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Sri Indu
College of Engineering & Technology
UGC Autonomous Institution
Recognized under 2(f) & 12(B) of UGC Act 1956,
NAAC, Approved by AICTE &
Permanently Affiliated to JNTUH

Estd.2001

NAAC
NATIONAL ASSESSMENT AND ACCREDITATION COUNCIL

DATA STRUCTURES LABORATORY (R22CSE2126)

LAB MANUAL

II Year I Semester

DEPARTMENT OF INFORMATION TECHNOLOGY

SRI INDU COLLEGE OF ENGINEERING & TECHNOLOGY

B. TECH –INFORMATION TECHNOLOGY

INSTITUTION VISION

To be a premier Institution in Engineering & Technology and Management with competency, values and social consciousness.

INSTITUTION MISSION

IM$_1$ Provide high quality academic programs, training activities and research facilities.

IM$_2$ Promote Continuous Industry-Institute Interaction for Employability, Entrepreneurship, Leadership and Research aptitude among stakeholders.

IM$_3$ Contribute to the Economical and technological development of the region, state and nation.

DEPARTMENT VISION

To be a recognized knowledge centre in the field of Information Technology with self - motivated, employable engineers to society.

DEPARTMENT MISSION

The Department has following Missions:

DM$_1$ To offer high quality student centric education in Information Technology.

DM$_2$ To provide a conducive environment towards innovation and skills.

DM$_3$ To involve in activities that provide social and professional solutions.

DM$_4$ To impart training on emerging technologies namely cloud computing and IOT with involvement of stake holders.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: **Higher Studies:** Graduates with an ability to apply knowledge of Basic sciences and programming skills in their career and higher education.

PEO2: **Lifelong Learning:** Graduates with an ability to adopt new technologies for ever changing IT industry needs through Self-Study, Critical thinking and Problem solving skills.

PEO3: **Professional skills:** Graduates will be ready to work in projects related to complex problems involving multi-disciplinary projects with effective analytical skills.

PEO4: **Engineering Citizenship:** Graduates with an ability to communicate well and exhibitsocial, technical and ethical responsibility in process or product.

PROGRAM OUTCOMES (POs) & PROGRAM SPECIFIC OUTCOMES (PSOs)

PO	Description
PO 1	**Engineering Knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.
PO 2	**Problem Analysis:** Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO 3	**Design/Development of Solutions:** Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)
PO 4	**Conduct Investigations of Complex Problems:** Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).
PO 5	**Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO 6	**The Engineer and The World:** Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
PO 7	**Ethics:** Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO 8	**Individual and Collaborative Team work:** Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO 10	**Project Management and Finance:** Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
PO 11	**Life-Long Learning:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)
Program Specific Outcomes	
PSO 1	**Software Development:** To apply the knowledge of Software Engineering, Data Communication, Web Technology and Operating Systems for building IOT and Cloud Computing applications.
PSO 2	**Industrial Skills Ability:** Design, develop and test software systems for world-wide network of computers toprovide solutions to real world problems.
PSO 3	**Project implementation:** Analyze and recommend the appropriate IT Infrastructure required for the implementationof a project.

GENERAL LABORATORY INSTRUCTIONS

1. Students are advised to come to the laboratory at least 5 minutes before (to the starting time),those who come after 5 minutes will not be allowed into the lab.
2. Plan your task properly much before to the commencement, come prepared to the lab with thesynopsis / program / experiment details.
3. Student should enter into the laboratory with:
    a) Laboratory observation notes with all the details (Problem statement, Aim, Algorithm,Procedure, Program, Expected Output, etc.,) filled in for the lab session.
    b) Laboratory Record updated up to the last session experiments and other utensils (if any)needed in the lab.
    c) Proper Dress code and Identity card.
4. Sign in the laboratory login register, write the TIME-IN, and occupy the computer system allotted to you by the faculty.
5. Execute your task in the laboratory, and record the results / output in the lab observation notebook, and get certified by the concerned faculty.
6. All the students should be polite and cooperative with the laboratory staff, must maintain thediscipline and decency in the laboratory.
7. Computer labs are established with sophisticated and high end branded systems, which should be utilized properly.
8. Students / Faculty must keep their mobile phones in SWITCHED OFF mode during the lab sessions. Misuse of the equipment, misbehaviors with the staff and systems etc., will attract severe punishment.
9. Students must take the permission of the faculty in case of any urgency to go out ; if anybody found loitering outside the lab / class without permission during working hours will be treated seriously and punished appropriately.
10. Students should LOG OFF/ SHUT DOWN the computer system before he/she leaves the labafter completing the task (experiment) in all aspects. He/she must ensure the system / seat is kept properly.

Head of the Department **Principal**

COs MAPPING WITH POs & PSOs

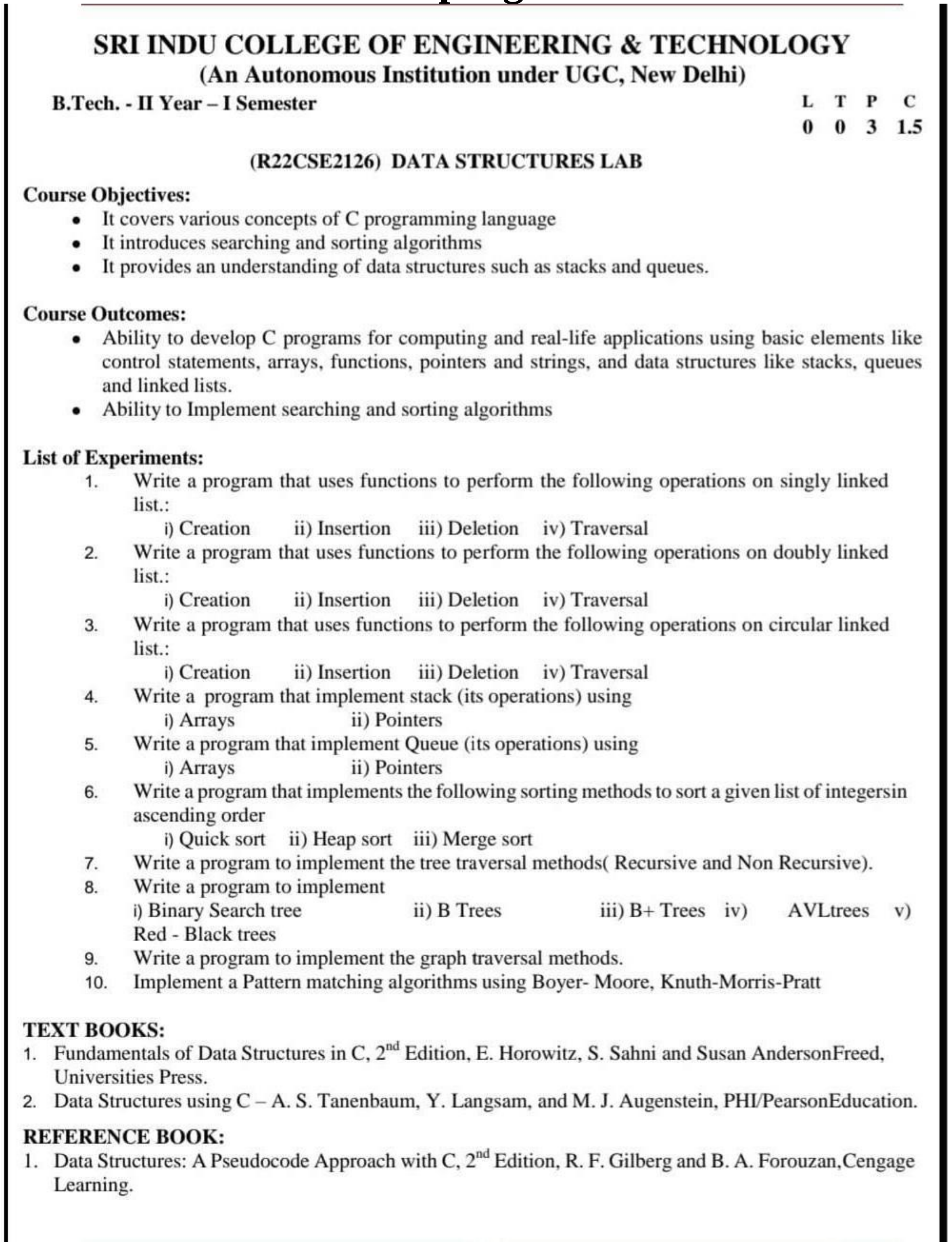
Data Structures

Course Outcomes	Statements
C217.1	Design a program to implement the linear data structures using static and dynamic memory allocation. (Create)
C217.2	Design a program to implement searching, sorting techniques for the given problem. (Create)
C217.3	Demonstrate the fundamental algorithms of tree data structures by experimenting the programs. (Apply)
C217.4	Design a program to implement sorting techniques for the given problem. (Create)
C217.5	Examine the traversing of a given graph by using the respect to graph traversal techniques (Apply)
C217.6	Design a program to implement the pattern matching algorithms for the given problem. (Create)
C217.7	Design programs using data structures like hash tables(create)

Course Articulation Matrix:

Course Outcome	PO 1	PO 2	P O 3	PO 4	PO5	PO6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
C217.1	1	2	2	2	3	-	-	-	-	-	-	-	2	1	1
C217.2	2	2	2	2	2	-	-	-	-	-	-	-	2	1	1
C217.3	1	1	2	2	2	-	-	-	-	-		-	2	2	2
C217.4	2	2	1	2	1	-	-	-	-	-	-	-	2	1	1
C217.5	2	2	2	1	1	-	-	-		-	-	-	2	1	1
C217.6	1	2	1	2	1	-	-	-	-	-	-	-	2	2	2
C217	**1.5**	**1.83**	**1.6**	**1.83**	**1.6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2**	**1.3**	**1.33**

List of programs



SRI INDU COLLEGE OF ENGINEERING & TECHNOLOGY

(An Autonomous Institution under UGC, New Delhi)

B.Tech. - II Year – I Semester

L	T	P	C
0	0	3	1.5

(R22CSE2126) DATA STRUCTURES LAB

Course Objectives:

- It covers various concepts of C programming language
- It introduces searching and sorting algorithms
- It provides an understanding of data structures such as stacks and queues.

Course Outcomes:

- Ability to develop C programs for computing and real-life applications using basic elements like control statements, arrays, functions, pointers and strings, and data structures like stacks, queues and linked lists.
- Ability to Implement searching and sorting algorithms

List of Experiments:

1. Write a program that uses functions to perform the following operations on singly linked list.:
   i) Creation ii) Insertion iii) Deletion iv) Traversal
2. Write a program that uses functions to perform the following operations on doubly linked list.:
   i) Creation ii) Insertion iii) Deletion iv) Traversal
3. Write a program that uses functions to perform the following operations on circular linked list.:
   i) Creation ii) Insertion iii) Deletion iv) Traversal
4. Write a program that implement stack (its operations) using
   i) Arrays ii) Pointers
5. Write a program that implement Queue (its operations) using
   i) Arrays ii) Pointers
6. Write a program that implements the following sorting methods to sort a given list of integersin ascending order
   i) Quick sort ii) Heap sort iii) Merge sort
7. Write a program to implement the tree traversal methods(Recursive and Non Recursive).
8. Write a program to implement
   i) Binary Search tree ii) B Trees iii) B+ Trees iv) AVLtrees v) Red - Black trees
9. Write a program to implement the graph traversal methods.
10. Implement a Pattern matching algorithms using Boyer- Moore, Knuth-Morris-Pratt

TEXT BOOKS:

1. Fundamentals of Data Structures in C, 2nd Edition, E. Horowitz, S. Sahni and Susan AndersonFreed, Universities Press.
2. Data Structures using C – A. S. Tanenbaum, Y. Langsam, and M. J. Augenstein, PHI/PearsonEducation.

REFERENCE BOOK:

1. Data Structures: A Pseudocode Approach with C, 2nd Edition, R. F. Gilberg and B. A. Forouzan,Cengage Learning.

Additional programs

S.no	Programs
1	Write a program to implement Quick sort
2	Write a program that implement circular Queue (its operations) using i) Arrays
3	Write a program to implement merge sort
4	Write a program to implement hashing

P1

Aim: Write a program that uses functions to perform the following operations on singly linked list.: i) Creation ii) Insertion iii) Deletion iv) Traversal

Source Code:

```
#include<stdio.h>
#include<conio.h>
#include<stdlib.h>
int count=0;
struct node
{
int data;
struct node *next;
}*head,*newn,*trav;
//-------------------------------------
void create_list()
{
int value;
struct node *temp;
temp=head;
newn=(struct node *)malloc(sizeof (struct node));
printf("\nenter the value to be inserted");
scanf("%d",&value);
newn->data=value;
if(head==NULL)
{
head=newn;
head->next=NULL;
count++;
}
else
{
while(temp->next!=NULL)
{
temp=temp->next;
}
temp->next=newn;
newn->next=NULL;
count++;
}
}
```

```
//-------------------------------------
void insert_at_begning(int value)
{
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
if(head==NULL)
{
head=newn;
head->next=NULL;
count++;
}
else
{
newn->next=head;
head=newn;
count++;
}
}
//-----------------------------------------
void insert_at_end(int value)
{
struct node *temp;
temp=head;
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
if(head==NULL)
{
head=newn;
head->next=NULL;
count++;
}
else
{
while(temp->next!=NULL)
{
temp=temp->next;
}
temp->next=newn;
newn->next=NULL;
count++;
}
}
//--------------------------------------
```

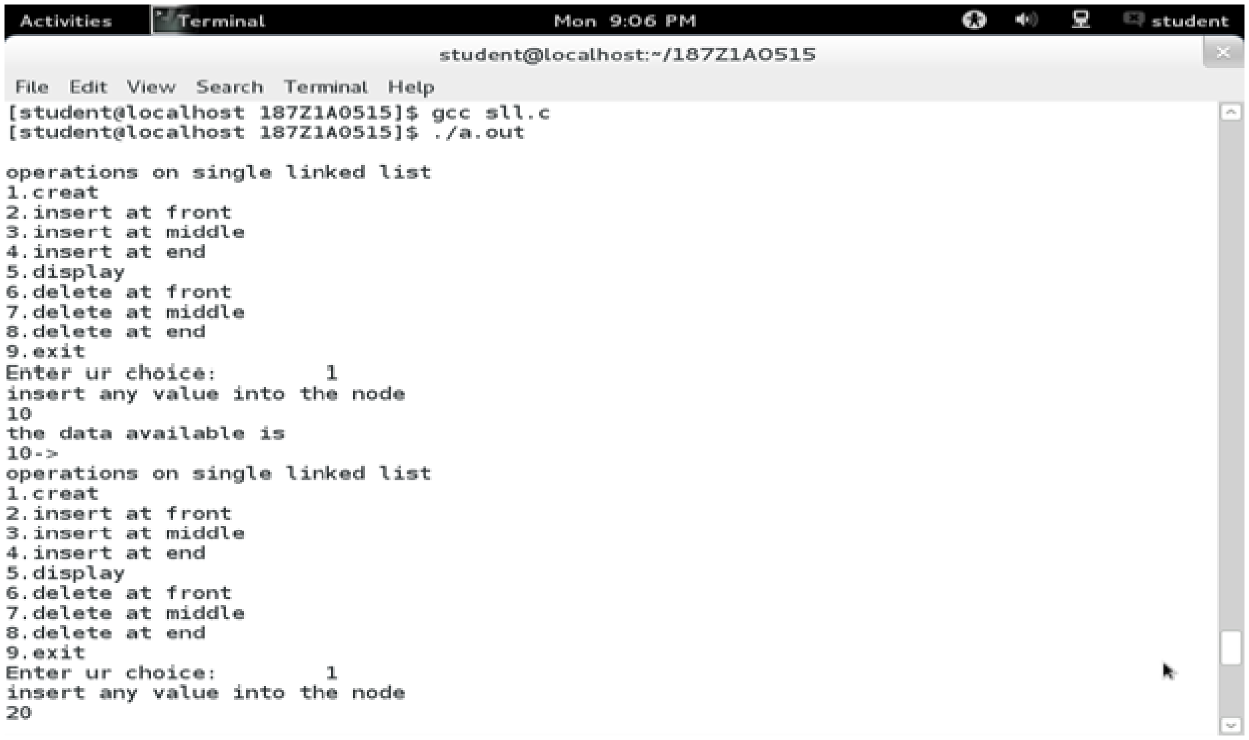
```
int insert_at_middle()
{
if(count>=2)
{
struct node *var1,*temp;
int loc,value;
printf("\n after which value you want to insert : ");
scanf("%d",&loc);
printf("\nenter the value to be inserted");
scanf("%d",&value);
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
temp=head;

/* if(head==NULL)
{
head=newn;
head->next=NULL;
count++;
return 0;
}
else
{*/
while(temp->data!=loc)
{
temp=temp->next;
if(temp==NULL)
{
printf("\nSORRY...there is no %d element",loc);
return 0;
}
}
//var1=temp->next;
newn->next=temp->next;//var1;
temp->next=newn;
count++;
//}
}
else
{
printf("\nthe no of nodes must be >=2");
}
}
```

```
//--------------------------------------------
int delete_from_middle()
{
if(count==0)
printf("\n List is Empty!!!! you can't delete elements\n");
else if(count>2)
{
struct node *temp,*var;
int value;
temp=head;
printf("\nenter the data that you want to delete from the list shown above");
scanf("%d",&value);
while(temp->data!=value)
{
var=temp;
temp=temp->next;
if(temp==NULL)
{
printf("\nSORRY...there is no %d element",value);
return 0;
}
}
if(temp==head)
{
head=temp->next;

}
else{
var->next=temp->next;
temp->next=NULL;
}
count--;
if(temp==NULL)
printf("Element is not avilable in the list \n**enter only middle elements..**");
else
printf("\ndata deleted from list is %d",value);
free(temp);
}
else
{
printf("\nthere no middle elemts..only %d elemts is avilable\n",count);
}
}
```

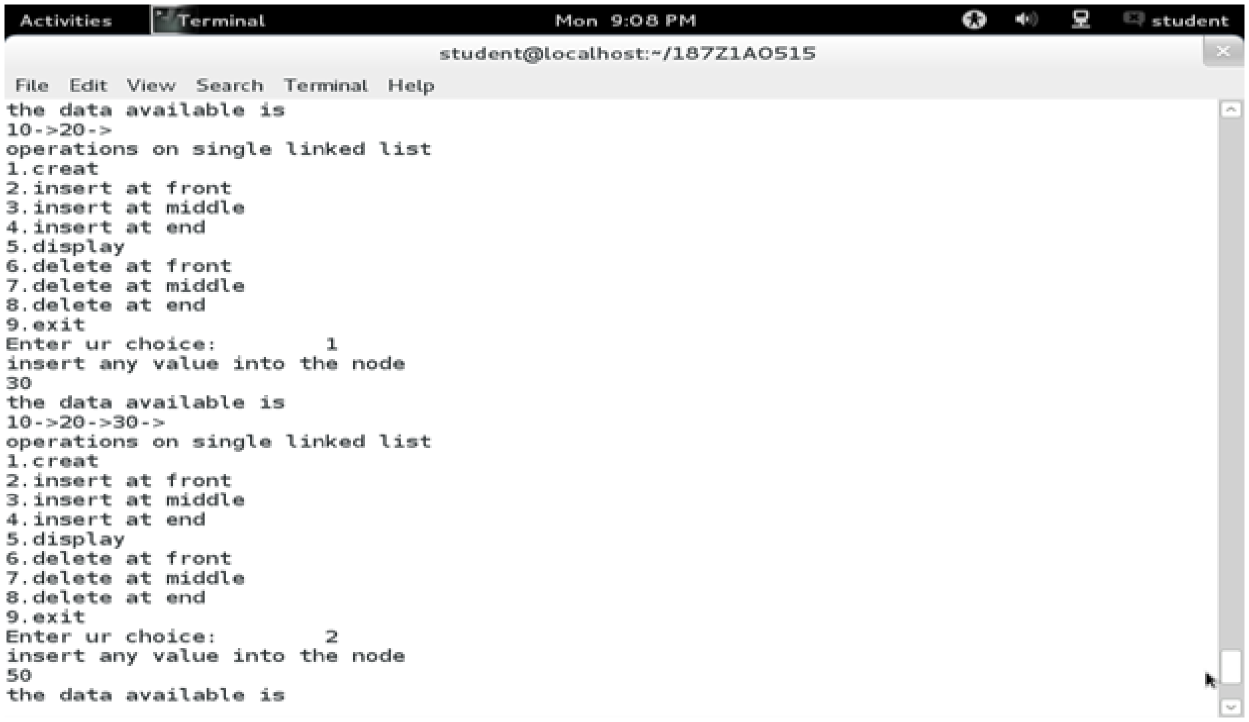
```
//--------------------------------------
int delete_from_front()
{
struct node *temp;
temp=head;
if(head==NULL)
{
printf("\nno elements for deletion in the list\n");
return 0;
}
else
{
printf("\ndeleted element is :%d",head->data);
if(temp->next==NULL)
{
head=NULL;
}
else{
head=temp->next;
temp->next=NULL;
}
count--;
free(temp);
}
}
//--------------------------------
int delete_from_end()
{
struct node *temp,*var;
temp=head;
if(head==NULL)
{
printf("\nno elemts in the list");
return 0;
}
else{
if(temp->next==NULL  )
{
head=NULL;//temp->next;
}
else{
while(temp->next != NULL)
{
```

```
var=temp;
temp=temp->next;
}
var->next=NULL;
}
printf("\ndata deleted from list is %d",temp->data);
free(temp);
count--;
}
return 0;
}
//-----------------------------------
int display()
{
trav=head;
if(trav==NULL)
{
printf("\nList is Empty\n");
return 0;
}
else
{
printf("\n\nElements in the Single Linked List is %d:\n",count);
while(trav!=NULL)
{
printf(" -> %d ",trav->data);
trav=trav->next;
}
printf("\n");
}
}
//----------------------------------------
int main()
{
int ch=0;
char ch1;
head=NULL;
while(1)
{
printf("\n1.create linked list");
printf("\n2.insertion at begning of linked list");
printf("\n3.insertion at the end of linked list");
printf("\n4.insertion at the middle where you want");
printf("\n5.deletion from the front of linked list");
printf("\n6.deletion from the end of linked list ");
printf("\n7.deletion of the middle data that you want");
printf("\n8.display the linked list");
printf("\n9.exit\n");
printf("\nenter the choice of operation to perform on linked list");
scanf("%d",&ch);
switch(ch)
{
case 1:
{
do{
create_list();
display();
printf("do you want to create list ,y / n");
getchar();
scanf("%c",&ch1);
}while(ch1=='y');
break;
}
case 2:
{
int value;
printf("\nenter the value to be inserted");
scanf("%d",&value);
insert_at_begning(value);
display();
break;
}
case 3:
{
int value;
printf("\nenter value to be inserted");
scanf("%d",&value);
insert_at_end(value);
display();
break;
}
case 4:
{
insert_at_middle();
display();
break;
}
case 5:
{
delete_from_front();
display();
}break;
case 6:
{
delete_from_end();
display();
break;
}
case 7:
{
display();
delete_from_middle();
display();
break;
}
case 8:
{
display();
break;
}
case 9:
{
exit(1);
}
default:printf("\n****Please enter correct choice****\n");
}
}
getch();
}
```

Output:


Activities
Terminal
Mon 9:06 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc sll.c
[student@localhost 187Z1A0515]$ ./a.out

operations on single linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
insert any value into the node
10
the data available is
10->
operations on single linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
insert any value into the node
20
```


Activities
Terminal
Mon 9:08 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
the data available is
10->20->
operations on single linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
insert any value into the node
30
the data available is
10->20->30->
operations on single linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        2
insert any value into the node
50
the data available is
```

Viva questions:

1. What is a data structure?
2. What are the goals of data structures?
3. What is single linked list? What are the operations of single linked list?
4. What is a linked list?

P2

Aim:

Write a program that uses functions to perform the following operations on Doubly Linked List.:i) Creation ii) Insertion iii) Deletion iv) Traversal

Source Code:

dll.c

```
#include<stdio.h>
#include<conio.h>
#include<stdlib.h>
int count=0;
struct node
{
int data;
struct node *next,*prev;
}*head,*last,*newn,*trav;
//---------------------------------
void create_list()
{
struct node *temp;
int value;
temp=last;
newn=(struct node *)malloc(sizeof (struct node));
printf("\n enter value");
scanf("%d",&value);
newn->data=value;
if(last==NULL)
{
head=last=newn;
head->prev=NULL;
head->next=NULL;
count++;
}
else
{
newn->next=NULL;
newn->prev=last;
last->next=newn;
```

```
last=newn;
count++;
}
}
//-----------------------------------
void insert_at_begning(int value)
{
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
if(head==NULL)
{
head=last=newn;
head->prev=NULL;
head->next=NULL;
count++;
}
else
{
newn->next=head;
head->prev=newn;
newn->prev=NULL;
head=newn;
count++;
}
}
//---------------------------------------
void insert_at_end(int value)
{
struct node *temp;
temp=last;
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
if(last==NULL)
{
head=last=newn;
head->prev=NULL;
head->next=NULL;
count++;
}
else
{
newn->next=NULL;
newn->prev=last;
```

```
last->next=newn;
last=newn;
count++;
}
}
//-----------------------------------
int insert_at_middle()
{
if(count>=2)
{
struct node *var2,*temp;
int loc,value;
printf("\nselect location where you want to insert the data");
scanf("%d",&loc);
printf("\nenter which value do u want to inserted");
scanf("%d",&value);
newn=(struct node *)malloc(sizeof (struct node));
newn->data=value;
temp=head;
while(temp->data!=loc)
{
temp=temp->next;
if(temp==NULL)
{
printf("\nSORRY...there is no %d element",loc);
return 0;
}
}
if(temp->next==NULL)
{
printf("\n%d is last node..please enter midddle node values ",loc) ;
return;
}
var2=temp->next;
temp->next=newn;
newn->next=var2;
newn->prev=temp;
var2->prev=newn;
count++;
}
else
{
printf("\nthe no of nodes must be >=2");
```

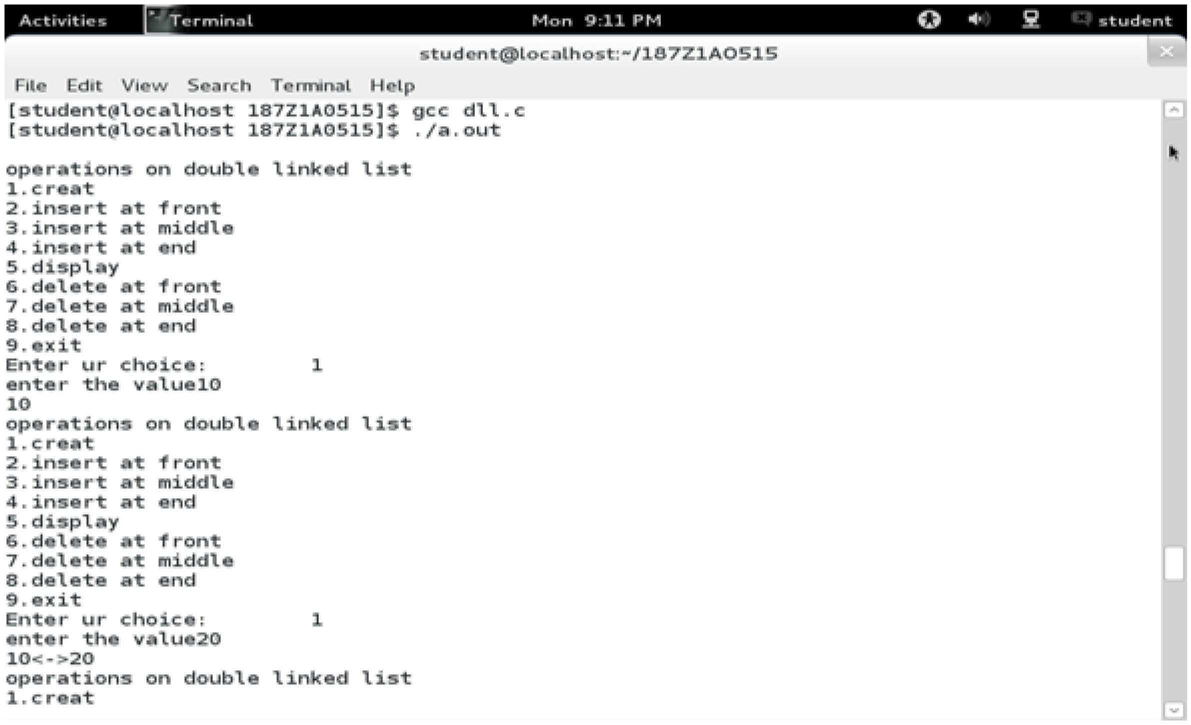
```
}
}
//------------------------------------------
int delete_from_middle()
{
if(count>2)
{
struct node *temp,*var;
int value;
temp=head;
printf("\nenter the data that you want to delete from the list shown above");
scanf("%d",&value);
while(temp!=NULL)
{
if(temp->data == value)
{
if(temp->next==NULL)//if(temp==head)
{
printf("\n\n sorry %d is last node ..please enter middle nodes only",value);
return 0;
}
else
{
if(temp==head)
{
printf("\n\n %d is first node..plz enter middle nodes",value);
return;
}
var->next=temp->next;
temp->next->prev=var;
free(temp);
count--;
return 0;
}
}
else
{
var=temp;
temp=temp->next;
}
}
if(temp==NULL)
printf("\n%d is not avilable.. enter only middle elements..",value);
```

```
else
printf("\ndata deleted from list is %d",value);
}
else
{
printf("\nthere no middle elemts..only %d elemts is avilable",count);
}
}
//-----------------------------------------
int delete_from_front()
{
struct node *temp;
if(head==NULL)
{
printf("no elements for deletion in the list");
return 0;
}
else if(head->next==NULL)
{
printf("deleted element is :%d",head->data);
head=last=NULL;
}
else
{
temp=head->next;
printf("deleted element is :%d",head->data);
head->next=NULL;
temp->prev=NULL;
head=temp;
count--;
return 0;
}
}
//----------------------------------
int delete_from_end()
{
struct node *temp,*var;
temp=last;
if(last==NULL)
{
printf("no elemts in the list");
return 0;
}
```

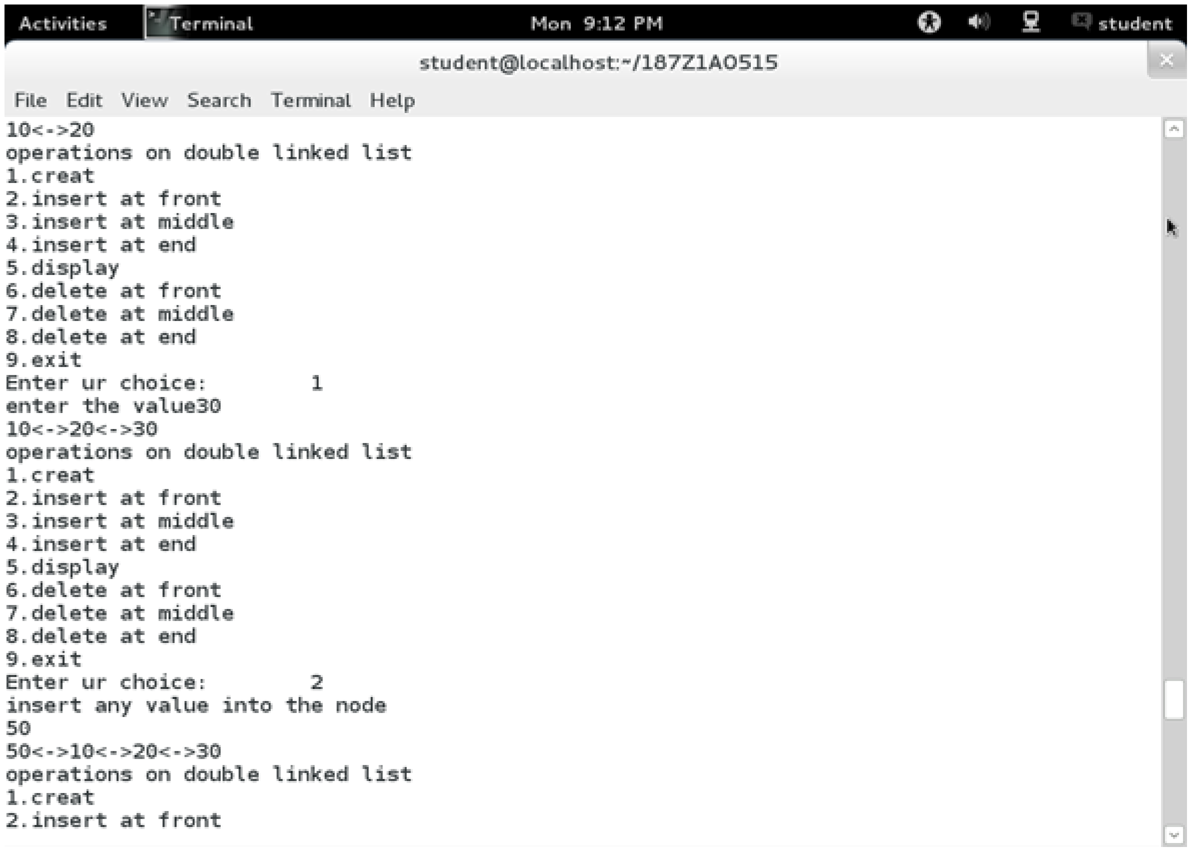
```
else if(last->prev==NULL)
{
printf("data deleted from list is %d",last->data);
head=last=NULL;
//free(last);
count--;
return 0;
}
else{
printf("data deleted from list is %d",last->data);
var=last->prev;
last->prev->next=NULL;
last=var;
count--;
return 0;
}
}
//-----------------------------------
int display()
{
trav=last;//head;
if(trav==NULL)
{
printf("\nList is Empty");
return 0;
}
else
{
printf("\n\nElements in the List is %d:\n",count);
while(trav!=NULL)
{
printf("%d<--> ",trav->data);
trav=trav->prev;//next;
}
printf("\n");
}
}
//-----------------------------------------
int main()
{
int ch=0;
char ch1;
// clrscr();
```

```
head=NULL;
last=NULL;
while(1)
{
Printf("\n Double Linked List Operations")
printf("\n1.Create Double Linked List");
printf("\n2.insertion at begning of linked list");
printf("\n3.insertion at the end of linked list");
printf("\n4.insertion at the middle where you want");
printf("\n5.deletion from the front of linked list");
printf("\n6.deletion from the end of linked list ");
printf("\n7.deletion of the middle data that you want");
printf("\n8.display");
printf("\n9.exit\n");
printf("\nenter the choice of operation to perform on linked list");
scanf("%d",&ch);
switch(ch)
{
case 1:
{
do{
create_list();
display();
printf("do you want to create list ,y / n");
getchar();
scanf("%c",&ch1);
}while(ch1=='y');
break;
}
case 2:
{
int value;
printf("\nenter the value to be inserted");
scanf("%d",&value);
insert_at_begning(value);
display();
break;
}
case 3:
{
int value;
printf("\nenter value to be inserted");
scanf("%d",&value);
insert_at_end(value);
display();
break;
}
case 4:
{
insert_at_middle();
display();
break;
}
case 5:
{
delete_from_front();
display();
}break;
case 6:
{
delete_from_end();
display();
break;
}
case 7:
{
display();
delete_from_middle();
display();
break;
}
case 8:display();break;
case 9:
{
exit(0);
}
}
}
getch();
}
```

Output:


Activities
Terminal
Mon 9:11 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc dll.c
[student@localhost 187Z1A0515]$ ./a.out

operations on double linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
enter the value10
10
operations on double linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
enter the value20
10<->20
operations on double linked list
1.creat
```


Activities
Terminal
Mon 9:12 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
10<->20
operations on double linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        1
enter the value30
10<->20<->30
operations on double linked list
1.creat
2.insert at front
3.insert at middle
4.insert at end
5.display
6.delete at front
7.delete at middle
8.delete at end
9.exit
Enter ur choice:        2
insert any value into the node
50
50<->10<->20<->30
operations on double linked list
1.creat
2.insert at front
```

Viva Questions

1) What is double linked list? What are the operations of double linked list?
2) List out the areas in which data structures are applied extensively?
3) Whether linked list is linear or non linear data structure?
4) How many elements can be stored in a double linked list?
5) How can you delete a node in a doubly linked list given only access to that node?

P3

Aim: Write a program that uses functions to perform the following operations on Circular Linked List.:i) Creation ii) Insertion iii) Deletion iv) Traversal

Source Code:

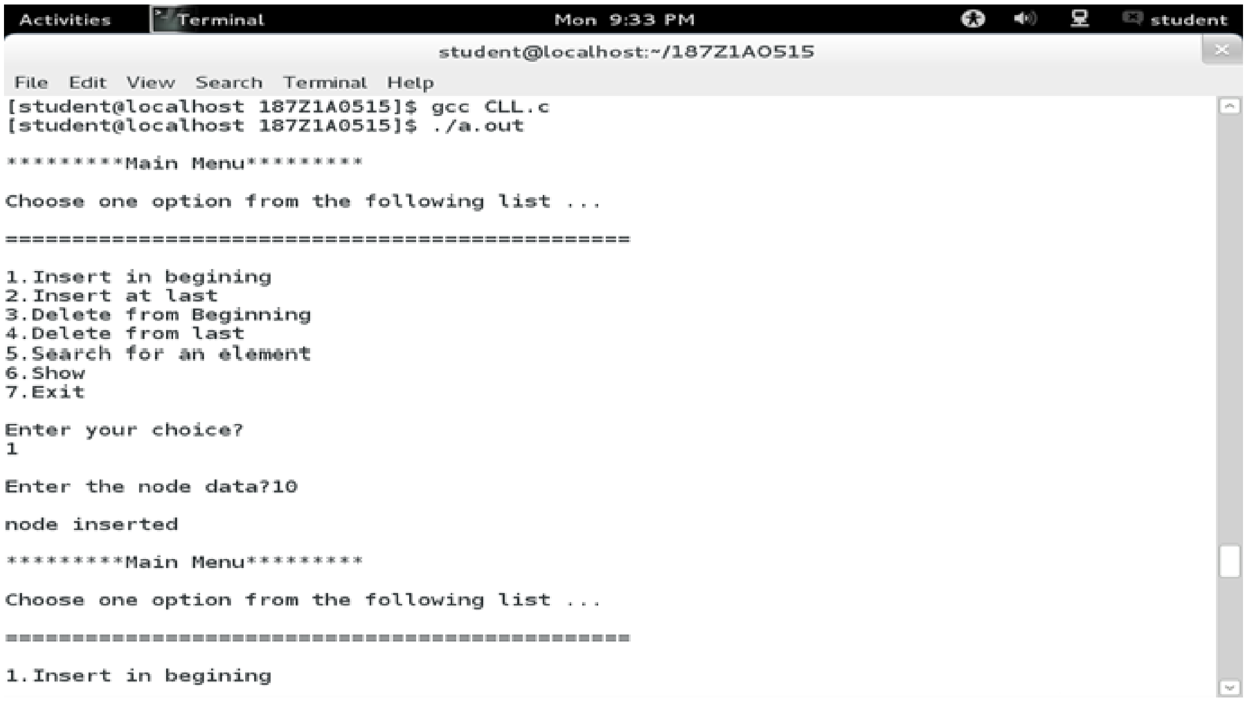
CLL.c

```
#include<stdio.h>
#include<stdlib.h>
struct node
{
int data;
struct node *next;
};
struct node *head;
void beginsert ();
void lastinsert ();
void randominsert();
void begin_delete();
void last_delete();
void random_delete();
void display();
void search();
void main ()
{
int choice =0;
while(choice != 7)
{
printf("\n*********Main Menu*********\n");
printf("\nChoose one option from the following list ...\n");
printf("\n==================================================\n");
printf("\n1.Insert in begining\n2.Insert at last\n3.Delete from Beginning\n4.Delete
from last\n5.Search for an element\n6.Show\n7.Exit\n");
printf("\nEnter your choice?\n");
scanf("\n%d",&choice);
switch(choice)
{
case 1:
beginsert();
break;
case 2:
lastinsert();
break;
case 3:
begin_delete();
break;
case 4:
last_delete();
break;
case 5:
search();
break;
case 6:
display();
break;
case 7:
exit(0);
break;
default:
printf("Please enter valid choice..");
}
}
}
void beginsert()
{
struct node *ptr,*temp;
int item;
ptr = (struct node *)malloc(sizeof(struct node));
if(ptr == NULL)
{
printf("\nOVERFLOW");
}
else
```

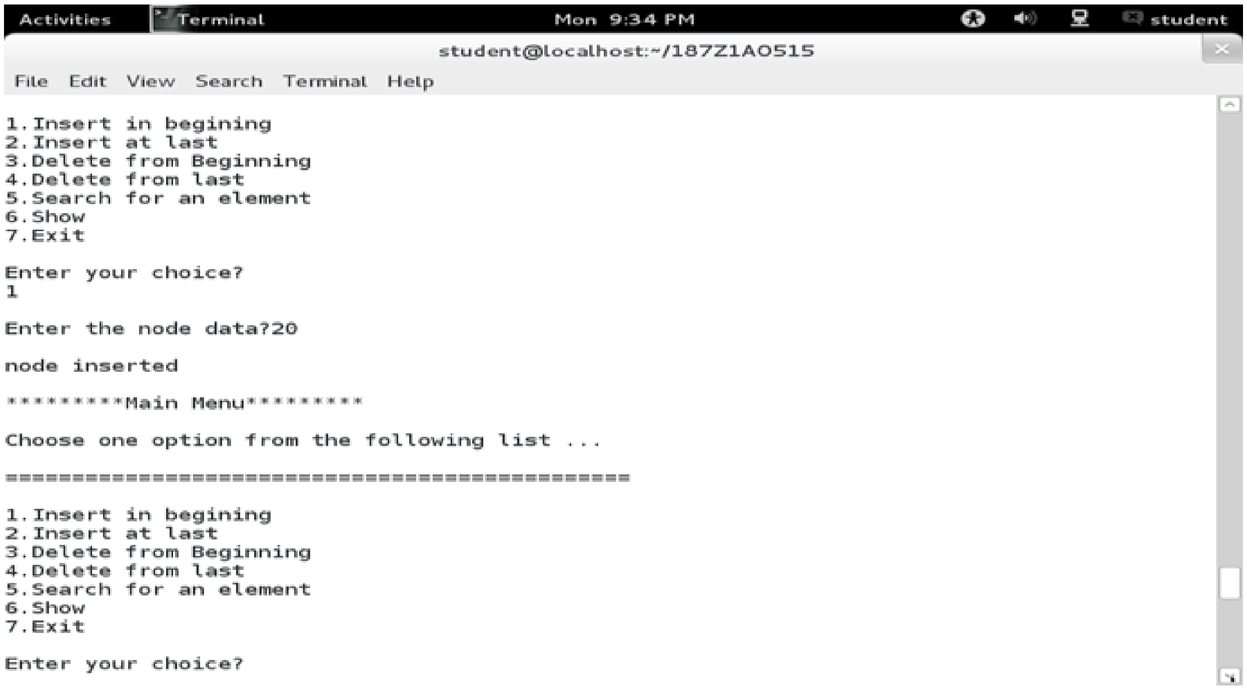
```
{
printf("\nEnter the node data?");
scanf("%d",&item);
ptr -> data = item;
if(head == NULL)
{
head = ptr;
ptr -> next = head;
}
else
{
temp = head;
while(temp->next != head)
temp = temp->next;
ptr->next = head;
temp -> next = ptr;
head = ptr;
}
printf("\nnode inserted\n");
}
}
void lastinsert()
{
struct node *ptr,*temp;
int item;
ptr = (struct node *)malloc(sizeof(struct node));
if(ptr == NULL)
{
printf("\nOVERFLOW\n");
}
else
{
printf("\nEnter Data?");
scanf("%d",&item);
ptr->data = item;
if(head == NULL)
{
head = ptr;
ptr -> next = head;
}
else
{
temp = head;
while(temp -> next != head)
{
temp = temp -> next;
}
temp -> next = ptr;
ptr -> next = head;
}

printf("\nnode inserted\n");
}
}

void begin_delete()
{
struct node *ptr;
if(head == NULL)
{
printf("\nUNDERFLOW");
}
else if(head->next == head)
{
head = NULL;
free(head);
printf("\nnode deleted\n");
}
else
{   ptr = head;
while(ptr -> next != head)
ptr = ptr -> next;
ptr->next = head->next;
free(head);
head = ptr->next;
printf("\nnode deleted\n");
}
}
void last_delete()
{
struct node *ptr, *preptr;
if(head==NULL)
{
printf("\nUNDERFLOW");
}
else if (head ->next == head)
```

```
{
head = NULL;
free(head);
printf("\nnode deleted\n");
}
else
{
ptr = head;
while(ptr ->next != head)
{
preptr=ptr;
ptr = ptr->next;
}
preptr->next = ptr -> next;
free(ptr);
printf("\nnode deleted\n");
}
}
void search()
{
struct node *ptr;
int item,i=0,flag=1;
ptr = head;
if(ptr == NULL)
{
printf("\nEmpty List\n");
}
else
{
printf("\nEnter item which you want to search?\n");
scanf("%d",&item);
if(head ->data == item)
{
printf("item found at location %d",i+1);
flag=0;
}
else
{
while (ptr->next != head)
{
if(ptr->data == item)
{
printf("item found at location %d ",i+1);
flag=0;
break;
}
else
{
flag=1;
}
i++;
ptr = ptr -> next;
}
}
if(flag != 0)
{
printf("Item not found\n");
} } }

void display()
{
struct node *ptr;
ptr=head;
if(head == NULL)
{
printf("\nnothing to print");
}
else
{
printf("\n printing values ... \n");
while(ptr -> next != head)
{
printf("%d\n", ptr -> data);
ptr = ptr -> next;
}
printf("%d\n", ptr -> data);
}
}
```

Output:



```
[student@localhost 187Z1A0515]$ gcc CLL.c
[student@localhost 187Z1A0515]$ ./a.out

*********Main Menu*********

Choose one option from the following list ...

===============================================

1.Insert in begining
2.Insert at last
3.Delete from Beginning
4.Delete from last
5.Search for an element
6.Show
7.Exit

Enter your choice?
1

Enter the node data?10

node inserted

*********Main Menu*********

Choose one option from the following list ...

===============================================

1.Insert in begining
```



```
1.Insert in begining
2.Insert at last
3.Delete from Beginning
4.Delete from last
5.Search for an element
6.Show
7.Exit

Enter your choice?
1

Enter the node data?20

node inserted

*********Main Menu*********

Choose one option from the following list ...

===============================================

1.Insert in begining
2.Insert at last
3.Delete from Beginning
4.Delete from last
5.Search for an element
6.Show
7.Exit

Enter your choice?
```

Viva Questions:

1) What is circular linked list? What are the operations of circular linked list?
2) What is the primary advantage of a linked list?
3) What are the parts of a linked list?
4) How do you insert a new node at the front of a circular linked list?
5) How do you delete an existing node in a circular linked list?

P4

Aim: Write a program that implement Stack (its operations) using Arrays

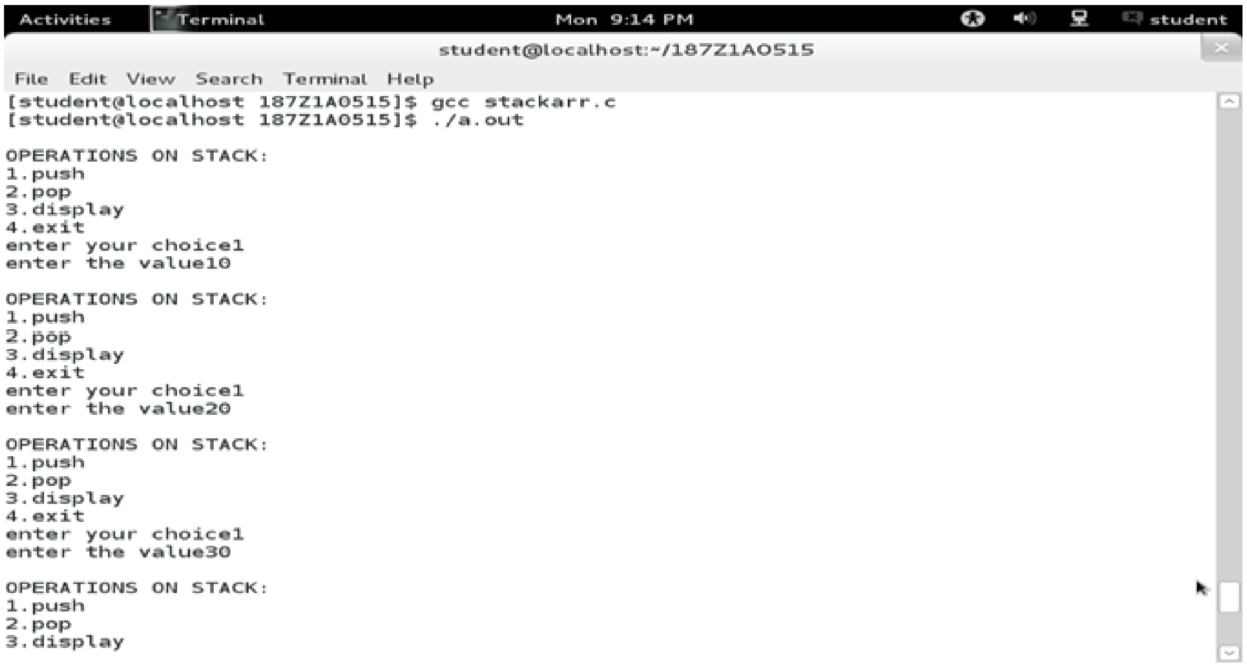
Source Code:

stackarr.c

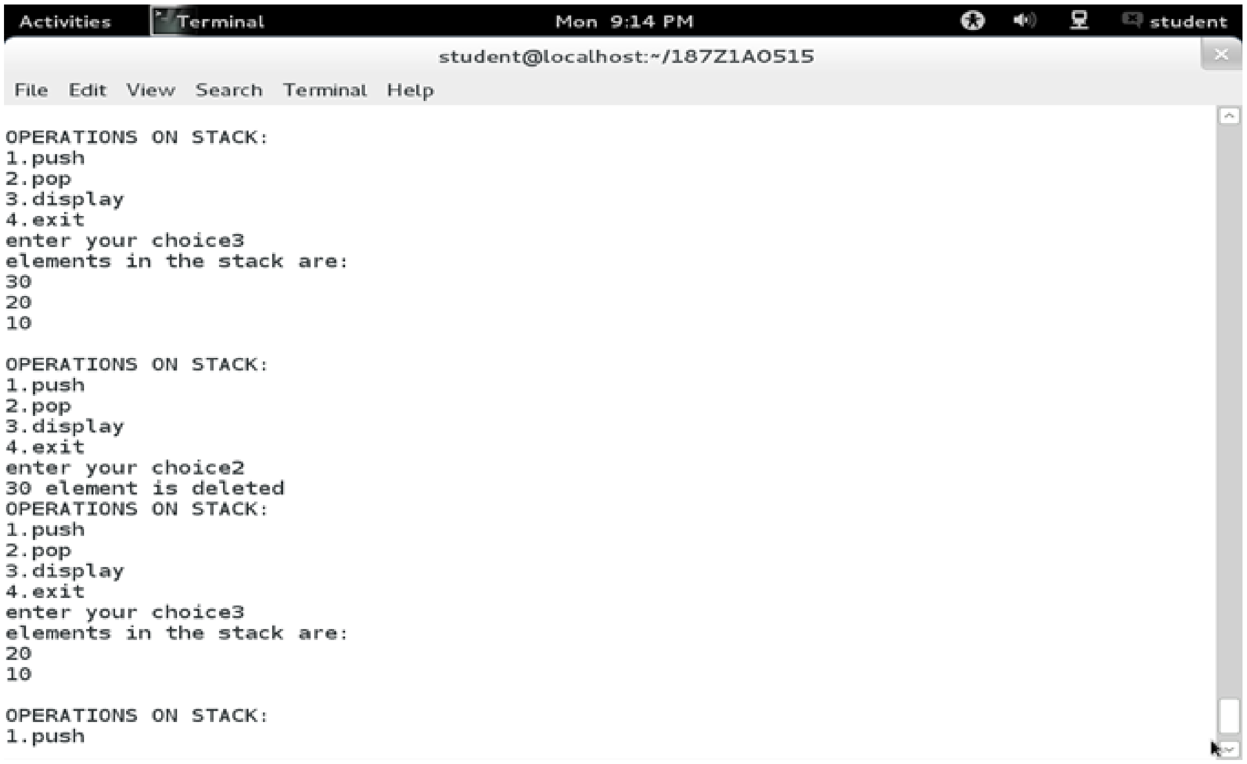
```
#include<stdio.h>
#include<conio.h>
#define max 5
int st[max],top=-1;
void push()
{
int x;
if(top==max-1)
{
printf("stack is full");
return;
}
printf("enter element");
scanf("%d",&x);
top++;
st[top]=x;
}
void pop()
{
int x;
if(top==-1)
{
printf("stack is empty");
return;
}
printf("enter element");
scanf("%d",&x);
top--;
printf("enter deleted element=%d",x);
}
void display()
{
```

```
int i;
if(top==-1)
{
printf("stack is empty");
return;}
for(i=top;i>=0;i--)
{
printf("%d",st[i]);
}}
int main()
{
int ch;
while(1)
{
printf("enter \n1.push\n2.pop\n3.display\n4.exit");
scanf("%d",&ch);
switch(ch)
{
case 1:push();break;
case 2:pop();break;
case 3:display();break;
case 4:exit(1);break;
}}
return 1;
}
```

Output:


Activities
Terminal
Mon 9:14 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc stackarr.c
[student@localhost 187Z1A0515]$ ./a.out

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value10

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value20

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value30

OPERATIONS ON STACK:
1.push
2.pop
3.display
```


Activities
Terminal
Mon 9:14 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice3
elements in the stack are:
30
20
10

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice2
30 element is deleted
OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice3
elements in the stack are:
20
10

OPERATIONS ON STACK:
1.push
```

<u>Viva Questions</u>

1) what is a stack?
2) what is an array?Types of arrays?
3) what are the operations of stack?
4) What is the difference between stack and array?
5) What are advantages of array?

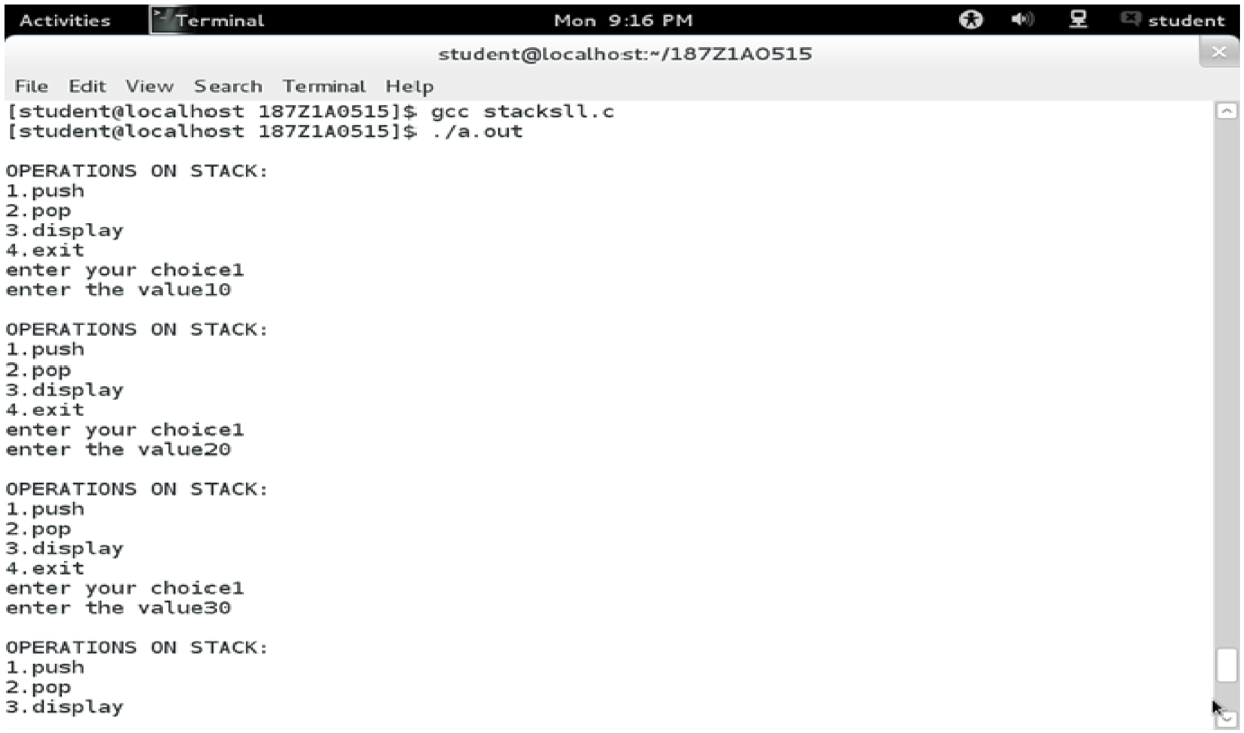
Aim: Write a program that implement Stack (its operations) using Pointers

Source Code:

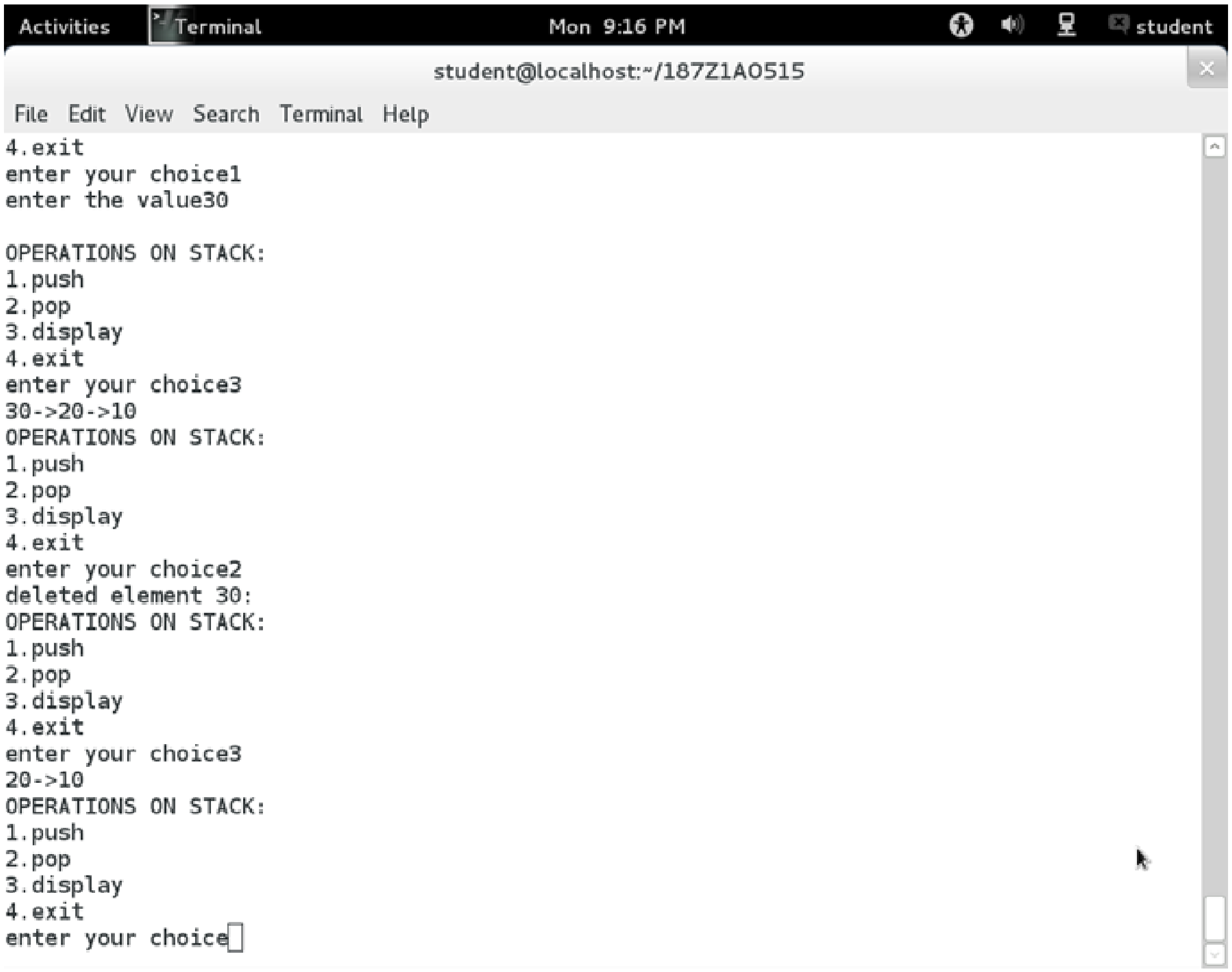
stacksll.c

```
#include<stdio.h>
#include<conio.h>
#include<stdlib.h>
#define MAX 50
int size;
// Defining the stack structure
struct stack {
int arr[MAX];
int top;
};
// Initializing the stack(i.e., top=-1)
void init_stk(struct stack *st) {
st->top = -1;
}
// Entering the elements into stack
void push(struct stack *st, int num) {
if (st->top == size - 1) {
printf("\nStack overflow(i.e., stack full).");
return;
}
st->top++;
st->arr[st->top] = num;
}
//Deleting an element from the stack.
int pop(struct stack *st) {
int num;
if (st->top == -1) {
printf("\nStack underflow(i.e., stack empty).");
return NULL;
}
num = st->arr[st->top];
st->top--;
return num;
}
void display(struct stack *st) {
int i;
for (i = st->top; i >= 0; i--)
printf("\n%d", st->arr[i]);
}
int main() {
int element, opt, val;
struct stack ptr;
init_stk(&ptr);
printf("\nEnter Stack Size :");
scanf("%d", &size);
while (1) {
printf("\n\nSTACK PRIMITIVE OPERATIONS");
printf("\n1.PUSH");
printf("\n2.POP");
printf("\n3.DISPLAY");
printf("\n4.QUIT");
printf("\n");
printf("\nEnter your option : ");
scanf("%d", &opt);
switch (opt) {
case 1:
printf("\nEnter the element into stack:");
scanf("%d", &val);
push(&ptr, val);
break;
case 2:       element = pop(&ptr);
printf("\nThe element popped from stack is : %d", element);
break;
case 3:
printf("\nThe current stack elements are:");
display(&ptr);
break;
case 4:
exit(0);
default:
printf("\nEnter correct option!Try again.");
}
}
return (0);}
```

Output:


Activities
Terminal
Mon 9:16 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc stacksll.c
[student@localhost 187Z1A0515]$ ./a.out

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value10

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value20

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice1
enter the value30

OPERATIONS ON STACK:
1.push
2.pop
3.display
```


Activities
Terminal
Mon 9:16 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
4.exit
enter your choice1
enter the value30

OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice3
30->20->10
OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice2
deleted element 30:
OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice3
20->10
OPERATIONS ON STACK:
1.push
2.pop
3.display
4.exit
enter your choice
```

Viva questions

1) What is pointer?
2) Differentiate stack from array?
3) Can we change the size of an array at run time?
4) What is the difference between an array and a pointer in C?

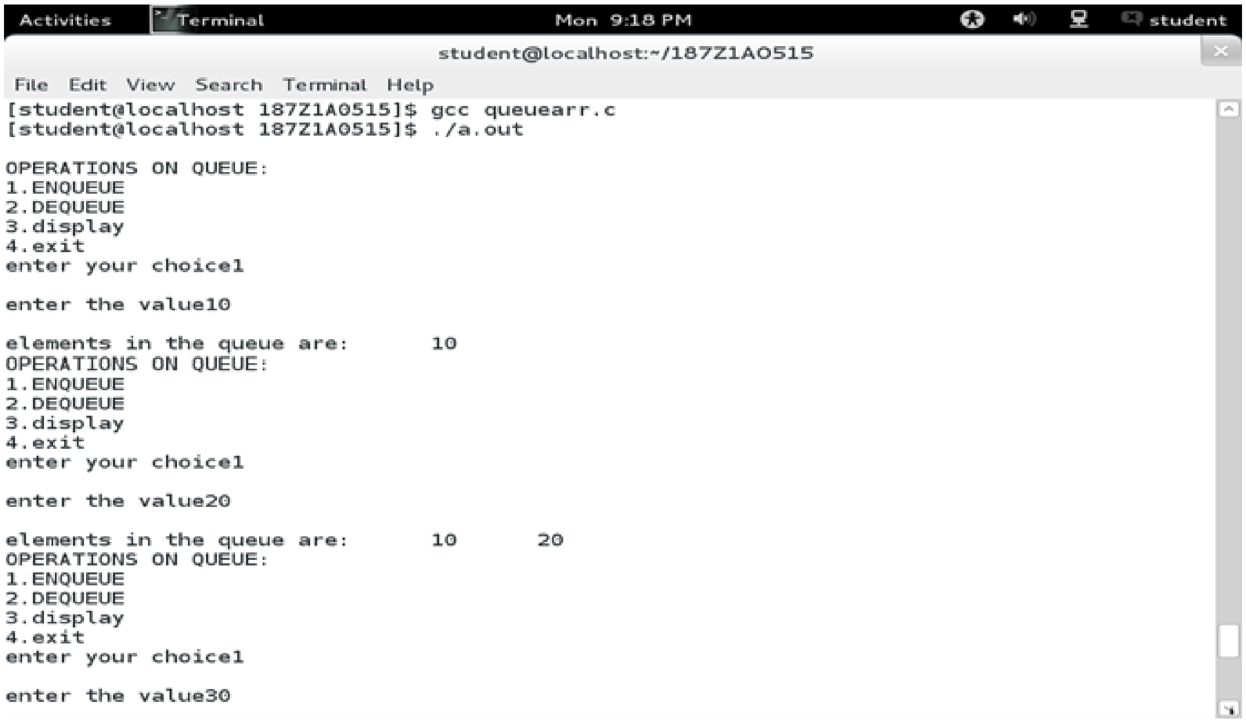
P5

Aim: Write a program that implement Queue (its operations) using Arrays

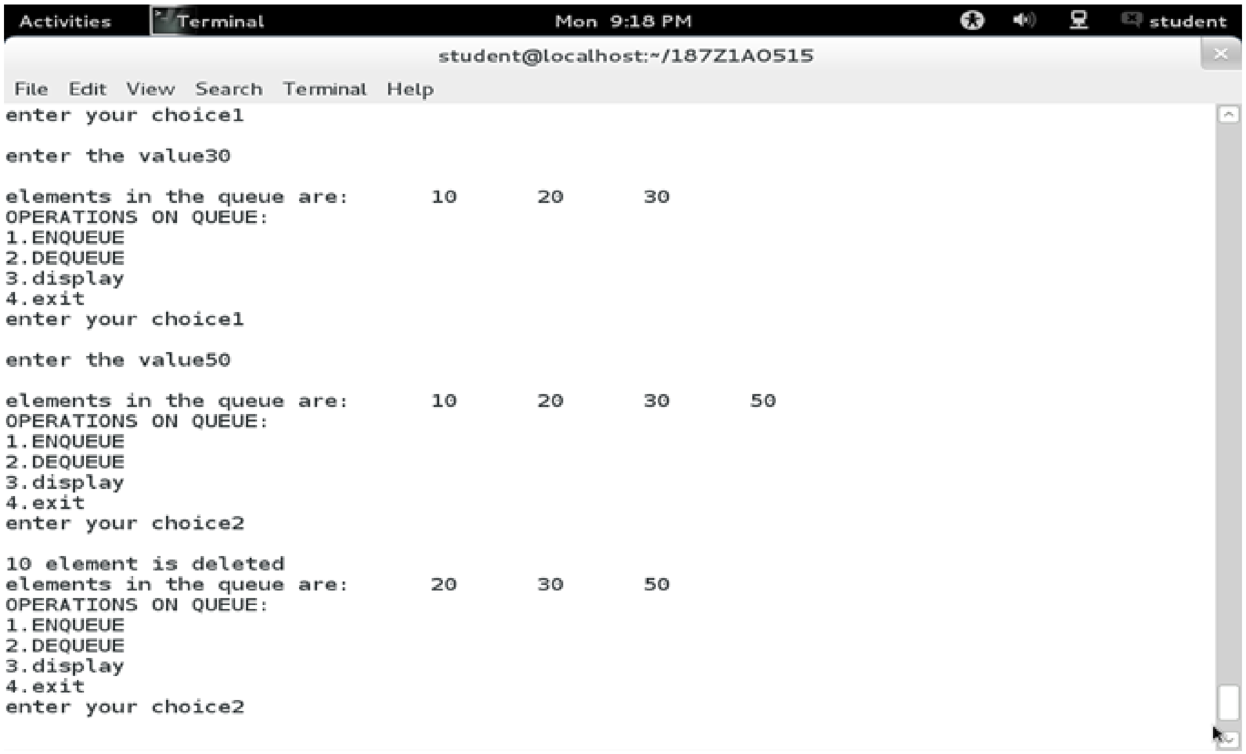
Source Code:

queuearr.c

```
#include<stdio.h>
#include<conio.h>
#define SIZE 5
int queue[SIZE], front = -1, rear = -1;
void enQueue(int value){
if(rear == SIZE-1)
printf("\nQueue is Full!!! Insertion is not possible!!!");
else{
if(front == -1)
front = 0;
rear++;
queue[rear] = value;
printf("\nInsertion success!!!");
}
}
void deQueue(){
if(front == rear)
printf("\nQueue is Empty!!! Deletion is not possible!!!");
else{
printf("\nDeleted : %d", queue[front]);
front++;
if(front == rear)
front = rear = -1;
}
}
void display(){
if(rear == -1)
printf("\nQueue is Empty!!!");
else{
int i;
printf("\nQueue elements are:\n");
for(i=front; i<=rear; i++)
printf("%d\t",queue[i]);
}
}
void main()
{
int value, choice;
while(1){
printf("\n\n***** MENU *****\n");
printf("1. Insertion\n2. Deletion\n3. Display\n4. Exit");
printf("\nEnter your choice: ");
scanf("%d",&choice);
switch(choice){
case 1: printf("Enter the value to be insert: ");
scanf("%d",&value);
enQueue(value);
break;
case 2: deQueue();
break;
case 3: display();
break;
case 4: exit(0);
default: printf("\nWrong selection!!! Try again!!!");
}
}
}
```
Output:


Activities
Terminal
Mon 9:18 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc queuearr.c
[student@localhost 187Z1A0515]$ ./a.out

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value10

elements in the queue are:      10
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value20

elements in the queue are:      10      20
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value30
```


Activities
Terminal
Mon 9:18 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
enter your choice1

enter the value30

elements in the queue are:      10      20      30
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value50

elements in the queue are:      10      20      30      50
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice2

10 element is deleted
elements in the queue are:      20      30      50
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice2
```

Viva Questions:

1) What is Queue?operations of Queue?
2) What is enqueue?
3) What is dequeue?
4) Characteristics of Queue?
5) How does a queue work?

Aim: Write a program that implement Queue (its operations) using Pointers

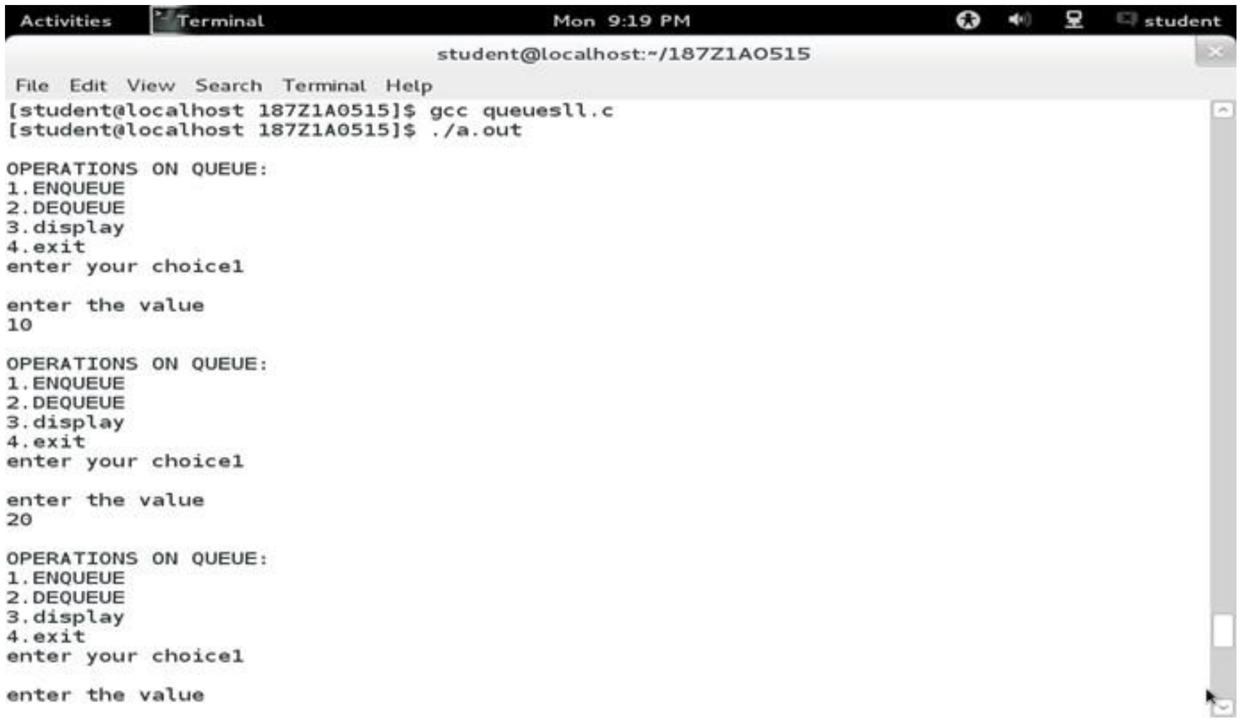
Source Code:

queuesll.c

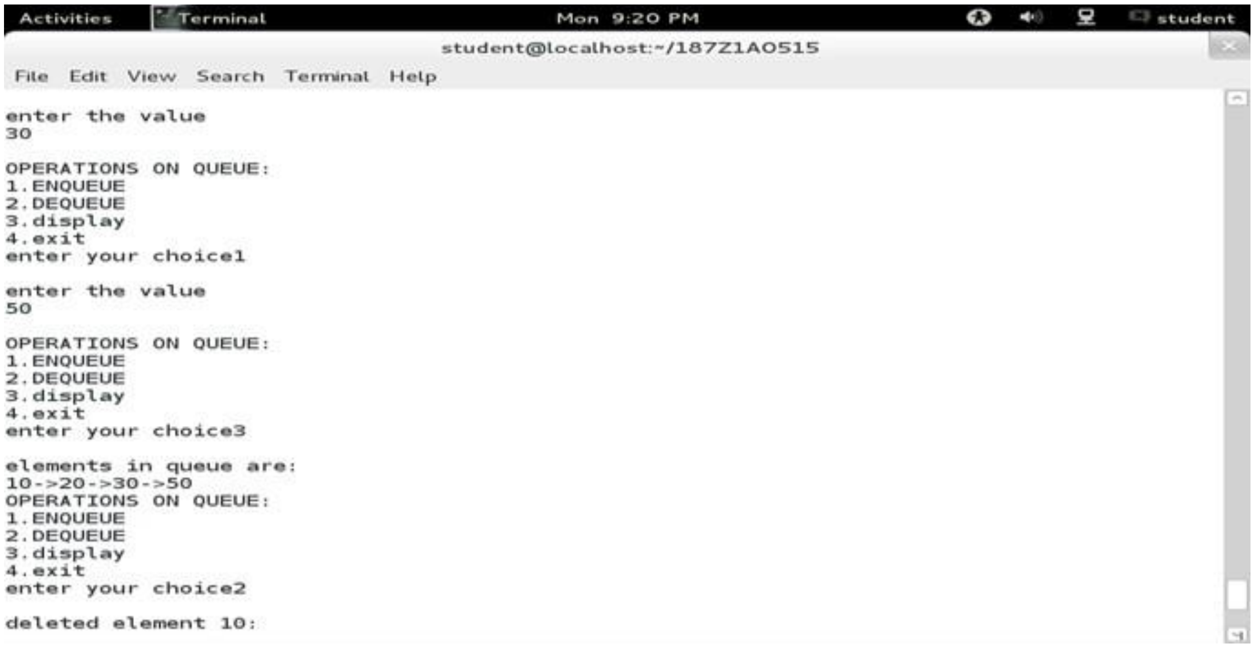
```
#include<stdlib.h>
struct q
{
int no;
struct q *next;
}
*start=NULL;
void add();
int del();
void display();
void main()
{
int ch;
char choice;
while(1)
{
printf(" \n MENU \n");
printf("\n1.Insert an element in Queue\n");
printf("\n2.Delete an element from Queue\n");
printf("\n3.Display the Queue\n");
printf("\n4.Exit!\n");
printf("\nEnter your choice:");
scanf("%d",&ch);
switch(ch)
{
case 1:add();
break;
case 2:
printf("\nThe deleted element is=%d",del());
break;
case 3:display();
getch();
break;
case 4:exit(0);
break;
default:printf("\nYou entered wrong choice");
getch();
break;
}
}
getch();
}
void add()
{
struct q *p,*temp;
temp=start;
p=(struct q*)malloc(sizeof(struct q));
printf("\nEnter the element:");
scanf("%d",&p->no);
p->next=NULL;
if(start==NULL)
{
start=p;
}
else
{
while(temp->next!=NULL)
{
temp=temp->next;
}
temp->next=p;
}
}
int del()
{
struct q *temp;
int value;
if(start==NULL)
{
printf("\nQueue is Empty");
getch();
return(0);
}
else
{
temp=start;
value=temp->no;
start=start->next;
free(temp);
```

```
}
return(value);
}
void display()
{
struct q *temp;
temp=start;
if(temp==NULL)
printf("queue is empty");
else
{
while(temp->next!=NULL)
{
printf("\nno=%d",temp->no);
temp=temp->next;
}
printf("\nno=%d",temp->no);
}
getch();
}
```

<u>Output:</u>


Activities
Terminal
Mon 9:19 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc queuesll.c
[student@localhost 187Z1A0515]$ ./a.out

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value
10

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value
20

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value
```


Activities
Terminal
Mon 9:20 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
enter the value
30

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice1

enter the value
50

OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice3

elements in queue are:
10->20->30->50
OPERATIONS ON QUEUE:
1.ENQUEUE
2.DEQUEUE
3.display
4.exit
enter your choice2

deleted element 10:
```

VIVA QUESTIONS

1) What are the disadvantages of representing a stack or Queue by a linked list?
2) How to create an Array?
3) Can we change the size of an array at run time?
4) Can you declare an array without assigning the size of an array?
5) What is the default value of Array?

P6

Aim:

Write a program that implements Quick Sort Method to sort a given list of integers in ascending order.

Source Code:

Quicksort.c

```
#include <stdio.h>
// function to swap elements
void swap(int *a, int *b) {
int t = *a;
  *a = *b;
  *b = t;
}
```

```
// function to find the partition position
int partition(int array[], int low, int high)
 {
  // select the rightmost element as pivot
  int pivot = array[high];
  // pointer for greater element
  int i = (low - 1);
  // traverse each element of the array
  // compare them with the pivot
  for (int j = low; j < high; j++) {
  if (array[j] <= pivot) {
    // if element smaller than pivot is found
      // swap it with the greater element pointed by i
      i++;
     // swap element at i with element at j
      swap(&array[i], &array[j]);
    }
  }
// swap the pivot element with the greater element at i
  swap(&array[i + 1], &array[high]);
  // return the partition point
  return (i + 1);
}
void quickSort(int array[], int low, int high) {
  if (low < high) {
     // find the pivot element such that
    // elements smaller than pivot are on left of pivot
    // elements greater than pivot are on right of pivot
    int pi = partition(array, low, high);
    // recursive call on the left of pivot
    quickSort(array, low, pi - 1);
    // recursive call on the right of pivot
    quickSort(array, pi + 1, high);
  }
}
// function to print array elements
void printArray(int array[], int size) {
for (int i = 0; i < size; ++i) {
    printf("%d  ", array[i]);
  }
  printf("\n");
}
// main function
```

```
int main() {
  int data[] = {8, 7, 2, 1, 0, 9, 6};
   int n = sizeof(data) / sizeof(data[0]);
  printf("Unsorted Array\n");
  printArray(data, n);
  // perform quicksort on data
  quickSort(data, 0, n - 1);
   printf("Sorted array in ascending order: \n");
  printArray(data, n);
}
```

OUTPUT:

```
Unsorted Array
8  7  2  1  0  9  6
Sorted array in ascending order:
O 1  2  6  7  8  9
```

Aim: Write a program that implements Heap Sort Method to sort a given list of integers in ascending order.

Source Code:

Heapsort.c

```
// Heap Sort in C
 #include <stdio.h>
  // Function to swap the the position of two elements
  void swap(int *a, int *b) {
    int temp = *a;
    *a = *b;
    *b = temp;
  }
  void heapify(int arr[], int n, int i) {
    // Find largest among root, left child and right child
    int largest = i;
    int left = 2 * i + 1;
    int right = 2 * i + 2;
   if (left < n && arr[left] > arr[largest])
      largest = left;
  if (right < n && arr[right] > arr[largest])
      largest = right;
// Swap and continue heapifying if root is not largest
```

```
    if (largest != i) {
      swap(&arr[i], &arr[largest]);
      heapify(arr, n, largest);
    }
  }
// Main function to do heap sort
  void heapSort(int arr[], int n) {
    // Build max heap
    for (int i = n / 2 - 1; i >= 0; i--)
      heapify(arr, n, i);
 // Heap sort
    for (int i = n - 1; i >= 0; i--) {
      swap(&arr[0], &arr[i]);
 // Heapify root element to get highest element at root again
      heapify(arr, i, 0);
    }
  }
 // Print an array
  void printArray(int arr[], int n) {
    for (int i = 0; i < n; ++i)
 printf("%d ", arr[i]);
printf("\n");
  }
 // Driver code
  int main() {
int arr[] = {1, 12, 9, 5, 6, 10};
int n = sizeof(arr) / sizeof(arr[0]);
heapSort(arr, n);
printf("Sorted array is \n");
 printArray(arr, n);
  }
```

OUTPUT:

```
Sorted array is
1 5 6 9 10 12
```

Aim: Write a program that implements Marge Sort Method to sort a given list of integers in ascending order.

Source Code:

margesort.c

```
// Merge sort in C
#include <stdio.h>
// Merge two subarrays L and M into arr
void merge(int arr[], int p, int q, int r)
 {
 // Create L ← A[p..q] and M ← A[q+1..r]
  int n1 = q - p + 1;
  int n2 = r - q;
int L[n1], M[n2];
for (int i = 0; i < n1; i++)
  L[i] = arr[p + i];
  for (int j = 0; j < n2; j++)
    M[j] = arr[q + 1 + j];
  // Maintain current index of sub-arrays and main array
  int i, j, k;
  i = 0;
  j = 0;
  k = p;
  // Until we reach either end of either L or M, pick larger among
  // elements L and M and place them in the correct position at A[p..r]
  while (i < n1 && j < n2) {
    if (L[i] <= M[j]) {
      arr[k] = L[i];
      i++;
    } else {
      arr[k] = M[j];
      j++;
    }
    k++;
  }
  // When we run out of elements in either L or M,
  // pick up the remaining elements and put in A[p..r]
  while (i < n1) {
    arr[k] = L[i];
    i++;
    k++;
  }
  while (j < n2) {
    arr[k] = M[j];
    j++;
    k++;
  }
}
// Divide the array into two subarrays, sort them and merge them
void mergeSort(int arr[], int l, int r) {
  if (l < r) {
 // m is the point where the array is divided into two subarrays
    int m = l + (r - l) / 2;
mergeSort(arr, l, m);
mergeSort(arr, m + 1, r);
  // Merge the sorted subarrays
 merge(arr, l, m, r);
  }
}
// Print the array
void printArray(int arr[], int size) {
  for (int i = 0; i < size; i++)
  printf("%d ", arr[i]);
  printf("\n");
}
// Driver program
int main() {
  int arr[] = {6, 5, 12, 10, 9, 1};
  int size = sizeof(arr) / sizeof(arr[0]);
  mergeSort(arr, 0, size - 1);
  printf("Sorted array: \n");
  printArray(arr, size);
}
```

OUTPUT:

```
Sorted array:
1 5 6 9 10 12
```

Viva Questions

1) what is quick sort?
2) what are the issues that hamper the efficiency in sorting a file?
3) What is heap sort?

4) What is merge sort?
5) What is slection sort?

P7

Aim: Write a program to implement the tree traversal methods (Recursive and Non-Recursive)

Source Code:

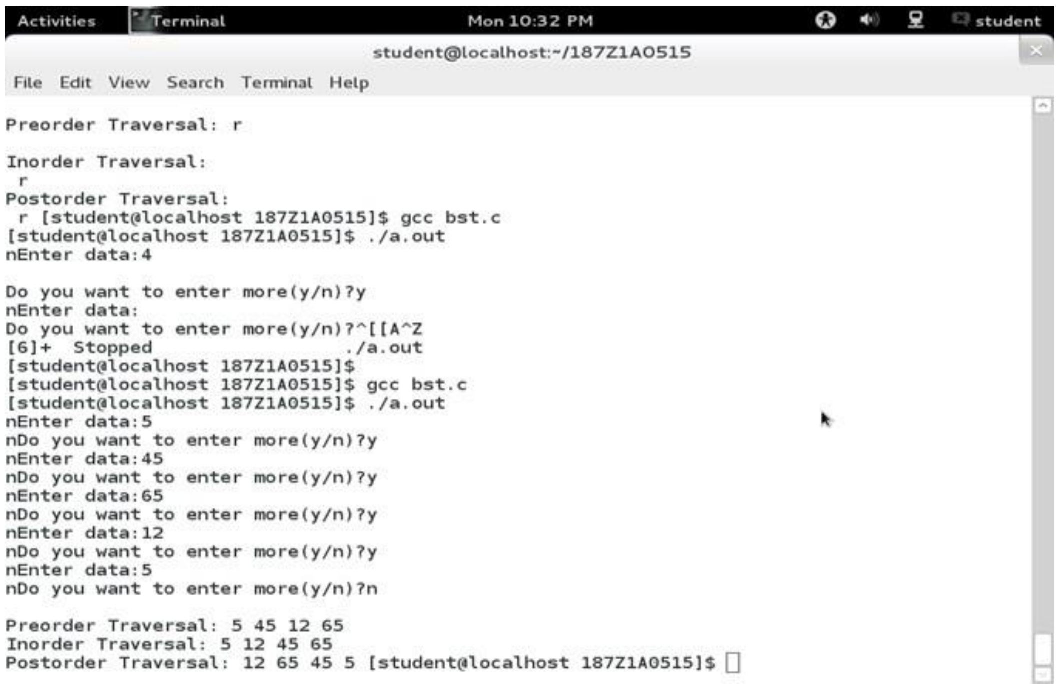
bst.c

```
#include<stdio.h>
#include<stdlib.h>
typedef struct BST
{
int data;
struct BST *left;
struct BST *right;
}node;
node *create();
void insert(node *,node *);
void preorder(node *);
void inorder(node *);
void postorder(node *);
int main()
{
char ch;
node *root=NULL,*temp;
do
{
temp=create();
if(root==NULL)
root=temp;
else
insert(root,temp);
printf("nDo you want to enter more(y/n)?");
getchar();
scanf("%c",&ch);
}while(ch=='y'|ch=='Y');
printf("\nPreorder Traversal: ");
preorder(root);
```

```
printf("\nInorder Traversal: ");
inorder(root);
printf("\nPostorder Traversal: ");
postorder(root);
return 0;
}
node *create()
{
node *temp;
printf("nEnter data:");
temp=(node*)malloc(sizeof(node));
scanf("%d",&temp->data);
temp->left=temp->right=NULL;
return temp;
}
void insert(node *root,node *temp)
{
if(temp->data<root->data)
{
if(root->left!=NULL)
insert(root->left,temp);
else
root->left=temp;
}
if(temp->data>root->data)
{
if(root->right!=NULL)
insert(root->right,temp);
else
root->right=temp;
}
}
void preorder(node *root)
{
if(root!=NULL)
{
printf("%d ",root->data);
preorder(root->left);
preorder(root->right);
}
}
void inorder(node *root)
{
```

```
if(root!=NULL)
{
inorder(root->left);
printf("%d ",root->data);
inorder(root->right);
}
}
void postorder(node *root)
{
if(root!=NULL)
{
postorder(root->left);
postorder(root->right);
printf("%d ",root->data);
}
}
```

Output:


Activities
Terminal
Mon 10:32 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
Preorder Traversal: r

Inorder Traversal:
 r
Postorder Traversal:
 r [student@localhost 187Z1A0515]$ gcc bst.c
[student@localhost 187Z1A0515]$ ./a.out
nEnter data:4

Do you want to enter more(y/n)?y
nEnter data:
Do you want to enter more(y/n)?^[[A^Z
[6]+  Stopped                 ./a.out
[student@localhost 187Z1A0515]$
[student@localhost 187Z1A0515]$ gcc bst.c
[student@localhost 187Z1A0515]$ ./a.out
nEnter data:5
nDo you want to enter more(y/n)?y
nEnter data:45
nDo you want to enter more(y/n)?y
nEnter data:65
nDo you want to enter more(y/n)?y
nEnter data:12
nDo you want to enter more(y/n)?y
nEnter data:5
nDo you want to enter more(y/n)?n

Preorder Traversal: 5 45 12 65
Inorder Traversal: 5 12 45 65
Postorder Traversal: 12 65 45 5 [student@localhost 187Z1A0515]$ 
```

b) Write a program to implement the tree traversal methods using Non-Recursive.

```
#include  <stdio.h>
#include <stdlib.h>
struct node
{
    int a;
    struct node *left;
    struct node *right;
};
 void generate(struct node **, int);
int search(struct node *, int);
void delete(struct node **);
 int main()
{
    struct node *head = NULL;
    int choice = 0, num, flag = 0, key;
 do
    {
        printf("\nEnter your choice:\n1. Insert\n2. Search\n3. Exit\nChoice: ");
        scanf("%d", &choice);
        switch(choice)
        {
        case 1:
            printf("Enter element to insert: ");
            scanf("%d", &num);
   generate(&head, num);
            break;
        case 2:
            printf("Enter key to search: ");
            scanf("%d", &key);
            flag = search(head, key);
            if (flag)
            {
                printf("Key found in tree\n");
            }
            else
            {
                printf("Key not found\n");
            }
            break;
        case 3:
            delete(&head);
            printf("Memory Cleared\nPROGRAM TERMINATED\n");
            break;
        default: printf("Not a valid input, try again\n");
        }
    } while (choice != 3);
    return 0;
```

```
}

void generate(struct node **head, int num)
{
   struct node *temp = *head, *prev = *head;

   if (*head == NULL)
   {
      *head = (struct node *)malloc(sizeof(struct node));
      (*head)->a = num;
      (*head)->left = (*head)->right = NULL;
   }
   else
   {
      while (temp != NULL)
      {
         if (num > temp->a)
         {
            prev = temp;
            temp = temp->right;
         }
         else
         {
            prev = temp;
            temp = temp->left;
         }
      }
      temp = (struct node *)malloc(sizeof(struct node));
      temp->a = num;
      if (num >= prev->a)
      {
         prev->right = temp;
      }
      else
      {
         prev->left = temp;
      }
   }
}

int search(struct node *head, int key)
{
   while (head != NULL)
```

```
    {
        if (key > head->a)
        {
            head = head->right;
        }
        else if (key < head->a)
        {
            head = head->left;
        }
        else
        {
            return 1;
        }
    }
          return 0;
}
 void delete(struct node **head)
{
    if (*head != NULL)
    {
        if ((*head)->left)
        {
            delete(&(*head)->left);
        }
        if ((*head)->right)
        {
            delete(&(*head)->right);
        }
        free(*head);
    }
}
```

OUTPUT:

```
Enter your choice:
1. Insert
2. Search
3. Exit
Choice: 1
Enter element to insert: 1
Enter your choice:
1. Insert
2. Search
3. Exit
```

```
Choice: 1
Enter element to insert: 2
Enter your choice:
1. Insert
2. Search
3. Exit
Choice: 1
Enter element to insert: 3
Enter your choice:
1. Insert
2. Search
3. Exit
Choice: 2
Enter key to search: 2
Key found in tree
Enter your choice:
1. Insert
2. Search
3. Exit
Choice:
```

Viva Questions

1) What is a tree?
2) What is BST?
3) In tree construction which is the suitable efficient data structure?
4) What is the important of tree traversal in data structure?
5) What is a leaf node?

P8

Aim: Write a program to implement i) Binary Search Tree ii) B Tree iii) B+ Tree iv) AVL Tree v) Red-Black Tree

Source code:
Bst.c

```c
#include  <stdio.h>
#include <stdlib.h>
struct node {
  int key;
  struct node *left, *right;
};
```

```
// Create a node
struct node *newNode(int item) {
  struct node *temp = (struct node *)malloc(sizeof(struct node));
  temp->key = item;
  temp->left = temp->right = NULL;
  return temp;
}
// Inorder Traversal
void inorder(struct node *root) {
  if (root != NULL) {
    // Traverse left
    inorder(root->left);
 // Traverse root
    printf("%d -> ", root->key);
 // Traverse right
    inorder(root->right);
  }
}
// Insert a node
struct node *insert(struct node *node, int key) {
  // Return a new node if the tree is empty
  if (node == NULL) return newNode(key);
 // Traverse to the right place and insert the node
  if (key < node->key)
    node->left = insert(node->left, key);
  else
    node->right = insert(node->right, key);
 return node;
}
// Find the inorder successor
struct node *minValueNode(struct node *node) {
  struct node *current = node;
 // Find the leftmost leaf
  while (current && current->left != NULL)
    current = current->left;
  return current;
}
// Deleting a node
struct node *deleteNode(struct node *root, int key) {
  // Return if the tree is empty
  if (root == NULL) return root;
  // Find the node to be deleted
  if (key < root->key)
```

```
    root->left = deleteNode(root->left, key);
  else if (key > root->key)
    root->right = deleteNode(root->right, key);
else {
    // If the node is with only one child or no child
    if (root->left == NULL) {
      struct node *temp = root->right;
      free(root);
      return temp;
    } else if (root->right == NULL) {
      struct node *temp = root->left;
      free(root);
      return temp;
    }
   // If the node has two children
    struct node *temp = minValueNode(root->right);
 // Place the inorder successor in position of the node to be deleted
    root->key = temp->key;
 // Delete the inorder successor
    root->right = deleteNode(root->right, temp->key);
  }
  return root;
}
// Driver code
int main() {
  struct node *root = NULL;
  root = insert(root, 8);
  root = insert(root, 3);
  root = insert(root, 1);
  root = insert(root, 6);
  root = insert(root, 7);
  root = insert(root, 10);
  root = insert(root, 14);
  root = insert(root, 4);

printf("Inorder traversal: ");
  inorder(root);
 printf("\nAfter deleting 10\n");
  root = deleteNode(root, 10);
  printf("Inorder traversal: ");
  inorder(root);
}
```

OUTPUT:

```
Inorder traversal: 1 -> 3 -> 4 -> 6 -> 7 -> 8 -> 10 -> 14 ->
After deleting 10
Inorder traversal: 1 -> 3 -> 4 -> 6 -> 7 -> 8 -> 14 ->
```

Aim: Write a program to implement B Tee.

Source code:
Bt.c

```
// Searching a key on a B-tree in C

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

#define MAX 3
#define MIN 2

struct BTreeNode {
  int val[MAX + 1], count;
  struct BTreeNode *link[MAX + 1];
};

struct BTreeNode *root;

// Create a node
struct BTreeNode *createNode(int val, struct BTreeNode *child) {
  struct BTreeNode *newNode;
  newNode = (struct BTreeNode *)malloc(sizeof(struct BTreeNode));
  newNode->val[1] = val;
  newNode->count = 1;
  newNode->link[0] = root;
  newNode->link[1] = child;
  return newNode;
}

// Insert node
void insertNode(int val, int pos, struct BTreeNode *node,
        struct BTreeNode *child) {
  int j = node->count;
  while (j > pos) {
    node->val[j + 1] = node->val[j];
    node->link[j + 1] = node->link[j];
    j--;
  }
  node->val[j + 1] = val;
  node->link[j + 1] = child;
  node->count++;
}

// Split node
void splitNode(int val, int *pval, int pos, struct BTreeNode *node,
         struct BTreeNode *child, struct BTreeNode **newNode) {
  int median, j;

  if (pos > MIN)
  median = MIN + 1;
  else
    median = MIN;

  *newNode = (struct BTreeNode *)malloc(sizeof(struct BTreeNode));
  j = median + 1;
  while (j <= MAX) {
    (*newNode)->val[j - median] = node->val[j];
    (*newNode)->link[j - median] = node->link[j];
    j++;
  }
  node->count = median;
  (*newNode)->count = MAX - median;

  if (pos <= MIN) {
    insertNode(val, pos, node, child);
  } else {
    insertNode(val, pos - median, *newNode, child);
  }
  *pval = node->val[node->count];
  (*newNode)->link[0] = node->link[node->count];
  node->count--;
}

// Set the value
int setValue(int val, int *pval,
           struct BTreeNode *node, struct BTreeNode **child) {
```

```
  int pos;
  if (!node) {
    *pval = val;
    *child = NULL;
    return 1;
  }

  if (val < node->val[1]) {
    pos = 0;
  } else {
    for (pos = node->count;
       (val < node->val[pos] && pos > 1); pos--)
      ;
    if (val == node->val[pos]) {
      printf("Duplicates are not permitted\n");
      return 0;
    }
  }
  if (setValue(val, pval, node->link[pos], child)) {
    if (node->count < MAX) {
      insertNode(*pval, pos, node, *child);
    } else {
      splitNode(*pval, pval, pos, node, *child, child);
      return 1;
    }
  }
  return 0;
}

// Insert the value
void insert(int val) {
int flag, i;
  struct BTreeNode *child;

  flag = setValue(val, &i, root, &child);
  if (flag)
    root = createNode(i, child);
}

// Search node
void search(int val, int *pos, struct BTreeNode *myNode) {
  if (!myNode) {
    return;
  }

  if (val < myNode->val[1]) {
    *pos = 0;
  } else {
    for (*pos = myNode->count;
       (val < myNode->val[*pos] && *pos > 1); (*pos)--)
      ;
    if (val == myNode->val[*pos]) {
      printf("%d is found", val);
      return;
    }
  }
  search(val, pos, myNode->link[*pos]);

  return;
}

// Traverse then nodes
void traversal(struct BTreeNode *myNode) {
  int i;
  if (myNode) {
    for (i = 0; i < myNode->count; i++) {
      traversal(myNode->link[i]);
      printf("%d ", myNode->val[i + 1]);
    }
    traversal(myNode->link[i]);
  }
}

int main() {
  int val, ch;
  insert(8);
  insert(9);
  insert(10);
  insert(11);
  insert(15);
  insert(16);
  insert(17);
  insert(18);
  insert(20);
  insert(23);
  traversal(root);
```

```
 printf("\n");
  search(11, &ch, root);
}
```

OUTPUT:

```
8 9 10 11 15 16 17 18 20 23
11 is found
```

Aim: Write a program to implement B+ Tree.

Source code:

B+t.c

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

// Default order
#define ORDER 3

typedef struct record {
  int value;
} record;

// Node
typedef struct node {
  void **pointers;
  int *keys;
  struct node *parent;
  bool is_leaf;
  int num_keys;
  struct node *next;
} node;

int order = ORDER;
node *queue = NULL;
bool verbose_output = false;

// Enqueue
void enqueue(node *new_node);
```

```
// Dequeue
node *dequeue(void);
int height(node *const root);
int pathToLeaves(node *const root, node *child);
void printLeaves(node *const root);
void printTree(node *const root);
void findAndPrint(node *const root, int key, bool verbose);
void findAndPrintRange(node *const root, int range1, int range2, bool verbose);
int findRange(node *const root, int key_start, int key_end, bool verbose,
        int returned_keys[], void *returned_pointers[]);
node *findLeaf(node *const root, int key, bool verbose);
record *find(node *root, int key, bool verbose, node **leaf_out);
int cut(int length);

record *makeRecord(int value);
node *makeNode(void);
node *makeLeaf(void);
int getLeftIndex(node *parent, node *left);
node *insertIntoLeaf(node *leaf, int key, record *pointer);
node *insertIntoLeafAfterSplitting(node *root, node *leaf, int key,
                   record *pointer);
node *insertIntoNode(node *root, node *parent,
           int left_index, int key, node *right);
node *insertIntoNodeAfterSplitting(node *root, node *parent,
                   int left_index,
                   int key, node *right);
node *insertIntoParent(node *root, node *left, int key, node *right);
node *insertIntoNewRoot(node *left, int key, node *right);
node *startNewTree(int key, record *pointer);
node *insert(node *root, int key, int value);

// Enqueue
void enqueue(node *new_node) {
  node *c;
  if (queue == NULL) {
    queue = new_node;
    queue->next = NULL;
  } else {
    c = queue;
    while (c->next != NULL) {
      c = c->next;
    }
    c->next = new_node;
    new_node->next = NULL;
  }
}

// Dequeue
node *dequeue(void) {
  node *n = queue;
  queue = queue->next;
  n->next = NULL;
  return n;
}

// Print the leaves
void printLeaves(node *const root) {
  if (root == NULL) {
    printf("Empty tree.\n");
    return;
  }
  int i;
  node *c = root;
  while (!c->is_leaf)
  c = c->pointers[0];
  while (true) {
    for (i = 0; i < c->num_keys; i++) {
      if (verbose_output)
        printf("%p ", c->pointers[i]);
      printf("%d ", c->keys[i]);
    }
    if (verbose_output)
      printf("%p ", c->pointers[order - 1]);
    if (c->pointers[order - 1] != NULL) {
    printf(" | ");
      c = c->pointers[order - 1];
    } else
      break;
  }
  printf("\n");
}

// Calculate height
int height(node *const root) {
  int h = 0;
  node *c = root;
  while (!c->is_leaf) {
    c = c->pointers[0];
    h++;
  }
  return h;
}

// Get path to root
int pathToLeaves(node *const root, node *child) {
  int length = 0;
  node *c = child;
  while (c != root) {
  c = c->parent;
  length++;
  }
  return length;
}

// Print the tree
void printTree(node *const root) {
  node *n = NULL;
  int i = 0;
  int rank = 0;
  int new_rank = 0;

  if (root == NULL) {
    printf("Empty tree.\n");
    return;
  }
  queue = NULL;
  enqueue(root);
  while (queue != NULL) {
    n = dequeue();
    if (n->parent != NULL && n == n->parent->pointers[0]) {
      new_rank = pathToLeaves(root, n);
      if (new_rank != rank) {
        rank = new_rank;
        printf("\n");
      }
    }
    if (verbose_output)
      printf("(%p)", n);
    for (i = 0; i < n->num_keys; i++) {
      if (verbose_output)
        printf("%p ", n->pointers[i]);
      printf("%d ", n->keys[i]);
    }
    if (!n->is_leaf)
      for (i = 0; i <= n->num_keys; i++)
        enqueue(n->pointers[i]);
    if (verbose_output) {
      if (n->is_leaf)
        printf("%p ", n->pointers[order - 1]);
      else
        printf("%p ", n->pointers[n->num_keys]);
    }
    printf("| ");
  }
  printf("\n");
}

// Find the node and print it
void findAndPrint(node *const root, int key, bool verbose) {
  node *leaf = NULL;
  record *r = find(root, key, verbose, NULL);
  if (r == NULL)
    printf("Record not found under key %d.\n", key);
  else
    printf("Record at %p -- key %d, value %d.\n",
         r, key, r->value);
}

// Find and print the range
void findAndPrintRange(node *const root, int key_start, int key_end,
            bool verbose) {
  int i;
  int array_size = key_end - key_start + 1;
  int returned_keys[array_size];
  void *returned_pointers[array_size];
  int num_found = findRange(root, key_start, key_end, verbose,
              returned_keys, returned_pointers);
  if (!num_found)
  printf("None found.\n");
  else {
    for (i = 0; i < num_found; i++)
      printf("Key: %d   Location: %p  Value: %d\n",
            returned_keys[i],
            returned_pointers[i],
            ((record *)
            returned_pointers[i])
              ->value);
  }
}

// Find the range
int findRange(node *const root, int key_start, int key_end, bool verbose,
        int returned_keys[], void *returned_pointers[]) {
  int i, num_found;
  num_found = 0;
  node *n = findLeaf(root, key_start, verbose);
  if (n == NULL)
    return 0;
  for (i = 0; i < n->num_keys && n->keys[i] < key_start; i++)
    ;
  if (i == n->num_keys)
    return 0;
  while (n != NULL) {
    for (; i < n->num_keys && n->keys[i] <= key_end; i++) {
      returned_keys[num_found] = n->keys[i];
      returned_pointers[num_found] = n->pointers[i];
      num_found++;
    }
    n = n->pointers[order - 1];
    i = 0;
  }
  return num_found;
}

// Find the leaf
node *findLeaf(node *const root, int key, bool verbose) {
  if (root == NULL) {
    if (verbose)
    printf("Empty tree.\n");
    return root;
  }
  int i = 0;
  node *c = root;
  while (!c->is_leaf) {
  if (verbose) {
      printf("[");
      for (i = 0; i < c->num_keys - 1; i++)
        printf("%d ", c->keys[i]);
      printf("%d] ", c->keys[i]);
    }
    i = 0;
    while (i < c->num_keys) {
      if (key >= c->keys[i])
      i++;
      else
        break;
    }
    if (verbose)
      printf("%d ->\n", i);
    c = (node *)c->pointers[i];
  }
  if (verbose) {
    printf("Leaf [");
    for (i = 0; i < c->num_keys - 1; i++)
      printf("%d ", c->keys[i]);
    printf("%d] ->\n", c->keys[i]);
  }
  return c;
}

record *find(node *root, int key, bool verbose, node **leaf_out) {
  if (root == NULL) {
    if (leaf_out != NULL) {
      *leaf_out = NULL;
    }
    return NULL;
  }

  int i = 0;
  node *leaf = NULL;

  leaf = findLeaf(root, key, verbose);

  for (i = 0; i < leaf->num_keys; i++)
    if (leaf->keys[i] == key)
      break;
  if (leaf_out != NULL) {
    *leaf_out = leaf;
  }
  if (i == leaf->num_keys)
    return NULL;
  else
    return (record *)leaf->pointers[i];
}

int cut(int length) {
  if (length % 2 == 0)
  return length / 2;
  else
    return length / 2 + 1;
}

record *makeRecord(int value) {
  record *new_record = (record *)malloc(sizeof(record));
  if (new_record == NULL) {
    perror("Record creation.");
    exit(EXIT_FAILURE);
  } else {
    new_record->value = value;
  }
  return new_record;
}

node *makeNode(void) {
  node *new_node;
  new_node = malloc(sizeof(node));
  if (new_node == NULL) {
  perror("Node creation.");
  exit(EXIT_FAILURE);
  }
  new_node->keys = malloc((order - 1) * sizeof(int));
  if (new_node->keys == NULL) {
    perror("New node keys array.");
    exit(EXIT_FAILURE);
  }
  new_node->pointers = malloc(order * sizeof(void *));
  if (new_node->pointers == NULL) {
    perror("New node pointers array.");
    exit(EXIT_FAILURE);
  }
  new_node->is_leaf = false;
  new_node->num_keys = 0;
  new_node->parent = NULL;
  new_node->next = NULL;
  return new_node;
}

node *makeLeaf(void) {
  node *leaf = makeNode();
  leaf->is_leaf = true;
  return leaf;
}

int getLeftIndex(node *parent, node *left) {
  int left_index = 0;
  while (left_index <= parent->num_keys &&
       parent->pointers[left_index] != left)
    left_index++;
  return left_index;
}

node *insertIntoLeaf(node *leaf, int key, record *pointer) {
  int i, insertion_point;

  insertion_point = 0;
  while (insertion_point < leaf->num_keys && leaf->keys[insertion_point] < key)
    insertion_point++;

  for (i = leaf->num_keys; i > insertion_point; i--) {
    leaf->keys[i] = leaf->keys[i - 1];
    leaf->pointers[i] = leaf->pointers[i - 1];
  }
  leaf->keys[insertion_point] = key;
  leaf->pointers[insertion_point] = pointer;
  leaf->num_keys++;
  return leaf;
}

node *insertIntoLeafAfterSplitting(node *root, node *leaf, int key, record
*pointer) {
  node *new_leaf;
  int *temp_keys;
  void **temp_pointers;
  int insertion_index, split, new_key, i, j;
```

```
new_leaf = makeLeaf();

temp_keys = malloc(order * sizeof(int));
if (temp_keys == NULL) {
perror("Temporary keys array.");
exit(EXIT_FAILURE);
}

temp_pointers = malloc(order * sizeof(void *));
if (temp_pointers == NULL) {
perror("Temporary pointers array.");
exit(EXIT_FAILURE);
}

insertion_index = 0;
while (insertion_index < order - 1 && leaf->keys[insertion_index] < key)
  insertion_index++;

for (i = 0, j = 0; i < leaf->num_keys; i++, j++) {
  if (j == insertion_index)
    j++;
  temp_keys[j] = leaf->keys[i];
  temp_pointers[j] = leaf->pointers[i];
}

temp_keys[insertion_index] = key;
temp_pointers[insertion_index] = pointer;

leaf->num_keys = 0;

split = cut(order - 1);

for (i = 0; i < split; i++) {
  leaf->pointers[i] = temp_pointers[i];
  leaf->keys[i] = temp_keys[i];
  leaf->num_keys++;
}

for (i = split, j = 0; i < order; i++, j++) {
  new_leaf->pointers[j] = temp_pointers[i];
  new_leaf->keys[j] = temp_keys[i];
  new_leaf->num_keys++;
  }

  free(temp_pointers);
  free(temp_keys);

  new_leaf->pointers[order - 1] = leaf->pointers[order - 1];
  leaf->pointers[order - 1] = new_leaf;

  for (i = leaf->num_keys; i < order - 1; i++)
    leaf->pointers[i] = NULL;
  for (i = new_leaf->num_keys; i < order - 1; i++)
    new_leaf->pointers[i] = NULL;

  new_leaf->parent = leaf->parent;
  new_key = new_leaf->keys[0];

  return insertIntoParent(root, leaf, new_key, new_leaf);
}

node *insertIntoNode(node *root, node *n,
           int left_index, int key, node *right) {
  int i;

  for (i = n->num_keys; i > left_index; i--) {
    n->pointers[i + 1] = n->pointers[i];
    n->keys[i] = n->keys[i - 1];
  }
  n->pointers[left_index + 1] = right;
  n->keys[left_index] = key;
  n->num_keys++;
  return root;
}

node *insertIntoNodeAfterSplitting(node *root, node *old_node, int left_index,
                   int key, node *right) {
  int i, j, split, k_prime;
  node *new_node, *child;
  int *temp_keys;
  node **temp_pointers;

  temp_pointers = malloc((order + 1) * sizeof(node *));
  if (temp_pointers == NULL) {
  exit(EXIT_FAILURE);
```

```
}
temp_keys = malloc(order * sizeof(int));
if (temp_keys == NULL) {
exit(EXIT_FAILURE);
}

for (i = 0, j = 0; i < old_node->num_keys + 1; i++, j++) {
  if (j == left_index + 1)
    j++;
  temp_pointers[j] = old_node->pointers[i];
}

for (i = 0, j = 0; i < old_node->num_keys; i++, j++) {
  if (j == left_index)
    j++;
  temp_keys[j] = old_node->keys[i];
}

temp_pointers[left_index + 1] = right;
temp_keys[left_index] = key;

split = cut(order);
new_node = makeNode();
old_node->num_keys = 0;
for (i = 0; i < split - 1; i++) {
  old_node->pointers[i] = temp_pointers[i];
  old_node->keys[i] = temp_keys[i];
  old_node->num_keys++;
}
old_node->pointers[i] = temp_pointers[i];
k_prime = temp_keys[split - 1];
for (++i, j = 0; i < order; i++, j++) {
  new_node->pointers[j] = temp_pointers[i];
  new_node->keys[j] = temp_keys[i];
  new_node->num_keys++;
}
new_node->pointers[j] = temp_pointers[i];
free(temp_pointers);
free(temp_keys);
new_node->parent = old_node->parent;
for (i = 0; i <= new_node->num_keys; i++) {
  child = new_node->pointers[i];
  child->parent = new_node;
  }

  return insertIntoParent(root, old_node, k_prime, new_node);
}

node *insertIntoParent(node *root, node *left, int key, node *right) {
  int left_index;
  node *parent;

  parent = left->parent;

  if (parent == NULL)
    return insertIntoNewRoot(left, key, right);

  left_index = getLeftIndex(parent, left);

  if (parent->num_keys < order - 1)
    return insertIntoNode(root, parent, left_index, key, right);

  return insertIntoNodeAfterSplitting(root, parent, left_index, key, right);
}

node *insertIntoNewRoot(node *left, int key, node *right) {
  node *root = makeNode();
  root->keys[0] = key;
  root->pointers[0] = left;
  root->pointers[1] = right;
  root->num_keys++;
  root->parent = NULL;
  left->parent = root;
  right->parent = root;
  return root;
}

node *startNewTree(int key, record *pointer) {
  node *root = makeLeaf();
  root->keys[0] = key;
  root->pointers[0] = pointer;
  root->pointers[order - 1] = NULL;
  root->parent = NULL;
  root->num_keys++;
  return root;
}
```

```
node *insert(node *root, int key, int value) {
  record *record_pointer = NULL;
  node *leaf = NULL;

  record_pointer = find(root, key, false, NULL);
  if (record_pointer != NULL) {
    record_pointer->value = value;
    return root;
  }

  record_pointer = makeRecord(value);

  if (root == NULL)
    return startNewTree(key, record_pointer);

  leaf = findLeaf(root, key, false);

  if (leaf->num_keys < order - 1) {
    leaf = insertIntoLeaf(leaf, key, record_pointer);
    return root;
  }

  return insertIntoLeafAfterSplitting(root, leaf, key, record_pointer);
}

int main() {
  node *root;
  char instruction;

  root = NULL;

  root = insert(root, 5, 33);
  root = insert(root, 15, 21);
  root = insert(root, 25, 31);
  root = insert(root, 35, 41);
  root = insert(root, 45, 10);

  printTree(root);

  findAndPrint(root, 15, instruction = 'a');
}
```

OUTPUT:

```
25 |
15 | 35 |
5 | 15 | 25 | 35 45 |
[25] 0 ->
[15] 1 ->
Leaf [15] ->
Record at 0x1609330 -- key 15, value 21.
```

Aim: Write a program to implement AVL tree .

Source code:

Avl.c

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

// Create Node
struct Node {
int key;
  struct Node *left;
  struct Node *right;
  int height;
};

int max(int a, int b);

// Calculate height
int height(struct Node *N) {
  if (N == NULL)
    return 0;
  return N->height;
}

int max(int a, int b) {
  return (a > b) ? a : b;
}

// Create a node
struct Node *newNode(int key) {
  struct Node *node = (struct Node *)
  malloc(sizeof(struct Node));
  node->key = key;
  node->left = NULL;
  node->right = NULL;
  node->height = 1;
  return (node);
}

// Right rotate
struct Node *rightRotate(struct Node *y) {
  struct Node *x = y->left;
  struct Node *T2 = x->right;

  x->right = y;
  y->left = T2;

  y->height = max(height(y->left), height(y->right)) + 1;
  x->height = max(height(x->left), height(x->right)) + 1;

  return x;
}

// Left rotate
struct Node *leftRotate(struct Node *x) {
  struct Node *y = x->right;
  struct Node *T2 = y->left;

  y->left = x;
  x->right = T2;

  x->height = max(height(x->left), height(x->right)) + 1;
  y->height = max(height(y->left), height(y->right)) + 1;

  return y;
}

// Get the balance factor
int getBalance(struct Node *N) {
  if (N == NULL)
    return 0;
  return height(N->left) - height(N->right);
}

// Insert node
```

```
struct Node *insertNode(struct Node *node, int key) {
  // Find the correct position to insertNode the node and insertNode it
  if (node == NULL)
    return (newNode(key));

  if (key < node->key)
    node->left = insertNode(node->left, key);
  else if (key > node->key)
    node->right = insertNode(node->right, key);
  else
    return node;

  // Update the balance factor of each node and
  // Balance the tree
  node->height = 1 + max(height(node->left),
               height(node->right));

  int balance = getBalance(node);
  if (balance > 1 && key < node->left->key)
    return rightRotate(node);

  if (balance < -1 && key > node->right->key)
    return leftRotate(node);

  if (balance > 1 && key > node->left->key) {
    node->left = leftRotate(node->left);
    return rightRotate(node);
  }

  if (balance < -1 && key < node->right->key) {
    node->right = rightRotate(node->right);
    return leftRotate(node);
  }

  return node;
}

struct Node *minValueNode(struct Node *node) {
  struct Node *current = node;

  while (current->left != NULL)
    current = current->left;
  return current;
}

// Delete a nodes
struct Node *deleteNode(struct Node *root, int key) {
  // Find the node and delete it
  if (root == NULL)
    return root;

  if (key < root->key)
    root->left = deleteNode(root->left, key);

  else if (key > root->key)
    root->right = deleteNode(root->right, key);

  else {
    if ((root->left == NULL) || (root->right == NULL)) {
      struct Node *temp = root->left ? root->left : root->right;

      if (temp == NULL) {
        temp = root;
        root = NULL;
      } else
        *root = *temp;
      free(temp);
    } else {
      struct Node *temp = minValueNode(root->right);

      root->key = temp->key;

      root->right = deleteNode(root->right, temp->key);
    }
  }

  if (root == NULL)
    return root;

  // Update the balance factor of each node and
  // balance the tree
  root->height = 1 + max(height(root->left),
              height(root->right));

  int balance = getBalance(root);
  if (balance > 1 && getBalance(root->left) >= 0)
    return rightRotate(root);

  if (balance > 1 && getBalance(root->left) < 0) {
    root->left = leftRotate(root->left);
    return rightRotate(root);
  }

  if (balance < -1 && getBalance(root->right) <= 0)
    return leftRotate(root);

  if (balance < -1 && getBalance(root->right) > 0) {
    root->right = rightRotate(root->right);
    return leftRotate(root);
  }

  return root;
}

// Print the tree
void printPreOrder(struct Node *root) {
  if (root != NULL) {
    printf("%d ", root->key);
    printPreOrder(root->left);
    printPreOrder(root->right);
  }
}

int main() {
  struct Node *root = NULL;

  root = insertNode(root, 2);
  root = insertNode(root, 1);
  root = insertNode(root, 7);
  root = insertNode(root, 4);
  root = insertNode(root, 5);
  root = insertNode(root, 3);
  root = insertNode(root, 8);

  printPreOrder(root);

  root = deleteNode(root, 3);
  printf("\nAfter deletion: ");
  printPreOrder(root);

  return 0;
}
```

OUTPUT:

```
4 2 1 3 7 5 8
After deletion: 4 2 1 7 5 8
```

Aim: Write a program to implement Red-Block tree.

Source code:
Rbt.c

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

enum nodeColor {
  RED,
  BLACK
};

struct rbNode {
  int data, color;
  struct rbNode *link[2];
};

struct rbNode *root = NULL;

// Create a red-black tree
struct rbNode *createNode(int data) {
  struct rbNode *newnode;
  newnode = (struct rbNode *)malloc(sizeof(struct rbNode));
  newnode->data = data;
  newnode->color = RED;
  newnode->link[0] = newnode->link[1] = NULL;
  return newnode;
}

// Insert an node
void insertion(int data) {
  struct rbNode *stack[98], *ptr, *newnode, *xPtr, *yPtr;
```

```
int dir[98], ht = 0, index;
ptr = root;
if (!root) {
  root = createNode(data);
  return;
}

stack[ht] = root;
dir[ht++] = 0;
while (ptr != NULL) {
  if (ptr->data == data) {
    printf("Duplicates Not Allowed!!\n");
    return;
  }
  index = (data - ptr->data) > 0 ? 1 : 0;
  stack[ht] = ptr;
  ptr = ptr->link[index];
  dir[ht++] = index;
}
stack[ht - 1]->link[index] = newnode = createNode(data);
while ((ht >= 3) && (stack[ht - 1]->color == RED)) {
  if (dir[ht - 2] == 0) {
    yPtr = stack[ht - 2]->link[1];
    if (yPtr != NULL && yPtr->color == RED) {
      stack[ht - 2]->color = RED;
      stack[ht - 1]->color = yPtr->color = BLACK;
      ht = ht - 2;
    } else {
      if (dir[ht - 1] == 0) {
        yPtr = stack[ht - 1];
      } else {
        xPtr = stack[ht - 1];
        yPtr = xPtr->link[1];
        xPtr->link[1] = yPtr->link[0];
        yPtr->link[0] = xPtr;
        stack[ht - 2]->link[0] = yPtr;
      }
      xPtr = stack[ht - 2];
      xPtr->color = RED;
      yPtr->color = BLACK;
      xPtr->link[0] = yPtr->link[1];
      yPtr->link[1] = xPtr;
      if (xPtr == root) {
          root = yPtr;
        } else {
          stack[ht - 3]->link[dir[ht - 3]] = yPtr;
        }
        break;
      }
    } else {
      yPtr = stack[ht - 2]->link[0];
      if ((yPtr != NULL) && (yPtr->color == RED)) {
        stack[ht - 2]->color = RED;
        stack[ht - 1]->color = yPtr->color = BLACK;
        ht = ht - 2;
      } else {
        if (dir[ht - 1] == 1) {
          yPtr = stack[ht - 1];
        } else {
          xPtr = stack[ht - 1];
          yPtr = xPtr->link[0];
          xPtr->link[0] = yPtr->link[1];
          yPtr->link[1] = xPtr;
          stack[ht - 2]->link[1] = yPtr;
        }
        xPtr = stack[ht - 2];
        yPtr->color = BLACK;
        xPtr->color = RED;
        xPtr->link[1] = yPtr->link[0];
        yPtr->link[0] = xPtr;
        if (xPtr == root) {
          root = yPtr;
        } else {
          stack[ht - 3]->link[dir[ht - 3]] = yPtr;
        }
        break;
      }
    }
  }
  root->color = BLACK;
}

// Delete a node
void deletion(int data) {
  struct rbNode *stack[98], *ptr, *xPtr, *yPtr;
  struct rbNode *pPtr, *qPtr, *rPtr;
```

```
int dir[98], ht = 0, diff, i;
enum nodeColor color;

if (!root) {
  printf("Tree not available\n");
  return;
}

ptr = root;
while (ptr != NULL) {
  if ((data - ptr->data) == 0)
    break;
  diff = (data - ptr->data) > 0 ? 1 : 0;
  stack[ht] = ptr;
  dir[ht++] = diff;
  ptr = ptr->link[diff];
}

if (ptr->link[1] == NULL) {
  if ((ptr == root) && (ptr->link[0] == NULL)) {
    free(ptr);
    root = NULL;
  } else if (ptr == root) {
    root = ptr->link[0];
    free(ptr);
  } else {
    stack[ht - 1]->link[dir[ht - 1]] = ptr->link[0];
  }
} else {
  xPtr = ptr->link[1];
  if (xPtr->link[0] == NULL) {
    xPtr->link[0] = ptr->link[0];
    color = xPtr->color;
    xPtr->color = ptr->color;
    ptr->color = color;

    if (ptr == root) {
      root = xPtr;
    } else {
      stack[ht - 1]->link[dir[ht - 1]] = xPtr;
    }

    dir[ht] = 1;
    stack[ht++] = xPtr;
  } else {
    i = ht++;
    while (1) {
      dir[ht] = 0;
      stack[ht++] = xPtr;
      yPtr = xPtr->link[0];
      if (!yPtr->link[0])
      break;
      xPtr = yPtr;
    }

    dir[i] = 1;
    stack[i] = yPtr;
    if (i > 0)
      stack[i - 1]->link[dir[i - 1]] = yPtr;

    yPtr->link[0] = ptr->link[0];

    xPtr->link[0] = yPtr->link[1];
    yPtr->link[1] = ptr->link[1];

    if (ptr == root) {
      root = yPtr;
    }

    color = yPtr->color;
    yPtr->color = ptr->color;
    ptr->color = color;
  }
}

if (ht < 1)
  return;

if (ptr->color == BLACK) {
  while (1) {
    pPtr = stack[ht - 1]->link[dir[ht - 1]];
    if (pPtr && pPtr->color == RED) {
    pPtr->color = BLACK;
      break;
    }
```

```
if (ht < 2)
  break;

if (dir[ht - 2] == 0) {
  rPtr = stack[ht - 1]->link[1];

  if (!rPtr)
    break;

  if (rPtr->color == RED) {
    stack[ht - 1]->color = RED;
    rPtr->color = BLACK;
    stack[ht - 1]->link[1] = rPtr->link[0];
    rPtr->link[0] = stack[ht - 1];

    if (stack[ht - 1] == root) {
      root = rPtr;
    } else {
      stack[ht - 2]->link[dir[ht - 2]] = rPtr;
    }
    dir[ht] = 0;
    stack[ht] = stack[ht - 1];
    stack[ht - 1] = rPtr;
    ht++;

    rPtr = stack[ht - 1]->link[1];
  }

  if ((!rPtr->link[0] || rPtr->link[0]->color == BLACK) &&
    (!rPtr->link[1] || rPtr->link[1]->color == BLACK)) {
    rPtr->color = RED;
  } else {
    if (!rPtr->link[1] || rPtr->link[1]->color == BLACK) {
      qPtr = rPtr->link[0];
      rPtr->color = RED;
      qPtr->color = BLACK;
      rPtr->link[0] = qPtr->link[1];
      qPtr->link[1] = rPtr;
      rPtr = stack[ht - 1]->link[1] = qPtr;
    }
    rPtr->color = stack[ht - 1]->color;
    stack[ht - 1]->color = BLACK;
    rPtr->link[1]->color = BLACK;
```

```
      stack[ht - 1]->link[1] = rPtr->link[0];
      rPtr->link[0] = stack[ht - 1];
      if (stack[ht - 1] == root) {
        root = rPtr;
      } else {
        stack[ht - 2]->link[dir[ht - 2]] = rPtr;
      }
      break;
    }
  } else {
    rPtr = stack[ht - 1]->link[0];
    if (!rPtr)
      break;

    if (rPtr->color == RED) {
      stack[ht - 1]->color = RED;
      rPtr->color = BLACK;
      stack[ht - 1]->link[0] = rPtr->link[1];
      rPtr->link[1] = stack[ht - 1];

      if (stack[ht - 1] == root) {
        root = rPtr;
      } else {
        stack[ht - 2]->link[dir[ht - 2]] = rPtr;
      }
      dir[ht] = 1;
      stack[ht] = stack[ht - 1];
      stack[ht - 1] = rPtr;
      ht++;

      rPtr = stack[ht - 1]->link[0];
    }
    if ((!rPtr->link[0] || rPtr->link[0]->color == BLACK) &&
      (!rPtr->link[1] || rPtr->link[1]->color == BLACK)) {
      rPtr->color = RED;
    } else {
      if (!rPtr->link[0] || rPtr->link[0]->color == BLACK) {
        qPtr = rPtr->link[1];
        rPtr->color = RED;
        qPtr->color = BLACK;
        rPtr->link[1] = qPtr->link[0];
        qPtr->link[0] = rPtr;
        rPtr = stack[ht - 1]->link[0] = qPtr;
```

```
          }
          rPtr->color = stack[ht - 1]->color;
          stack[ht - 1]->color = BLACK;
          rPtr->link[0]->color = BLACK;
          stack[ht - 1]->link[0] = rPtr->link[1];
          rPtr->link[1] = stack[ht - 1];
          if (stack[ht - 1] == root) {
            root = rPtr;
          } else {
            stack[ht - 2]->link[dir[ht - 2]] = rPtr;
          }
          break;
        }
      }
      ht--;
    }
  }
}

// Print the inorder traversal of the tree
void inorderTraversal(struct rbNode *node) {
  if (node) {
    inorderTraversal(node->link[0]);
    printf("%d  ", node->data);
    inorderTraversal(node->link[1]);
  }
  return;
}

// Driver code
int main() {
int ch, data;
while (1) {
    printf("1. Insertion\t2. Deletion\n");
    printf("3. Traverse\t4. Exit");
    printf("\nEnter your choice:");
    scanf("%d", &ch);
    switch (ch) {
      case 1:
        printf("Enter the element to insert:");
        scanf("%d", &data);
        insertion(data);
        break;
      case 2:
        printf("Enter the element to delete:");
        scanf("%d", &data);
        deletion(data);
        break;
      case 3:
        inorderTraversal(root);
        printf("\n");
        break;
      case 4:
        exit(0);
      default:
        printf("Not available\n");
        break;
    }
    printf("\n");
  }
  return 0;
}
```

OUTPUT:

```
1. Insertion
2. Deletion
3. Traverse
4. Exit
Enter your choice:1
Enter the element to insert:2
1. Insertion
2. Deletion
3. Traverse
4. Exit
Enter your choice:1
Enter the element to insert:5
1. Insertion
2. Deletion
3. Traverse
4. Exit
Enter your choice:1
Enter the element to insert:8
1. Insertion
2. Deletion
3. Traverse
4. Exit
```

```
Enter your choice:1
Enter the element to insert:3
1. Insertion
2. Deletion
3. Traverse
4. Exit
Enter your choice:3
2  3  5  8
```

VIVA QUESTIONS:

1. What is binary search tree?
2. What is B+ tree?
3. What is AVL tree?
4. What is Red black tree?
5. What is B tree?

P9

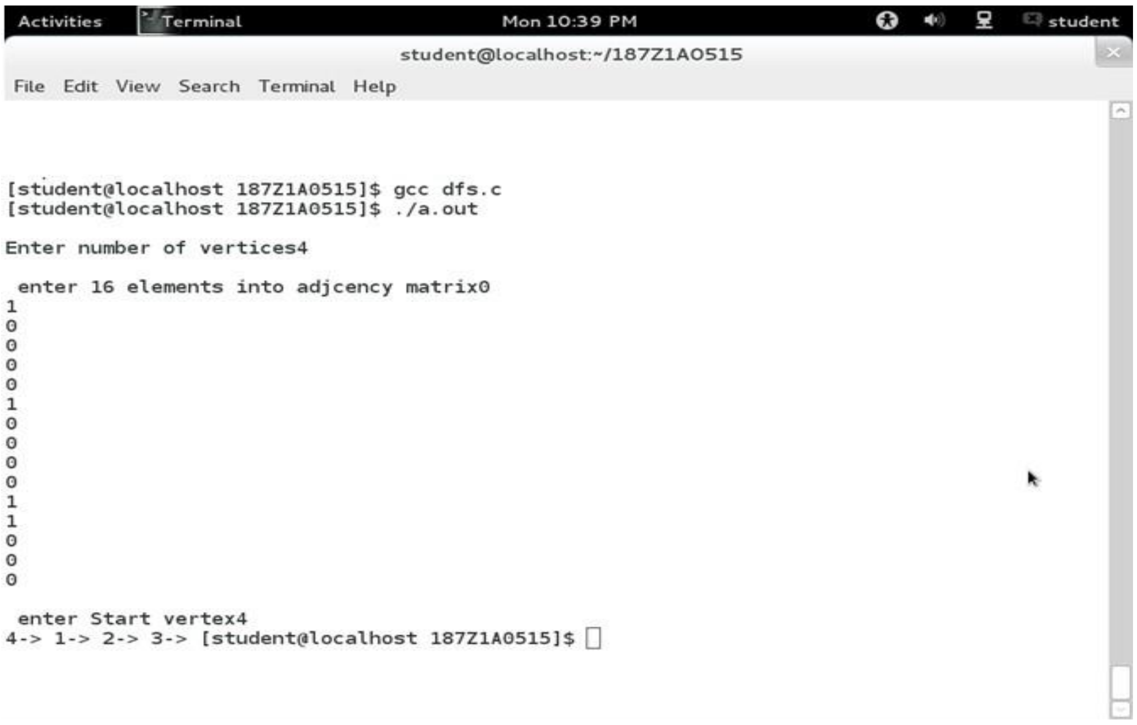
Aim: Write a program to implement Depth First Search (DFS) graph traversal methods.

Source Code:

dfs.c

```c
#include <stdio.h>
int stack[5],top=-1,known[10],n,a[10][10];
void push(int val){
stack[++top]=val;
}
int pop(){
int ver=stack[top--];
printf("%d-> ",ver);
return ver;
}
int stackempty(){
if(top==-1)
return 1;
else
return 0;
}
void dfs(int sv){
push(sv);
known[sv]=1;
while(!stackempty()){
int i;
int v=pop();
for(i=n;i>0;i--){
if(!(!(a[v][i]))&&!(known[i])){
push(i);
known[i]=1;
}
}
}
}
int main(void) {
// your code goes here
int i,j,sv;
printf("\nEnter number of vertices");
scanf("%d",&n);
printf("\n enter %d elements into adjcency matrix",n*n);
for(i=1;i<=n;i++){
for(j=1;j<=n;j++){
scanf("%d",&a[i][j]);
}
}
printf("\n enter Start vertex");
scanf("%d",&sv);
dfs(sv);
return 0;
}
```

Output:



```
[student@localhost 187Z1A0515]$ gcc dfs.c
[student@localhost 187Z1A0515]$ ./a.out

Enter number of vertices4

 enter 16 elements into adjcency matrix0
1
0
0
0
0
1
0
0
0
0
1
1
0
0
0

 enter Start vertex4
4-> 1-> 2-> 3-> [student@localhost 187Z1A0515]$ 
```

Aim: Write a program to implement Breadth First Search (BFS) graph traversal methods.

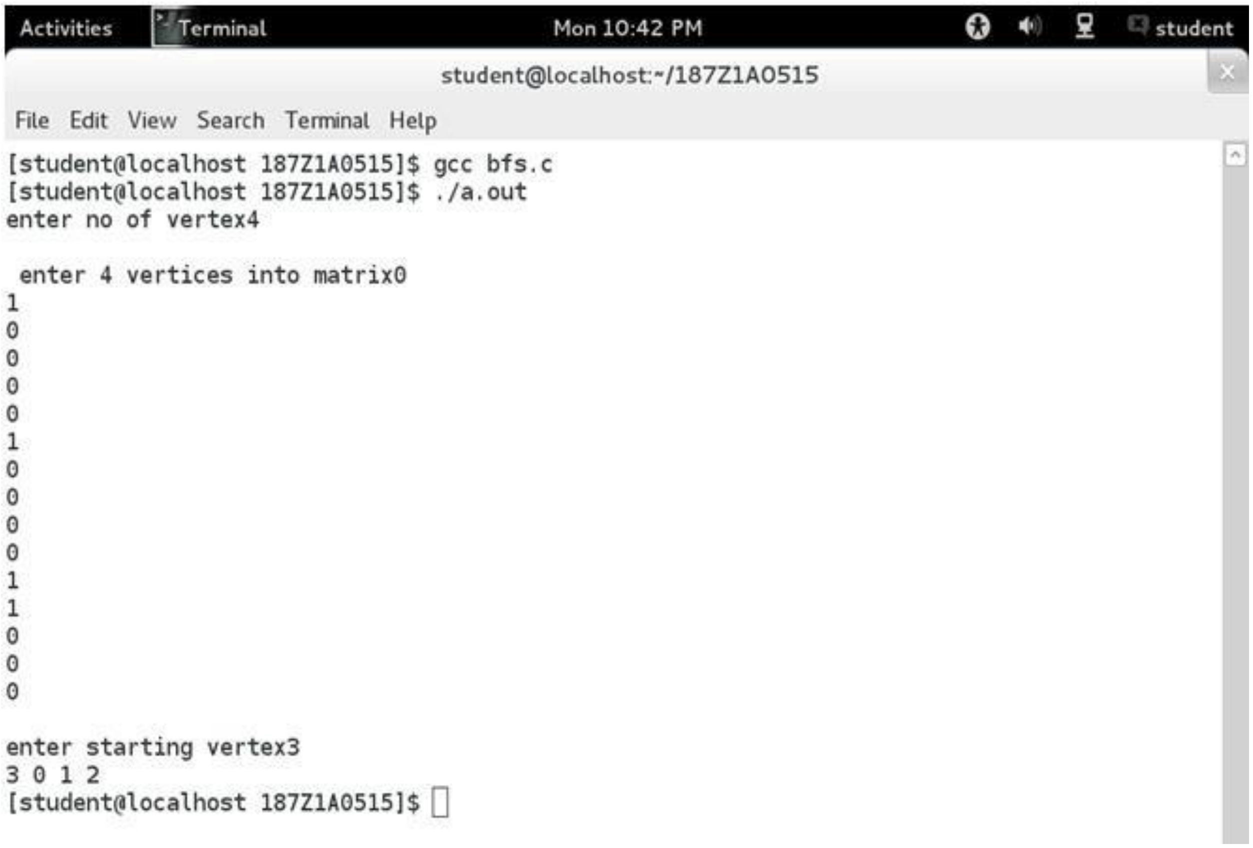
Source Code:

bfs.c

```
#include <stdio.h>
#define QUEUE_SIZE 20
#define MAX 20
//queue
int queue[QUEUE_SIZE];
int queue_front, queue_end;
void enqueue(int v);
int dequeue();
void bfs(int Adj[MAX][MAX], int n, int source);
int main(void) {
//Adj matrix
int Adj[MAX][MAX] ;//= {{0,1,0,0},{0,0,0,1},{1,0,0,0},{1,0,1,0}};//     {0,1,0,0},
{0,1,1,1},    {1,0,0,1},    {0,0,1,0}  };
int i,j,n;// = 4;  //no. of vertex
int starting_vertex ;//= 2;
printf("enter no of vertex");
```

```
scanf("%d",&n);
printf("\n enter %d vertices into matrix",n);
for(i=0;i<n;i++)
for(j=0;j<n;j++)
scanf("%d",&Adj[i][j]);
printf("\nenter starting vertex");
scanf("%d",&starting_vertex);

bfs(Adj, n, starting_vertex);

return 0;
}

void bfs(int Adj[MAX][MAX], int n, int source) {
//variables
int i, j;

//visited array to flag the vertex that
//were visited
int visited[MAX];

//queue
queue_front = 0;
queue_end = 0;

//set visited for all vertex to 0 (means unvisited)
for(i = 0; i <= MAX; i++) {
visited[i] = 0;
}

//mark the visited source
visited[source] = 1;

//enqueue visited vertex
enqueue(source);

//print the vertex as result
printf("%d ", source);

//continue till queue is not empty
while(queue_front <= queue_end) {
//dequeue first element from the queue
i = dequeue();
for(j = 0; j <n; j++) {
if(visited[j] == 0 && Adj[i][j] == 1) {
//mark vertex as visited
visited[j] = 1;

//push vertex into stack
enqueue(j);

//print the vertex as result
printf("%d ", j);
}
}
}
printf("\n");
}

void enqueue(int v) {
queue[queue_end] = v;
queue_end++;
}

int dequeue() {
int index = queue_front;
queue_front++;
return queue[index];
}
```

Output:


Activities
Terminal
Mon 10:42 PM
student
student@localhost:~/187Z1A0515
File Edit View Search Terminal Help

```
[student@localhost 187Z1A0515]$ gcc bfs.c
[student@localhost 187Z1A0515]$ ./a.out
enter no of vertex4

 enter 4 vertices into matrix0
1
0
0
0
0
1
0
0
0
0
1
1
0
0
0

enter starting vertex3
3 0 1 2
[student@localhost 187Z1A0515]$
```

Viva Questions

1. What is DFS?
2. What is BFS? Where can we use BFS?
3. What is a graph?
4. What is the use of graph traversal?
5. How many types of graph traversal techniques are there?

P10

Aim: Implement a pattern matching algorithm using Boyer-Moore, Knuth-Morris-Pratt

Source Code:

Boyer-moore.c

```
# include <limits.h>
# include <string.h>
# include <stdio.h>
 # define NO_OF_CHARS 256
 // A utility function to get maximum of two integers
int max(int a, int b) {
    return (a > b) ? a : b;
}
 // The preprocessing function for Boyer Moore's bad character heuristic
void badCharHeuristic(char *str, int size, int badchar[NO_OF_CHARS]) {
    int i;
// Initialize all occurrences as -1
    for (i = 0; i < NO_OF_CHARS; i++)
        badchar[i] = -1;
         for (i = 0; i < size; i++)
        badchar[(int) str[i]] = i;
}
 void search(char *txt, char *pat) {
    int m = strlen(pat);
    int n = strlen(txt);
  int badchar[NO_OF_CHARS];
  badCharHeuristic(pat, m, badchar);
 int s = 0; // s is shift of the pattern with respect to text
    while (s <= (n - m)) {
        int j = m - 1;

        while (j >= 0 && pat[j] == txt[s + j])
            j--;
            if (j < 0) {
            printf("\n pattern occurs at shift = %d", s);
 s += (s + m < n) ? m - badchar[txt[s + m]] : 1;
  }
  else
  s += max(1, j - badchar[txt[s + j]]);
    }
}
 int main() {
    char txt[] = "AAABCDE";
    char pat[] = "ABCDE";
    search(txt, pat);
    return 0;
}
```

OUTPUT:

```
pattern  occurs  at  shift = 2
```

Source Code:

ii) Knuth-Morris-Pratt.C

```
#include <stdio.h>
 void computeLPSArray(char* pat, int M, int* lps);
 // Prints occurrences of pat[] in txt[]
void KMPSearch(char* pat, char* txt)
{
    int M = strlen(pat);
    int N = strlen(txt);
// create lps[] that will hold the longest prefix suffix
    // values for pattern
    int lps[M];
 // Preprocess the pattern (calculate lps[] array)
    computeLPSArray(pat, M, lps);
  int i = 0; // index for txt[]
    int j = 0; // index for pat[]
    while ((N - i) >= (M - j)) {
        if (pat[j] == txt[i]) {
            j++;
            i++;
        }
   if (j == M) {
            printf("Found pattern at index %d ", i - j);
            j = lps[j - 1];
        }
  // mismatch after j matches
        else if (i < N && pat[j] != txt[i]) {
            // Do not match lps[0..lps[j-1]] characters,
            // they will match anyway
            if (j != 0)
                j = lps[j - 1];
            else
                i = i + 1;
        }
    }
}
 // Fills lps[] for given pattern pat[0..M-1]
void computeLPSArray(char* pat, int M, int* lps)
{
    // length of the previous longest prefix suffix
    int len = 0;
  lps[0] = 0; // lps[0] is always 0
  // the loop calculates lps[i] for i = 1 to M-1
    int i = 1;
    while (i < M) {
        if (pat[i] == pat[len]) {
            len++;
            lps[i] = len;
            i++;
        }
        else // (pat[i] != pat[len])
        {
            // This is tricky. Consider the example.
            // AAACAAAA and i = 7. The idea is similar
            // to search step.
            if (len != 0) {
                len = lps[len - 1];
    // Also, note that we do not increment
                // i here
            }
            else // if (len == 0)
            {
                lps[i] = 0;
                i++;
            }
        }
    }
}
 // Driver code
int main()
{
    char txt[] = "BDABACDABABCABABCD";
    char pat[] = "ABABCABAB";
    KMPSearch(pat, txt);
    return 0;
}
```

OUTPUT:

```
Found  pattern  at  index  7
```

Viva:

1) What is Boyer-Moore used for?
2) How does Boyer-Moore work?
3) What is the basic principle of Knuth-Morris-Pratt algorithm?
4) What is the problem statement of KMP algorithm?
5) What is KMP algorithm used for?