FR
R
@
F
(E)
F
i

8
E
E+T
E
T
T
T*F
T
F
F
```

```
G^F
F
G
G
(E)
G
i

4
S
AB
A
aAb
A
a
B
d

                                                (        )        *        +
^        i        $        E        F        G        T
                  0:       S5        -        -        -        -        S6
-       1       3       4       2
                  1:        -        -        -       S7        -        -
A0        -        -        -        -
                  2:        -       R2       S8       R2        -        -
R2        -        -        -        -
                  3:        -       R4       R4       R4        -        -
R4        -        -        -        -
                  4:        -       R6       R6       R6       S9        -
R6        -        -        -        -
                  5:       S5        -        -        -        -       S6
-       10        3       4       2
                  6:        -       R8       R8       R8       R8        -
R8        -        -        -        -
                  7:       S5        -        -        -        -       S6
-        -        3       4       11
                  8:       S5        -        -        -        -       S6
-        -       12       4        -
                  9:       S5        -        -        -        -       S6
-        -       13       4        -
             10:        -       S14        -       S7        -        -
-        -        -        -        -
             11:        -       R1       S8       R1        -        -
R1        -        -        -        -
             12:        -       R3       R3       R3        -        -
R3        -        -        -        -
             13:        -       R5       R5       R5        -        -
R5        -        -        -        -
             14:        -       R7       R7       R7       R7        -
R7        -        -        -        -
```

```
*/
```