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University of Delhi

Data Structures

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2	Given a list of N elements, which is sorted in ascending order, you are required to search an element x in the list. The list is stored using array data structure. If the search is successful, the output should be the index at which the element occurs, otherwise returns -1 to indicate that the element is not present in the list. Assume that the elements of the list are all distinct. Write a program to perform the desired task.	
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PRACTICAL 1

Objective

Given a list of N elements, which follows no particular arrangement, you are required to search an element x in the list. The list is stored using array data structure. If the search is successful, the output should be the index at which the element occurs, otherwise returns -1 to indicate that the element is not present in the list. Assume that the elements of the list are all distinct. Write a program to perform the desired task.

Code

```cpp
/**
 * Given a list of N elements, which follows no particular
 * arrangement, you are required to search an element x in
 * the list. The list is stored using array data structure.
 * If the search is successful, the output should be the
 * index at which the element occurs, otherwise returns -1
 * to indicate that the element is not present in the list.
 * Assume that the elements of the list are all distinct.
 * Write a program to perform the desired task.
 *
 * Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>
#define MAX_SIZE 100

using namespace std;

template <class T>
int linearSearch(T *arr, int size, T el)
{
  for (int i = 0; i < size; i++)
    if (arr[i] == el)
      return i;
  return -1;
}

int main(void)
{
  int ch = 1, el, res, N, arr[MAX_SIZE];

  cout << "Enter Number of Elements: ";
  cin >> N;

  cout << "Enter Array Elements: ";
  for (int i = 0; i < N; i++)
    cin >> arr[i];
```

```
  cout << "Enter Search Element: ";
  cin >> el;

  res = linearSearch<int>(arr, N, el);

  if (res != -1)
    cout << "FOUND: Element found at index "
         << res << endl;
  else
    cout << "NOT FOUND: Element not found in array"
         << endl;

  return 0;
}
```

Output

PRACTICAL 2

Objective

Given a list of N elements, which is sorted in ascending order, you are required to search an element x in the list. The list is stored using array data structure. If the search is successful, the output should be the index at which the element occurs, otherwise returns -1 to indicate that the element is not present in the list. Assume that the elements of the list are all distinct. Write a program to perform the desired task.

Code

```
/**
 * Given a list of N elements, which is sorted in ascending
 * order, you are required to search an element x in the list.
 * The list is stored using array data structure. If the search
 * is successful, the output should be the index at which
 * the element occurs, otherwise returns -1 to indicate that
 * the element is not present in the list. Assume that the
 * elements of the list are all distinct. Write a program to
 * perform the desired task.
 *
 * Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>
#define MAX_SIZE 100
```

```
using namespace std;

template <class T>
int binarySearch(T *arr, int left, int right, T el)
{
  if (right >= left)
  {
    int mid = (right + left) / 2;
    if (arr[mid] == el)
      return mid;
    if (arr[mid] > el)
      return binarySearch(arr, left, mid - 1, el);
    return binarySearch(arr, mid + 1, right, el);
  }
  return -1;
}

int main(void)
{
  int ch = 1, el, res, N, arr[MAX_SIZE];

  cout << "Enter Number of Elements: ";
  cin >> N;

  cout << "Enter Array Elements: ";
  for (int i = 0; i < N; i++)
    cin >> arr[i];

  cout << "Enter Search Element: ";
  cin >> el;

  res = binarySearch<int>(arr, 0, N - 1, el);

  if (res != -1)
    cout << "FOUND: Element found at index "
         << res << endl;
  else
    cout << "NOT FOUND: Element not found in array"
         << endl;

  return 0;
}
```

Output

PRACTICAL 3

Objective

Write a program to implement singly linked list which supports the following operations:

i. Insert an element x at the beginning of the singly linked list

ii. Insert an element x at i^{th} position in the singly linked list

iii. Remove an element from the beginning of the singly linked list

iv. Remove an element from i^{th} position in the singly linked list

v. Search for an element x in the singly linked list and return its pointer

vi. Concatenate two singly linked lists

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>

using namespace std;

void getch();
void clrscr();

template <class T>
class Node
{
public:
  T info;
  Node *ptr;
};

template <class T>
class SinglyLinkedList
{
protected:
  Node<T> *head, *tail;

public:
  // Constructor
  SinglyLinkedList()
  {
    head = tail = NULL;
```

```
}

// Destructor
~SinglyLinkedList()
{
  if (this->isEmpty())
    return;
  Node<T> *ptr, *temp = head;
  while (temp != NULL)
  {
    ptr = temp->ptr;
    delete temp;
    temp = ptr;
  }
  head = tail = NULL;
  return;
}

// Checks if the list is empty - O(1)
bool isEmpty()
{
  return (head == NULL || tail == NULL);
}

// Inserts a node at the beginning - O(1)
void insertFront(T info)
{
  Node<T> *temp = new Node<T>();
  temp->info = info;
  temp->ptr = head;
  if (this->isEmpty())
    tail = temp;
  head = temp;
  cout << "Inserted " << info << " at front...";
  this->display();
  return;
}

// Inserts a node at a specified location - O(n)
void insertAtLoc(int loc, T info)
{
  if (loc == 1)
  {
    this->insertFront(info);
    return;
  }
  Node<T> *temp = head;
```

```
    for (int i = 1; temp != NULL && i < loc - 1; i++)
      temp = temp->ptr;
    if (temp == NULL)
    {
      cout << "Invalid location...\n";
      return;
    }
    if (temp == tail)
    {
      this->insertBack(info);
      return;
    }
    Node<T> *node = new Node<T>();
    node->info = info;
    node->ptr = temp->ptr;
    temp->ptr = node;
    cout << "Inserted node " << info << " at location " << loc << "...";
    this->display();
    return;
  }

  // Inserts a node at the end - O(1)
  void insertBack(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    temp->ptr = NULL;
    if (this->isEmpty())
      head = tail = temp;
    else
      tail->ptr = temp;
    tail = temp;
    cout << "Inserted " << info << " at back...";
    this->display();
    return;
  }

  // Removes a node from the beginning - O(1)
  void deleteFront()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    head = temp->ptr;
```

```cpp
    delete temp;
    if (this->isEmpty())
      tail = NULL;
    cout << "\nDeleted node at front...";
    this->display();
    return;
  }

  // Removes a node at a specified location - O(n)
  void deleteAtLoc(int loc)
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    if (loc == 1)
    {
      this->deleteFront();
      return;
    }
    Node<T> *node, *temp = head;
    for (int i = 1; temp != NULL && i < loc - 1; i++)
      temp = temp->ptr;
    if (temp == NULL || temp->ptr == NULL)
    {
      cout << "Invalid location...\n";
      return;
    }
    if (temp == tail)
    {
      this->deleteBack();
      return;
    }
    node = temp->ptr->ptr;
    delete temp->ptr;
    temp->ptr = node;
    cout << "Deleted node "
         << "at location " << loc << "...";
    this->display();
    return;
  }

  // Removes a node at the end - O(n)
  void deleteBack()
  {
    if (this->isEmpty())
```

```
  {
    cout << "\nList is empty...\n";
    return;
  }
  if (head == tail)
  {
    this->deleteFront();
    return;
  }
  else
  {
    Node<T> *temp = head;
    while (temp->ptr->ptr != NULL)
      temp = temp->ptr;
    delete temp->ptr;
    temp->ptr = NULL;
    tail = temp;
  }
  cout << "\nDeleted node at back...";
  this->display();
  return;
}

// Reverses the linked list - O(n)
void reverse()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  Node<T> *temp = head,
          *prev = NULL,
          *next = NULL;
  tail = temp;
  while (temp != NULL)
  {
    next = temp->ptr;
    temp->ptr = prev;
    prev = temp;
    temp = next;
  }
  head = prev;
  cout << "\nList reversed...";
  this->display();
  return;
}
```

```
// Concatenates two lists - O(n)
void concat(SinglyLinkedList<T> &list)
{
  if (!list.isEmpty() && !this->isEmpty())
  {
    Node<T> *node,
        *temp = tail,
        *temp1 = list.head;
    while (temp1 != NULL)
    {
      node = new Node<T>();
      node->info = temp1->info;
      node->ptr = NULL;
      temp->ptr = node;
      temp = temp->ptr;
      temp1 = temp1->ptr;
    }
    tail = node;
    cout << "Concatenated two lists...\n";
    this->display();
  }
  else
    cout << "\nOne of the lists is empty...\n";
  return;
}

// Overloads the + operator - O(n)
void operator+(SinglyLinkedList<T> &list)
{
  this->concat(list);
  return;
}

// Searches for an element - O(n)
Node<T> *search(T ele)
{
  if (this->isEmpty())
    return nullptr;
  Node<T> *temp = head;
  while (temp != NULL)
  {
    if (temp->info == ele)
      return temp;
    temp = temp->ptr;
  }
  return nullptr;
```

```
  }

  // Calculates the number of nodes - O(n)
  int count()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return -1;
    }
    int count = 0;
    Node<T> *temp;
    for (temp = head; temp != NULL;
         temp = temp->ptr, count++)
      ;
    return count;
  }

  // Traverses the list and prints all nodes - O(n)
  void display()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    cout << "\nList: ";
    while (temp->ptr != NULL)
    {
      cout << temp->info << " -> ";
      temp = temp->ptr;
    }
    cout << temp->info << endl;
    return;
  }
};

int main(void)
{
  int choice, ele, info, loc, count;
  SinglyLinkedList<int> list, list2;
  do
  {
    cout << "\tSingly Linked List\n"
         << "===================================\n"
         << "  (1)  Search      (2)  InsertFront\n"
```

```cpp
         << "  (3)  InsertBack  (4)  InsertAtLoc\n"
         << "  (5)  DeleteFront (6)  DeleteBack\n"
         << "  (7)  DeleteAtLoc (8)  Display\n"
         << "  (9)  Count       (10) Reverse\n"
         << "  (11) Concat      (0)  Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Search Element: ";
      cin >> ele;
      if (list.search(ele) != nullptr)
        cout << "Element " << ele << " found...\n";
      else
        cout << "Element not found or List is Empty...\n";
      break;
    case 2:
      cout << "\nEnter Element: ";
      cin >> info;
      list.insertFront(info);
      break;
    case 3:
      cout << "\nEnter Element: ";
      cin >> info;
      list.insertBack(info);
      break;
    case 4:
      cout << "\nEnter Location: ";
      cin >> loc;
      cout << "Enter Element: ";
      cin >> info;
      list.insertAtLoc(loc, info);
      break;
    case 5:
      list.deleteFront();
      break;
    case 6:
      list.deleteBack();
      break;
    case 7:
      cout << "\nEnter Location: ";
      cin >> loc;
      list.deleteAtLoc(loc);
      break;
    case 8:
      list.display();
```

```
      break;
    case 9:
      count = list.count();
      if (count != -1)
        cout << "\nNumber of Nodes: " << count << endl;
      break;
    case 11:
      if (!list2.isEmpty())
      {
        cout << "\nList B:";
        list2.display();
      }
      cout << "\nNumber of Nodes to add in List B: ";
      cin >> count;
      if (count)
      {
        cout << "Enter Elements to List B: ";
        for (int i = 0; i < count; i++)
        {
          cin >> info;
          list2.insertBack(info);
        }
        list + list2;
      }
      break;
    case 10:
      list.reverse();
      break;
    case 0:
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
```

```
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 4

Objective

Write a program to implement doubly linked list which supports the following operations:

i. Insert an element x at the beginning of the doubly linked list
ii. Insert an element x at i^{th} position in the doubly linked list
iii. Insert an element x at the end of the doubly linked list
iv. Remove an element from the beginning of the doubly linked list
v. Remove an element from i^{th} position in the doubly linked list
vi. Remove an element from the end of the doubly linked list
vii. Search for an element x in the doubly linked list and return its pointer
viii. Concatenate two doubly linked lists

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */
```

```cpp
#include <iostream>

using namespace std;

void getch();
void clrscr();

template <class T>
class Node
{
public:
  T info;
  Node *prev;
  Node *next;
};

template <class T>
class DoublyLinkedList
{
protected:
  Node<T> *head, *tail;

public:
  // Constructor
  DoublyLinkedList()
  {
    head = tail = NULL;
  }

  // Destructor
  ~DoublyLinkedList()
  {
    if (this->isEmpty())
      return;
    Node<T> *ptr;
    for (; !isEmpty();)
    {
      ptr = head->next;
      delete head;
      head = ptr;
    }
    head = tail = ptr;
    return;
  }

  // Checks if the list is empty - O(1)
  bool isEmpty()
```

```
{
  return (head == NULL || tail == NULL);
}

// Inserts a node at the beginning - O(1)
void insertFront(T info)
{
  Node<T> *temp = new Node<T>();
  temp->info = info;
  temp->next = head;
  temp->prev = NULL;
  if (this->isEmpty())
    tail = temp;
  else
    head->prev = temp;
  head = temp;
  cout << "Inserted " << info << " at front...";
  this->display();
  return;
}

// Inserts a node at a specified location - O(n)
void insertAtLoc(int loc, T info)
{
  if (loc == 1)
  {
    this->insertFront(info);
    return;
  }
  Node<T> *temp = head;
  for (int i = 1; temp != NULL && i < loc - 1; i++)
    temp = temp->next;
  if (temp == NULL)
  {
    cout << "Invalid location...\n";
    return;
  }
  if (temp == tail)
  {
    this->insertBack(info);
    return;
  }
  Node<T> *node = new Node<T>();
  node->info = info;
  node->next = temp->next;
  node->prev = temp;
  temp->next->prev = node;
```

```
    temp->next = node;
    cout << "Inserted node " << info << " at location " << loc << "...";
    this->display();
    return;
  }

  // Inserts a node at the end - O(1)
  void insertBack(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    temp->next = NULL;
    temp->prev = tail;
    if (this->isEmpty())
      head = tail = temp;
    else
      tail->next = temp;
    tail = temp;
    cout << "Inserted " << info << " at back...";
    this->display();
    return;
  }

  // Removes a node from the beginning - O(1)
  void deleteFront()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    head = temp->next;
    if (this->isEmpty())
      tail = NULL;
    else
      head->prev = NULL;
    delete temp;
    cout << "\nDeleted node at front...";
    this->display();
    return;
  }

  // Removes a node at a specified location - O(n)
  void deleteAtLoc(int loc)
  {
    if (this->isEmpty())
```

```
    {
      cout << "\nList is empty...\n";
      return;
    }
    if (loc == 1)
    {
      this->deleteFront();
      return;
    }
    Node<T> *node, *temp = head;
    for (int i = 1; temp != NULL && i < loc - 1; i++)
      temp = temp->next;
    if (temp == NULL || temp->next == NULL)
    {
      cout << "Invalid location...\n";
      return;
    }
    if (temp->next == tail)
    {
      this->deleteBack();
      return;
    }
    node = temp->next->next;
    node->prev = temp;
    delete temp->next;
    temp->next = node;
    cout << "Deleted node "
         << "at location " << loc << "...";
    this->display();
    return;
  }

  // Removes a node at the end - O(1)
  void deleteBack()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = tail;
    tail = temp->prev;
    if (this->isEmpty())
      head = NULL;
    else
      tail->next = NULL;
    delete temp;
```

```
    cout << "\nDeleted node at back...";
    this->display();
    return;
  }

  // Reverses the linked list - O(n)
  void reverse()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head,
            *temp1 = NULL;
    tail = temp;
    while (temp != NULL)
    {
      temp1 = temp->prev;
      temp->prev = temp->next;
      temp->next = temp1;
      temp = temp->prev;
    }
    if (temp1 != NULL)
      head = temp1->prev;
    cout << "\nList reversed...";
    this->display();
    return;
  }

  // Concatenates two lists - O(n)
  void concat(DoublyLinkedList<T> &list)
  {
    if (!list.isEmpty() && !this->isEmpty())
    {
      Node<T> *node,
          *temp = tail,
          *temp1 = list.head;
      while (temp1 != NULL)
      {
        node = new Node<T>();
        node->info = temp1->info;
        node->next = NULL;
        node->prev = temp;
        temp->next = node;
        temp = temp->next;
        temp1 = temp1->next;
```

```
    }
    tail = node;
    cout << "Concatenated two lists...\n";
    this->display();
  }
  else
    cout << "\nOne of the lists is empty...\n";
  return;
}

// Overloads the + operator - O(n)
void operator+(DoublyLinkedList<T> &list)
{
  this->concat(list);
  return;
}

// Searches for an element - O(n)
Node<T> *search(T ele)
{
  if (this->isEmpty())
    return nullptr;
  Node<T> *temp = head;
  while (temp != NULL)
  {
    if (temp->info == ele)
      return temp;
    temp = temp->next;
  }
  return nullptr;
}

// Calculates the number of nodes - O(n)
int count()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return -1;
  }
  int count = 0;
  Node<T> *temp;
  for (temp = head; temp != NULL;
       temp = temp->next, count++)
    ;
  return count;
}
```

```
  // Traverses the list and prints all nodes - O(n)
  void display()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    cout << "\nList: ";
    while (temp->next != NULL)
    {
      cout << temp->info << " -> ";
      temp = temp->next;
    }
    cout << temp->info << endl;
    return;
  }
};

int main(void)
{
  int info, ele, choice, loc, count;
  DoublyLinkedList<int> list, list2;
  do
  {
    cout << "\tDoubly Linked List\n"
         << "===================================\n"
         << "  (1)  Search      (2)  InsertFront\n"
         << "  (3)  InsertBack  (4)  InsertAtLoc\n"
         << "  (5)  DeleteFront (6)  DeleteBack\n"
         << "  (7)  DeleteAtLoc (8)  Display\n"
         << "  (9)  Count       (10) Reverse\n"
         << "  (11) Concat      (0)  Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Search Element: ";
      cin >> ele;
      if (list.search(ele) != nullptr)
        cout << "Element " << ele << " found...\n";
      else
        cout << "Element not found or List is Empty...\n";
      break;
```

```
case 2:
  cout << "\nEnter Element: ";
  cin >> info;
  list.insertFront(info);
  break;
case 3:
  cout << "\nEnter Element: ";
  cin >> info;
  list.insertBack(info);
  break;
case 4:
  cout << "\nEnter Location: ";
  cin >> loc;
  cout << "Enter Element: ";
  cin >> info;
  list.insertAtLoc(loc, info);
  break;
case 5:
  list.deleteFront();
  break;
case 6:
  list.deleteBack();
  break;
case 7:
  cout << "\nEnter Location: ";
  cin >> loc;
  list.deleteAtLoc(loc);
  break;
case 8:
  list.display();
  break;
case 9:
  count = list.count();
  if (count != -1)
    cout << "\nNumber of Nodes: " << count << endl;
  break;
case 10:
  list.reverse();
  break;
case 11:
  if (!list2.isEmpty())
  {
    cout << "\nList B:";
    list2.display();
  }
  cout << "\nNumber of Nodes to add in List B: ";
  cin >> count;
```

```
      if (count)
      {
        cout << "Enter Elements to List B: ";
        for (int i = 0; i < count; i++)
        {
          cin >> info;
          list2.insertBack(info);
        }
        list + list2;
      }
      break;
    case 0:
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

OBJ

OBJ

OBJ

OBJ

OBJ

PRACTICAL 5

Objective

Write a program to implement circularly linked list which supports the following operations:

i. Insert an element x at the front of the circularly linked list

ii. Insert an element x after an element y in the circularly linked list

iii. Insert an element x at the back of the circularly linked list

iv. Remove an element from the back of the circularly linked list

v. Remove an element from the front of the circularly linked list

vi. Remove the element x from the circularly linked list

vii. Search for an element x in the circularly linked list and return its pointer

viii. Concatenate two circularly linked lists

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>

using namespace std;

void getch();
void clrscr();

template <class T>
class Node
{
public:
  T info;
  Node *prev;
  Node *next;
};

template <class T>
class CircularDoublyLinkedList
{
protected:
```

```
  Node<T> *tail;

public:
  // Constructor
  CircularDoublyLinkedList()
  {
    tail = NULL;
  }

  // Destructor
  ~CircularDoublyLinkedList()
  {
    if (this->isEmpty())
      return;
    Node<T> *ptr, *temp = tail->next;
    while (temp != tail)
    {
      ptr = temp;
      temp = ptr->next;
      delete ptr;
    }
    delete temp;
    tail = NULL;
    return;
  }

  // Checks if the list is empty - O(1)
  bool isEmpty()
  {
    return tail == NULL;
  }

  // Inserts a node at the beginning - O(1)
  void insertFront(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    if (this->isEmpty())
    {
      temp->next = temp;
      temp->prev = temp;
      tail = temp;
    }
    else
    {
      temp->prev = tail;
      temp->next = tail->next;
```

```
      tail->next->prev = temp;
      tail->next = temp;
    }
    cout << "Inserted " << info << " at front...";
    this->display();
    return;
  }

  // Inserts a node at a specified location - O(n)
  void insertAtLoc(T searchEle, T info)
  {
    int loc = 0;

    if (this->isEmpty())
    {
      cout << "List Empty...\n";
      return;
    }

    int i = 0;
    Node<T> *temp = tail->next;
    do
    {
      ++i;
      if (temp->info == searchEle)
        loc = i;
      temp = temp->next;
    } while (temp != tail->next);

    if (loc == 0)
    {
      cout << "Search Element Not Found...\n";
      return;
    }

    loc++;

    if (loc == 1)
    {
      this->insertFront(info);
      return;
    }
    int size = this->count();
    if (loc > size + 1 || loc < 1)
    {
      cout << "Invalid location...\n";
      return;
```

```
    }
    if (loc == size + 1)
    {
      this->insertBack(info);
      return;
    }
    temp = tail->next;
    for (int i = 1; temp->next != tail && i < loc - 1; i++)
      temp = temp->next;
    Node<T> *node = new Node<T>();
    node->info = info;
    node->next = temp->next;
    temp->next->prev = node;
    node->prev = temp;
    temp->next = node;
    cout << "Inserted node " << info << " at location " << loc << "...";
    this->display();
    return;
  }

  // Inserts a node at the end - O(1)
  void insertBack(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    if (this->isEmpty())
    {
      temp->next = temp;
      temp->prev = temp;
    }
    else
    {
      temp->next = tail->next;
      temp->prev = tail;
      tail->next = temp;
      temp->next->prev = temp;
    }
    tail = temp;
    cout << "Inserted " << info << " at back...";
    this->display();
    return;
  }

  // Removes a node from the beginning - O(1)
  void deleteFront()
  {
    if (this->isEmpty())
```

```
  {
    cout << "\nList is empty...\n";
    return;
  }
  if (tail->next == tail)
  {
    delete tail;
    tail = NULL;
  }
  else
  {
    Node<T> *temp = tail->next;
    tail->next = temp->next;
    temp->next->prev = tail;
    delete temp;
  }
  cout << "\nDeleted node at front...";
  this->display();
  return;
}

// Removes a node at a specified location - O(n)
void deleteAtLoc(T ele)
{
  int loc = 0;

  if (this->isEmpty())
  {
    cout << "List Empty...\n";
    return;
  }

  int i = 0;
  Node<T> *temp = tail->next;
  do
  {
    ++i;
    if (temp->info == ele)
      loc = i;
    temp = temp->next;
  } while (temp != tail->next);

  if (loc == 0)
  {
    cout << "Search Element Not Found...\n";
    return;
  }
```

```
  int size = this->count();
  if (loc > size || loc < 1)
  {
    cout << "Invalid location...\n";
    return;
  }
  if (loc == size)
  {
    this->deleteBack();
    return;
  }
  temp = tail->next;
  for (int i = 1; temp->next != tail && i < loc; i++)
    temp = temp->next;
  temp->prev->next = temp->next;
  temp->next->prev = temp->prev;
  delete temp;
  cout << "Deleted node "
       << "at location " << loc << "...";
  this->display();
  return;
}

// Removes a node at the end - O(1)
void deleteBack()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  if (tail->next == tail)
  {
    delete tail;
    tail = NULL;
  }
  else
  {
    Node<T> *temp = tail;
    tail = temp->prev;
    temp->next->prev = tail;
    tail->next = temp->next;
    delete temp;
  }
  cout << "\nDeleted node at back...";
  this->display();
```

```
  return;
}

// Reverses the linked list - O(n)
void reverse()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  Node<T> *temp = tail->next,
          *headRef = tail->next,
          *temp1 = NULL;
  do
  {
    temp1 = temp->prev;
    temp->prev = temp->next;
    temp->next = temp1;
    temp = temp->prev;
  } while (temp != headRef);
  tail = headRef;
  cout << "\nList reversed...";
  this->display();
  return;
}

// Concatenates two lists - O(n)
void concat(CircularDoublyLinkedList<T> &list)
{
  if (!list.isEmpty() && !this->isEmpty())
  {
    tail->next->prev = list.tail;
    Node<T> *temp = tail->next;
    tail->next = list.tail->next;
    list.tail->next = temp;
    tail = list.tail;
    cout << "Concatenated two lists...\n";
    this->display();
  }
  else
    cout << "\nOne of the lists is empty...\n";
  return;
}

// Overloads the + operator - O(n)
void operator+(CircularDoublyLinkedList<T> &list)
```

```
{
  this->concat(list);
  return;
}

// Searches for an element - O(n)
Node<T> *search(T ele)
{
  if (this->isEmpty())
    return nullptr;
  Node<T> *temp = tail->next;
  do
  {
    if (temp->info == ele)
      return temp;
    temp = temp->next;
  } while (temp != tail->next);
  return nullptr;
}

// Calculates the number of nodes - O(n)
int count()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return -1;
  }
  int count = 0;
  Node<T> *temp = tail->next;
  do
  {
    temp = temp->next;
    count++;
  } while (temp != tail->next);
  return count;
}

// Traverses the list and prints all nodes - O(n)
void display()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  Node<T> *temp = tail->next;
```

```
    cout << "\nList: ";
    while (temp != tail)
    {
      cout << temp->info << " -> ";
      temp = temp->next;
    }
    cout << temp->info << endl;
    return;
  }
};

int main(void)
{
  int info, ele, choice, loc, count;
  CircularDoublyLinkedList<int> list, list2;
  do
  {
    cout << "\tCircular Doubly Linked List\n"
         << "===================================\n"
         << "  (1)  Search      (2)  InsertFront\n"
         << "  (3)  InsertBack  (4)  InsertAtLoc\n"
         << "  (5)  DeleteFront (6)  DeleteBack\n"
         << "  (7)  DeleteAtLoc (8)  Display\n"
         << "  (9)  Count       (10) Reverse\n"
         << "  (11) Concat      (0)  Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Search Element: ";
      cin >> ele;
      if (list.search(ele) != nullptr)
        cout << "Element " << ele << " found...\n";
      else
        cout << "Element not found or List is Empty...\n";
      break;
    case 2:
      cout << "\nEnter Element: ";
      cin >> info;
      list.insertFront(info);
      break;
    case 3:
      cout << "\nEnter Element: ";
      cin >> info;
      list.insertBack(info);
      break;
```

```
case 4:
  cout << "\nInsert After: ";
  cin >> ele;
  cout << "Enter Element: ";
  cin >> info;
  list.insertAtLoc(ele, info);
  break;
case 5:
  list.deleteFront();
  break;
case 6:
  list.deleteBack();
  break;
case 7:
  cout << "\nEnter Element: ";
  cin >> ele;
  list.deleteAtLoc(ele);
  break;
case 8:
  list.display();
  break;
case 9:
  count = list.count();
  if (count != -1)
    cout << "\nNumber of Nodes: " << count << endl;
  break;
case 10:
  list.reverse();
  break;
case 11:
  if (!list2.isEmpty())
  {
    cout << "\nList B:";
    list2.display();
  }
  cout << "\nNumber of Nodes to add in List B: ";
  cin >> count;
  if (count)
  {
    cout << "Enter Elements to List B: ";
    for (int i = 0; i < count; i++)
    {
      cin >> info;
      list2.insertBack(info);
    }
    list + list2;
  }
```

```
      break;
    case 0:
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 6

Objective

Implement a Stack using Array representation.

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>
#define MAX_SIZE 100

using namespace std;

void getch();
void clrscr();

template <class T>
class Stack
{
protected:
  int tos, size;
  T arr[MAX_SIZE];

public:
  Stack(int size = 30)
  {
    this->tos = -1;
    this->size = size;
  }

  bool push(T ele)
  {
    if (this->tos >= (this->size - 1))
    {
      cerr << "ERROR: Stack Overflow\n";
      return false;
    }
    this->arr[++(this->tos)] = ele;
    return true;
  }

  T pop()
  {
    if (this->isEmpty())
    {
      cout << "ERROR: Stack Underflow\n";
```

```
      return (T)(NULL);
    }
    return this->arr[(this->tos)--];
  }

  T top()
  {
    if (this->isEmpty())
    {
      cout << "Stack Empty";
      return (T)(NULL);
    }
    return this->arr[this->tos];
  }

  bool isEmpty()
  {
    return this->tos == -1;
  }

  void clear()
  {
    while (!this->isEmpty())
      this->pop();
  }

  void display()
  {
    if (this->isEmpty())
    {
      cout << "Stack Empty";
      return;
    }
    int i;
    cout << "Stack: ";
    for (i = 0; i < this->tos; i++)
      cout << this->arr[i] << " -> ";
    cout << this->arr[i] << endl;
    return;
  }
};

int main(void)
{
  int n, el, res, choice;
  cout << "Enter size of stack: ";
  cin >> n;
```

```
  Stack<int> stack(n);
  do
  {
    cout << "\tStack - Arrays\n"
         << "=============================\n"
         << "  (1) Push     (2) Pop\n"
         << "  (3) Top      (4) Clear\n"
         << "  (5) Display  (0) Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Element: ";
      cin >> el;
      res = stack.push(el);
      if (res)
      {
        cout << "\nPushed " << el << "...\n";
        stack.display();
      }
      break;
    case 2:
      res = stack.pop();
      if (res)
      {
        cout << "\nPopped " << res << "...\n";
        stack.display();
      }
      break;
    case 3:
      cout << "\nTop Element: "
           << stack.top() << endl;
      break;
    case 4:
      stack.clear();
      break;
    case 5:
      stack.display();
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}
```

```
void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

￼

￼

￼

￼

￼

PRACTICAL 7

Objective

Implement a Stack using Linked List representation.

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

// singlyLinkedList.hpp
#include <iostream>

using namespace std;

void getch();
void clrscr();
```

```
template <class T>
class Node
{
public:
  T info;
  Node *ptr;
};

template <class T>
class SinglyLinkedList
{
protected:
  Node<T> *head, *tail;

public:
  // Constructor
  SinglyLinkedList()
  {
    head = tail = NULL;
  }

  // Destructor
  ~SinglyLinkedList()
  {
    if (this->isEmpty())
      return;
    Node<T> *ptr, *temp = head;
    while (temp != NULL)
    {
      ptr = temp->ptr;
      delete temp;
      temp = ptr;
    }
    head = tail = NULL;
    return;
  }

  // Returns the data on the head of the list - O(1)
  T getHead()
  {
    return this->isEmpty() ? (T)(NULL) : head->info;
  }

  // Checks if the list is empty - O(1)
  bool isEmpty()
  {
```

```
    return (head == NULL || tail == NULL);
  }

  // Inserts a node at the beginning - O(1)
  void insertFront(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    temp->ptr = head;
    if (this->isEmpty())
      tail = temp;
    head = temp;
    return;
  }

  // Inserts a node at a specified location - O(n)
  void insertAtLoc(int loc, T info)
  {
    if (loc == 1)
    {
      this->insertFront(info);
      return;
    }
    Node<T> *temp = head;
    for (int i = 1; temp != NULL && i < loc - 1; i++)
      temp = temp->ptr;
    if (temp == NULL)
    {
      cout << "Invalid location...\n";
      return;
    }
    if (temp == tail)
    {
      this->insertBack(info);
      return;
    }
    Node<T> *node = new Node<T>();
    node->info = info;
    node->ptr = temp->ptr;
    temp->ptr = node;
    return;
  }

  // Inserts a node at the end - O(1)
  void insertBack(T info)
  {
    Node<T> *temp = new Node<T>();
```

```
    temp->info = info;
    temp->ptr = NULL;
    if (this->isEmpty())
      head = tail = temp;
    else
      tail->ptr = temp;
    tail = temp;
    return;
  }

  // Removes a node from the beginning - O(1)
  void deleteFront()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    head = temp->ptr;
    delete temp;
    if (this->isEmpty())
      tail = NULL;
    return;
  }

  // Removes a node at a specified location - O(n)
  void deleteAtLoc(int loc)
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    if (loc == 1)
    {
      this->deleteFront();
      return;
    }
    Node<T> *node, *temp = head;
    for (int i = 1; temp != NULL && i < loc - 1; i++)
      temp = temp->ptr;
    if (temp == NULL || temp->ptr == NULL)
    {
      cout << "Invalid location...\n";
      return;
    }
```

```
    if (temp == tail)
    {
      this->deleteBack();
      return;
    }
    node = temp->ptr->ptr;
    delete temp->ptr;
    temp->ptr = node;
    return;
  }

  // Removes a node at the end - O(n)
  void deleteBack()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    if (head == tail)
    {
      this->deleteFront();
      return;
    }
    else
    {
      Node<T> *temp = head;
      while (temp->ptr->ptr != NULL)
        temp = temp->ptr;
      delete temp->ptr;
      temp->ptr = NULL;
      tail = temp;
    }
    return;
  }

  // Reverses the linked list - O(n)
  void reverse()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head,
            *prev = NULL,
            *next = NULL;
```

```
  tail = temp;
  while (temp != NULL)
  {
    next = temp->ptr;
    temp->ptr = prev;
    prev = temp;
    temp = next;
  }
  head = prev;
  return;
}

// Concatenates two lists - O(n)
void concat(SinglyLinkedList<T> &list)
{
  if (!list.isEmpty() && !this->isEmpty())
  {
    Node<T> *node,
        *temp = tail,
        *temp1 = list.head;
    while (temp1 != NULL)
    {
      node = new Node<T>();
      node->info = temp1->info;
      node->ptr = NULL;
      temp->ptr = node;
      temp = temp->ptr;
      temp1 = temp1->ptr;
    }
    tail = node;
  }
  return;
}

// Overloads the + operator - O(n)
void operator+(SinglyLinkedList<T> &list)
{
  this->concat(list);
  return;
}

// Searches for an element - O(n)
bool search(T ele)
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
```

```
      return false;
    }
    Node<T> *temp = head;
    while (temp != NULL)
    {
      if (temp->info == ele)
        return true;
      temp = temp->ptr;
    }
    return false;
  }

  // Calculates the number of nodes - O(n)
  int count()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return -1;
    }
    int count = 0;
    Node<T> *temp;
    for (temp = head; temp != NULL;
         temp = temp->ptr, count++)
      ;
    return count;
  }

  // Traverses the list and prints all nodes - O(n)
  void display()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = head;
    while (temp->ptr != NULL)
    {
      cout << temp->info << " <- ";
      temp = temp->ptr;
    }
    cout << temp->info << endl;
    return;
  }
};
```

```cpp
// main.cpp
#include "singlyLinkedList.hpp"

using namespace std;

void getch();
void clrscr();

template <class T>
class Stack
{
protected:
  SinglyLinkedList<T> list;

public:
  bool push(T ele)
  {
    this->list.insertFront(ele);
    return true;
  }

  T pop()
  {
    if (this->isEmpty())
    {
      cout << "ERROR: Stack Underflow\n";
      return (T)(NULL);
    }
    T ele = this->list.getHead();
    this->list.deleteFront();
    return ele;
  }

  T top()
  {
    if (this->isEmpty())
    {
      cout << "Stack Empty";
      return (T)(NULL);
    }
    return this->list.getHead();
  }

  bool isEmpty()
  {
    return this->list.isEmpty();
  }
```

```
  void clear()
  {
    while (!this->isEmpty())
      this->pop();
  }

  void display()
  {
    if (this->isEmpty())
    {
      cout << "Stack Empty";
      return;
    }
    int i;
    cout << "Stack: ";
    this->list.display();
    return;
  }
};

int main(void)
{
  int el, res, choice;
  Stack<int> stack;
  do
  {
    cout << "\tStack - SLList\n"
         << "==============================\n"
         << "  (1) Push     (2) Pop\n"
         << "  (3) Top      (4) Clear\n"
         << "  (5) Display  (0) Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Element: ";
      cin >> el;
      res = stack.push(el);
      if (res)
      {
        cout << "\nPushed " << el << "...\n";
        stack.display();
      }
      break;
    case 2:
```

```
      res = stack.pop();
      if (res)
      {
        cout << "\nPopped " << res << "...\n";
        stack.display();
      }
      break;
    case 3:
      cout << "\nTop Element: "
           << stack.top() << endl;
      break;
    case 4:
      stack.clear();
      break;
    case 5:
      stack.display();
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 8

Objective

Implement a Queue using Circular Array representation.

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

#include <iostream>
#define MAX_SIZE 100

using namespace std;

void getch();
void clrscr();

template <class T>
class Queue
{
protected:
  T arr[MAX_SIZE];
  int front, rear, size;

public:
  Queue(int size = 5)
  {
    this->front = -1;
    this->rear = -1;
    this->size = size;
  }

  bool enqueue(T ele)
  {
    if (this->isFull())
    {
```

```
    cerr << "ERROR: Queue Filled\n";
    return false;
  }
  else
  {
    if (this->rear == this->size - 1 ||
        this->rear == -1)
    {
      this->arr[0] = ele;
      this->rear = 0;
      if (this->isEmpty())
        this->front = 0;
    }
    else
      this->arr[++(this->rear)] = ele;
    return true;
  }
}

T dequeue()
{
  if (this->isEmpty())
  {
    cout << "ERROR: Queue Empty\n";
    return (T)(NULL);
  }
  else
  {
    T temp = this->arr[this->front];
    if (this->front == this->rear)
      this->clear();
    else if (this->front == this->size - 1)
      this->front = 0;
    else
      this->front++;
    return temp;
  }
}

T frontEl()
{
  if (this->isEmpty())
  {
    cout << "Queue Empty";
    return (T)(NULL);
  }
  return this->arr[this->front];
```

```
  }

  bool isFull()
  {
    return this->front == 0 &&
                this->rear == this->size - 1 ||
            this->front == this->rear + 1;
  }

  bool isEmpty()
  {
    return this->front == -1;
  }

  void clear()
  {
    this->front = this->rear = -1;
  }

  void display()
  {
    if (this->isEmpty())
    {
      cout << "Queue Empty";
      return;
    }
    int i;
    if (this->rear >= this->front)
    {
      for (i = this->front; i < this->rear; i++)
        cout << this->arr[i] << " <- ";
      cout << this->arr[i] << endl;
    }
    else
    {
      for (i = this->front; i < this->size; i++)
        cout << this->arr[i] << " <- ";
      for (i = 0; i < this->rear; i++)
        cout << this->arr[i] << " <- ";
      cout << this->arr[i] << endl;
    }
    return;
  }
};

int main(void)
{
```

```cpp
int n, el, res, choice;
cout << "Enter Size of Queue: ";
cin >> n;
Queue<int> q(n);
do
{
  cout << "\tCircular Queue - Array\n"
       << "===================================\n"
       << "  (1) Enqueue  (2) Dequeue\n"
       << "  (3) Front    (4) Clear\n"
       << "  (5) Display  (0) Exit\n\n";
  cout << "Enter Choice: ";
  cin >> choice;
  switch (choice)
  {
  case 1:
    cout << "\nEnter Element: ";
    cin >> el;
    res = q.enqueue(el);
    if (res)
    {
      cout << "\nEnqueued " << el << "...\n";
      cout << "Queue: ";
      q.display();
    }
    break;
  case 2:
    res = q.dequeue();
    if (res)
    {
      cout << "\nDequeued " << res << "...\n";
      cout << "Queue: ";
      q.display();
    }
    break;
  case 3:
    cout << "\nFront Element: "
         << q.frontEl() << endl;
    break;
  case 4:
    q.clear();
    break;
  case 5:
    cout << "\nQueue: ";
    q.display();
  default:
    break;
```

```
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 9

Objective

Implement a Queue using Circular Linked List representation.

Code

```
/**
```

```
 *  Written by Sudipto Ghosh for the University of Delhi
 */

// circularSinglyLinkedList.hpp
#include <iostream>

using namespace std;

template <class T>
class Node
{
public:
  T info;
  Node *ptr;
};

template <class T>
class CircularSinglyLinkedList
{
public:
  Node<T> *tail;

  // Constructor
  CircularSinglyLinkedList()
  {
    tail = NULL;
  }

  // Destructor
  ~CircularSinglyLinkedList()
  {
    if (this->isEmpty())
      return;
    Node<T> *ptr, *temp = tail->ptr;
    while (temp != tail)
    {
      ptr = temp;
      temp = ptr->ptr;
      delete ptr;
    }
    delete temp;
    tail = NULL;
    return;
  }

  // Checks if the list is empty - O(1)
  bool isEmpty()
```

```
{
  return tail == NULL;
}

// Inserts a node at the beginning - O(1)
void insertFront(T info)
{
  Node<T> *temp = new Node<T>();
  temp->info = info;
  if (this->isEmpty())
  {
    temp->ptr = temp;
    tail = temp;
  }
  else
  {
    temp->ptr = tail->ptr;
    tail->ptr = temp;
  }
  return;
}

// Inserts a node at a specified location - O(n)
void insertAtLoc(int loc, T info)
{
  if (loc == 1)
  {
    this->insertFront(info);
    return;
  }
  int size = this->count();
  if (loc > size + 1 || loc < 1)
  {
    cout << "Invalid location...\n";
    return;
  }
  if (loc == size + 1)
  {
    this->insertBack(info);
    return;
  }
  Node<T> *temp = tail->ptr;
  for (int i = 1; temp->ptr != tail && i < loc - 1; i++)
    temp = temp->ptr;
  Node<T> *node = new Node<T>();
  node->info = info;
  node->ptr = temp->ptr;
```

```
    temp->ptr = node;
    return;
  }

  // Inserts a node at the end - O(1)
  void insertBack(T info)
  {
    Node<T> *temp = new Node<T>();
    temp->info = info;
    if (this->isEmpty())
      temp->ptr = temp;
    else
    {
      temp->ptr = tail->ptr;
      tail->ptr = temp;
    }
    tail = temp;
    return;
  }

  // Removes a node from the beginning - O(1)
  void deleteFront()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    else if (tail->ptr == tail)
    {
      delete tail;
      tail = NULL;
    }
    else
    {
      Node<T> *temp;
      temp = tail->ptr->ptr;
      delete tail->ptr;
      tail->ptr = temp;
    }
    return;
  }

  // Removes a node at a specified location - O(n)
  void deleteAtLoc(int loc)
  {
    if (this->isEmpty())
```

```
    {
      cout << "\nList is empty...\n";
      return;
    }
    int size = this->count();
    if (loc > size || loc < 1)
    {
      cout << "Invalid location...\n";
      return;
    }
    if (loc == size)
    {
      this->deleteBack();
      return;
    }
    Node<T> *node, *temp = tail->ptr;
    for (int i = 1; temp->ptr != tail && i < loc - 1; i++)
      temp = temp->ptr;
    node = temp->ptr->ptr;
    delete temp->ptr;
    temp->ptr = node;
    return;
  }

  // Removes a node at the end - O(n)
  void deleteBack()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    else if (tail->ptr == tail)
    {
      delete tail;
      tail = NULL;
    }
    else
    {
      Node<T> *temp = tail->ptr;
      while (temp->ptr != tail)
        temp = temp->ptr;
      temp->ptr = tail->ptr;
      delete tail;
      tail = temp;
    }
    return;
```

```
  }

  // Traverses the list and prints all nodes - O(n)
  void display()
  {
    if (this->isEmpty())
    {
      cout << "\nList is empty...\n";
      return;
    }
    Node<T> *temp = tail->ptr;
    while (temp != tail)
    {
      cout << temp->info << " -> ";
      temp = temp->ptr;
    }
    cout << temp->info << endl;
    return;
  }
};

// main.cpp
#include "circularSinglyLinkedList.hpp"

using namespace std;

void getch();
void clrscr();

template <class T>
class Queue
{
protected:
  Node<T> *front, *rear;
  CircularSinglyLinkedList<T> list;

public:
  Queue()
  {
    this->front = this->list.tail;
    this->rear = this->list.tail;
  }

  bool enqueue(T ele)
  {
    this->list.insertBack(ele);
    this->front = this->list.tail->ptr;
```

```
  this->rear = this->list.tail;
  return true;
}

T dequeue()
{
  if (this->isEmpty())
  {
    cout << "ERROR: Queue Empty\n";
    return (T)(NULL);
  }
  T temp = this->front->info;
  this->list.deleteFront();
  if (this->isEmpty())
    this->front = this->list.tail;
  else
    this->front = this->list.tail->ptr;
  this->rear = this->list.tail;
  return temp;
}

T frontEl()
{
  if (this->isEmpty())
  {
    cout << "Queue Empty";
    return (T)(NULL);
  }
  return this->front->info;
}

bool isEmpty()
{
  return this->list.isEmpty();
}

void clear()
{
  while (!this->isEmpty())
    this->dequeue();
}

void display()
{
  if (this->isEmpty())
  {
    cout << "Queue Empty";
```

```
        return;
      }
      this->list.display();
      return;
    }
};

int main(void)
{
  int el, res, choice;
  Queue<int> q;
  do
  {
    cout << "\tCircular Queue - CSLList\n"
         << "===================================\n"
         << "  (1) Enqueue  (2) Dequeue\n"
         << "  (3) Front    (4) Clear\n"
         << "  (5) Display  (0) Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Element: ";
      cin >> el;
      res = q.enqueue(el);
      if (res)
      {
        cout << "\nEnqueued " << el << "...\n";
        cout << "Queue: ";
        q.display();
      }
      break;
    case 2:
      res = q.dequeue();
      if (res)
      {
        cout << "\nDequeued " << res << "...\n";
        cout << "Queue: ";
        q.display();
      }
      break;
    case 3:
      cout << "\nFront Element: "
           << q.frontEl() << endl;
      break;
    case 4:
```

```
      q.clear();
      break;
    case 5:
      cout << "\nQueue: ";
      q.display();
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 10

Objective

Implement Double-ended Queues using Linked List representation.

Code

```
/**
 *  Implement Double-ended Queues using Linked List representation.
 *
 *  Written by Sudipto Ghosh for the University of Delhi
 */

// doublyLinkedList.hpp
#include <iostream>

using namespace std;

void getch();
void clrscr();

template <class T>
class Node
{
public:
  T info;
  Node *prev;
  Node *next;
};

template <class T>
class DoublyLinkedList
{
public:
  Node<T> *head, *tail;

  // Constructor
  DoublyLinkedList()
  {
    head = tail = NULL;
  }

  // Destructor
  ~DoublyLinkedList()
  {
    if (this->isEmpty())
      return;
    Node<T> *ptr;
    for (; !isEmpty();)
    {
      ptr = head->next;
      delete head;
      head = ptr;
```

```
  }
  head = tail = ptr;
  return;
}

// Checks if the list is empty - O(1)
bool isEmpty()
{
  return (head == NULL || tail == NULL);
}

// Inserts a node at the beginning - O(1)
void insertFront(T info)
{
  Node<T> *temp = new Node<T>();
  temp->info = info;
  temp->next = head;
  temp->prev = NULL;
  if (this->isEmpty())
    tail = temp;
  else
    head->prev = temp;
  head = temp;
  return;
}

// Inserts a node at the end - O(1)
void insertBack(T info)
{
  Node<T> *temp = new Node<T>();
  temp->info = info;
  temp->next = NULL;
  temp->prev = tail;
  if (this->isEmpty())
    head = tail = temp;
  else
    tail->next = temp;
  tail = temp;
  return;
}

// Removes a node from the beginning - O(1)
void deleteFront()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
```

```
    return;
  }
  Node<T> *temp = head;
  head = temp->next;
  if (this->isEmpty())
    tail = NULL;
  else
    head->prev = NULL;
  delete temp;
  return;
}

// Removes a node at the end - O(1)
void deleteBack()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  Node<T> *temp = tail;
  tail = temp->prev;
  if (this->isEmpty())
    head = NULL;
  else
    tail->next = NULL;
  delete temp;
  return;
}

// Traverses the list and prints all nodes - O(n)
void display()
{
  if (this->isEmpty())
  {
    cout << "\nList is empty...\n";
    return;
  }
  Node<T> *temp = head;
  while (temp->next != NULL)
  {
    cout << temp->info << " -> ";
    temp = temp->next;
  }
  cout << temp->info << endl;
  return;
}
```

```
};

// main.cpp
#include "doublyLinkedList.hpp"

using namespace std;

void getch();
void clrscr();

template <class T>
class DoublyEndedQueue
{
protected:
  Node<T> *front, *rear;
  DoublyLinkedList<T> list;

public:
  DoublyEndedQueue()
  {
    this->front = this->list.head;
    this->rear = this->list.tail;
  }

  void enqueueFront(T ele)
  {
    this->list.insertFront(ele);
    this->front = this->list.head;
    this->rear = this->list.tail;
  }

  void enqueueRear(T ele)
  {
    this->list.insertBack(ele);
    this->front = this->list.head;
    this->rear = this->list.tail;
  }

  T dequeueFront()
  {
    if (this->isEmpty())
    {
      cout << "ERROR: Queue Empty\n";
      return (T)(NULL);
    }
    T temp = this->front->info;
    this->list.deleteFront();
```

```
    this->front = this->list.head;
    this->rear = this->list.tail;
    return temp;
  }

  T dequeueRear()
  {
    if (this->isEmpty())
    {
      cout << "ERROR: Queue Empty\n";
      return (T)(NULL);
    }
    T temp = this->rear->info;
    this->list.deleteBack();
    this->front = this->list.head;
    this->rear = this->list.tail;
    return temp;
  }

  T frontEl()
  {
    if (this->isEmpty())
    {
      cout << "Queue Empty";
      return (T)(NULL);
    }
    return this->front->info;
  }

  bool isEmpty()
  {
    return this->list.isEmpty();
  }

  void clear()
  {
    while (!this->isEmpty())
      this->dequeue();
  }

  void display()
  {
    if (this->isEmpty())
    {
      cout << "Queue Empty";
      return;
    }
```

```
    this->list.display();
    return;
  }
};

int main(void)
{
  int el, res, choice;
  DoublyEndedQueue<int> q;
  do
  {
    cout << "\tDoubly Ended Queue - Deque\n"
         << "====================================\n"
         << "  (1) EnqueueBack   (2) DequeueRear\n"
         << "  (3) EnqueueFront  (4) DequeueFront\n"
         << "  (5) Front         (6) Display\n"
         << "  (0) Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;
    switch (choice)
    {
    case 1:
      cout << "\nEnter Element: ";
      cin >> el;
      q.enqueueRear(el);
      cout << "\nEnqueued " << el << " at rear...\n";
      cout << "Queue: ";
      q.display();
      break;
    case 2:
      res = q.dequeueRear();
      if (res)
      {
        cout << "\nDequeued " << res << " from rear...\n";
        cout << "Queue: ";
        q.display();
      }
      break;
    case 3:
      cout << "\nEnter Element: ";
      cin >> el;
      q.enqueueFront(el);
      cout << "\nEnqueued " << el << " at front...\n";
      cout << "Queue: ";
      q.display();
      break;
    case 4:
```

```
      res = q.dequeueFront();
      if (res)
      {
        cout << "\nDequeued " << res << " from front...\n";
        cout << "Queue: ";
        q.display();
      }
      break;
    case 5:
      cout << "\nFront Element: "
           << q.frontEl() << endl;
      break;
    case 6:
      cout << "\nQueue: ";
      q.display();
    default:
      break;
    }
    getch();
    clrscr();
  } while (choice != 0);
  return 0;
}

void getch()
{
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

PRACTICAL 11

Objective

Write a program to implement Binary Search Tree which supports the following operations:

i. Insert an element x

ii. Delete an element x

iii. Search for an element x in the BST and change its value to y and then place the node with value y at its appropriate position in the BST

iv. Display the elements of the BST in preorder, inorder, and postorder traversal

v. Display the elements of the BST in level-by-level traversal

vi. Display the height of the BST

Code

```
/**
 *  Written by Sudipto Ghosh for the University of Delhi
 */

// stack.hpp
#include <iostream>
#define MAX_SIZE 100

using namespace std;

template <class T>
class Stack
{
protected:
  int tos, size;
  T arr[MAX_SIZE];

public:
  Stack(int size = 30)
  {
    this->tos = -1;
    this->size = size;
  }

  bool push(T ele)
  {
    if (this->tos >= (this->size - 1))
```

```
    {
      cerr << "ERROR: Stack Overflow\n";
      return false;
    }
    this->arr[++(this->tos)] = ele;
    return true;
  }

  T pop()
  {
    if (this->isEmpty())
    {
      cout << "ERROR: Stack Underflow\n";
      return (T)(NULL);
    }
    return this->arr[(this->tos)--];
  }

  T top()
  {
    if (this->isEmpty())
    {
      cout << "Stack Empty";
      return (T)(NULL);
    }
    return this->arr[this->tos];
  }

  bool isEmpty()
  {
    return this->tos == -1;
  }

  void clear()
  {
    while (!this->isEmpty())
      this->pop();
  }
};

// queue.hpp
#include <iostream>
#define MAX_SIZE 100

using namespace std;

template <class T>
```

```
class Queue
{
protected:
  T arr[MAX_SIZE];
  int front, rear, size;

public:
  Queue(int size = 100)
  {
    this->front = -1;
    this->rear = -1;
    this->size = size;
  }

  bool enqueue(T ele)
  {
    if (this->rear >= (this->size - 1))
    {
      cerr << "ERROR: Queue Filled\n";
      return false;
    }
    else if (this->isEmpty())
    {
      this->rear++;
      this->front++;
      this->arr[this->front] = ele;
    }
    else
      this->arr[++(this->rear)] = ele;
    return true;
  }

  T dequeue()
  {
    if (this->front >= this->size)
    {
      cout << "ERROR: Queue Finished\n";
      return (T)(NULL);
    }
    else if (this->isEmpty())
    {
      cout << "ERROR: Queue Empty\n";
      return (T)(NULL);
    }
    else if (this->front == this->rear)
    {
      T temp = this->arr[this->front];
```

```
      this->clear();
      return temp;
    }
    return this->arr[(this->front)++];
  }

  T frontEl()
  {
    if (this->isEmpty())
    {
      cout << "Queue Empty";
      return (T)(NULL);
    }
    return this->arr[this->front];
  }

  bool isEmpty()
  {
    return this->front == -1;
  }

  void clear()
  {
    this->front = this->rear = -1;
  }

  void display()
  {
    if (this->isEmpty())
    {
      cout << "Queue Empty";
      return;
    }
    int i;
    for (i = this->front; i < this->rear; i++)
      cout << this->arr[i] << " <- ";
    cout << this->arr[i] << endl;
    return;
  }
};

// main.cpp
#include "stack.hpp"
#include "queue.hpp"

void getch();
void clrscr();
```

```
template <class T>
class Node
{
public:
  T data;
  Node *left, *right;
  Node()
  {
    left = nullptr;
    right = nullptr;
  }
};

class BinarySearchTree
{
public:
  Node<int> *root;
  Stack<Node<int> *> stack;
  Queue<Node<int> *> queue;
  int countLeaf, countNonLeaf;

  BinarySearchTree()
  {
    root = nullptr;
  }

  void insert(int data, Node<int> *current)
  {
    Node<int> *temp;
    if (root == nullptr)
    {
      root = new Node<int>;
      root->data = data;
      root->left = root->right = nullptr;
    }
    else
    {
      if ((data < current->data) &&
          (current->left == nullptr))
      {
        temp = new Node<int>;
        temp->data = data;
        temp->left = temp->right = nullptr;
        current->left = temp;
      }
      else if ((data >= current->data) &&
```

```
              (current->right == nullptr))
    {
      temp = new Node<int>;
      temp->data = data;
      temp->left = temp->right = nullptr;
      current->right = temp;
    }
    else
    {
      if (data < current->data)
        insert(data, current->left);
      else
        insert(data, current->right);
    }
  }
}

bool search(Node<int> *node, int key)
{
  if (node == nullptr)
    return false;

  if (node->data == key)
    return true;

  bool left = search(node->left, key);
  if (left)
    return true;
  bool right = search(node->right, key);
  return right;
}

void inOrderRecursive(Node<int> *root)
{
  if (root != nullptr)
  {
    inOrderRecursive(root->left);
    cout << root->data << " ";
    inOrderRecursive(root->right);
  }
}

void preOrderRecursive(Node<int> *root)
{
  if (root != nullptr)
  {
    cout << root->data << " ";
```

```
    preOrderRecursive(root->left);
    preOrderRecursive(root->right);
  }
}

void postOrderRecursive(Node<int> *root)
{
  if (root != nullptr)
  {
    postOrderRecursive(root->left);
    postOrderRecursive(root->right);
    cout << root->data << " ";
  }
}

void inOrderIterative()
{
  Node<int> *current = root;

  while (current != nullptr ||
         stack.isEmpty() == false)
  {
    while (current != nullptr)
    {
      stack.push(current);
      current = current->left;
    }
    current = stack.pop();
    cout << current->data << " ";
    current = current->right;
  }
}

void preOrderIterative()
{
  Node<int> *node, *temp = root;
  if (temp == nullptr)
    return;
  stack.push(temp);
  while (!stack.isEmpty())
  {
    node = stack.pop();
    cout << node->data << " ";
    if (node->right)
      stack.push(node->right);
    if (node->left)
      stack.push(node->left);
```

```
  }
}

void postOrderIterative()
{
  Node<int> *temp = root;
  if (temp == nullptr)
    return;
  do
  {
    while (temp)
    {
      if (temp->right)
        stack.push(temp->right);
      stack.push(temp);
      temp = temp->left;
    }
    temp = stack.pop();
    if (temp->right && !stack.isEmpty() &&
        stack.top() == temp->right)
    {
      stack.pop();
      stack.push(temp);
      temp = temp->right;
    }
    else
    {
      cout << temp->data << " ";
      temp = nullptr;
    }
  } while (!stack.isEmpty());
}

void levelByLevelTraversal()
{
  Node<int> *current = root;

  if (current == nullptr)
    return;

  queue.enqueue(current);
  while (!queue.isEmpty())
  {
    current = queue.dequeue();
    cout << current->data << " ";
    if (current->left)
      queue.enqueue(current->left);
```

```
    if (current->right)
      queue.enqueue(current->right);
  }

  cout << endl;
}

void mirror(Node<int> *current)
{
  if (current == nullptr)
    return;

  else
  {
    mirror(current->left);
    mirror(current->right);

    Node<int> *temp = current->left;
    current->left = current->right;
    current->right = temp;
  }
}

int height(Node<int> *current)
{
  if (current == nullptr)
    return 0;

  else
  {
    int leftHeight = height(current->left);
    int rightHeight = height(current->right);

    if (leftHeight > rightHeight)
      return (leftHeight + 1);
    else
      return (rightHeight + 1);
  }
}

void countNodes(Node<int> *current)
{
  if (current == nullptr)
    return;
  if (current->left != nullptr ||
      current->right != nullptr)
    countNonLeaf++;
```

```
  if (current->left == nullptr &&
      current->right == nullptr)
    countLeaf++;
  countNodes(current->left);
  countNodes(current->right);
}

void deleteByMerging(Node<int> *temp, int key)
{
  Node<int> *prev = nullptr;

  while (temp != nullptr)
  {
    if (temp->data == key)
      break;
    prev = temp;
    if (temp->data < key)
      temp = temp->right;
    else
      temp = temp->left;
  }

  if (temp != nullptr && temp->data == key)
  {
    if (temp == root)
      mergeHelper(root);
    else if (prev->left == temp)
      mergeHelper(prev->left);
    else
      mergeHelper(prev->right);
  }
  else if (root != nullptr)
    cout << "\nNode Not Found...";

  return;
}

void mergeHelper(Node<int> *&node)
{
  Node<int> *temp = node;

  if (node == nullptr)
    return;

  // no right child - single child
  if (node->right == nullptr)
    node = node->left;
```

```
  // no left child - single chold
  else if (node->left == nullptr)
    node = node->right;

  // node has both children
  else
  {
    // find in-order predecessor
    temp = node->left;
    while (temp->right != nullptr)
      temp = temp->right;
    // merge subtree to predecessor
    temp->right = node->right;
    temp = node;
    node = node->left;
  }

  // delete the node
  delete temp;

  return;
}

void deleteByCopying(Node<int> *temp, int key)
{
  Node<int> *prev = nullptr;

  while (temp != nullptr && temp->data != key)
  {
    prev = temp;
    if (temp->data < key)
      temp = temp->right;
    else
      temp = temp->left;
  }

  if (temp != nullptr && temp->data == key)
  {
    if (temp == root)
      copyHelper(root);
    else if (prev->left == temp)
      copyHelper(prev->left);
    else
      copyHelper(prev->right);
  }
  else if (root != nullptr)
```

```
    cout << "\nNode Not Found...";

  return;
}

void copyHelper(Node<int> *&node)
{
  Node<int> *prev, *temp = node;

  // no right child - single child
  if (node->right == nullptr)
    node = node->left;

  // no left child - single chold
  else if (node->left == nullptr)
    node = node->right;

  // node has both children
  else
  {
    prev = node;
    // find the in-order predecessor
    temp = node->left;
    while (temp->right != nullptr)
    {
      prev = temp;
      temp = temp->right;
    }
    // copy the prdecessor key
    node->data = temp->data;
    // handle dangling subtrees
    if (prev == node)
      prev->left = temp->left;
    else
      prev->right = temp->left;
  }

  // delete the node
  delete temp;

  return;
}

void searchAndReplace(int key, int newKey)
{
  if (search(root, key))
  {
```

```
      deleteByMerging(root, key);
      insert(newKey, root);
    }
    else
    {
      cout << "Node Not Found...";
    }
  }
};

int main(void)
{
  BinarySearchTree tree;
  int choice, data, data2;

  do
  {
    cout << "      MENU      \n"
         << "================\n"
         << "(1) Insertion\n"
         << "(2) Searching a node\n"
         << "(3) Display its preorder, postorder and inorder traversals. (recu
rsive)\n"
         << "(4) Display its preorder, postorder and inorder traversals. (iter
ative)\n"
         << "(5) Display level-by-level traversal. (BFS)\n"
         << "(6) Create a mirror image of tree\n"
         << "(7) Count the non-leaf, leaf and total number of nodes  \n"
         << "(8) Search for an element x in the BST and change its value to y
\n"
         << "    and then place the node with value y at its appropriate posit
ion\n"
         << "(9) Display height of tree\n"
         << "(10) Perform deletion by merging\n"
         << "(11) Perform deletion by copying\n"
         << "(0) Exit\n\n";
    cout << "Enter Choice: ";
    cin >> choice;

    switch (choice)
    {
    case 1:
      cout << "\nEnter Node Data: ";
      cin >> data;
      tree.insert(data, tree.root);
      break;
    case 2:
```

```
    cout << "\nEnter Search Data: ";
    cin >> data;
    cout << "Search Result: ";
    if (tree.search(tree.root, data))
      cout << "Found";
    else
      cout << "Not Found";
    cout << endl;
    break;
  case 3:
    cout << endl;
    cout << "In-Order Recursive Traversal: ";
    tree.inOrderRecursive(tree.root);
    cout << endl;
    cout << "Pre-Order Recursive Traversal: ";
    tree.preOrderRecursive(tree.root);
    cout << endl;
    cout << "Post-Order Recursive Traversal: ";
    tree.postOrderRecursive(tree.root);
    cout << endl;
    break;
  case 4:
    cout << endl;
    cout << "In-Order Iterative Traversal: ";
    tree.inOrderIterative();
    cout << endl;
    cout << "Pre-Order Iterative Traversal: ";
    tree.preOrderIterative();
    cout << endl;
    cout << "Post-Order Iterative Traversal: ";
    tree.postOrderIterative();
    cout << endl;
    break;
  case 5:
    cout << endl;
    cout << "Level-by-level Traversal: \n";
    tree.levelByLevelTraversal();
    break;
  case 6:
    cout << endl;
    tree.mirror(tree.root);
    cout << "Tree converted to its Mirror Tree..."
         << endl;
    break;
  case 7:
    tree.countLeaf = tree.countNonLeaf = 0;
    tree.countNodes(tree.root);
```

```
        cout << endl;
        cout << "Leaf Nodes: "
             << tree.countLeaf << endl;
        cout << "Non-Leaf Nodes: "
             << tree.countNonLeaf << endl;
        cout << "Total Nodes: "
             << tree.countNonLeaf +
                    tree.countLeaf
             << endl;
        break;
      case 8:

        cout << "\nEnter Search Data: ";
        cin >> data;
        cout << "Enter Replacement: ";
        cin >> data2;
        tree.searchAndReplace(data, data2);
        break;
      case 9:
        cout << endl;
        cout << "Height of Tree: "
             << tree.height(tree.root)
             << endl;
        break;
      case 10:
        cout << "\nEnter Node to Delete: ";
        cin >> data;
        tree.deleteByMerging(tree.root, data);
        break;
      case 11:
        cout << "\nEnter Node to Delete: ";
        cin >> data;
        tree.deleteByCopying(tree.root, data);
        break;
      case 0:
      default:
        break;
      }
      getch();
      clrscr();
    } while (choice != 0);

    return 0;
}

void getch()
{
```

```
  cout << "\nPress any key to continue...";
  cin.ignore();
  cin.get();
  return;
}

void clrscr()
{
#ifdef _WIN32
  system("cls");
#elif __unix__
  system("clear");
#endif
  return;
}
```

Output

```
      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 10

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
```

```
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 5

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 14

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
```

```
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 0

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 6

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
```

```
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 10

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 1

Enter Node Data: 14

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit
```

```
Enter Choice: 2

Enter Search Data: 14
Search Result: Found

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 2

Enter Search Data: 2
Search Result: Not Found

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit
```

```
Enter Choice: 3

In-Order Recursive Traversal: 0 5 6 10 10 14 14
Pre-Order Recursive Traversal: 10 5 0 6 14 10 14
Post-Order Recursive Traversal: 0 6 5 10 14 14 10

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 4

In-Order Iterative Traversal: 0 5 6 10 10 14 14
Pre-Order Iterative Traversal: 10 5 0 6 14 10 14
Post-Order Iterative Traversal: 0 6 5 10 14 14 10

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit
```

```
Enter Choice: 5

Level-by-level Traversal:
10 5 14 0 6 10 14

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit

Enter Choice: 7

Leaf Nodes: 4
Non-Leaf Nodes: 3
Total Nodes: 7

Press any key to continue...

      MENU
================
(1) Insertion
(2) Searching a node
(3) Display its preorder, postorder and inorder traversals. (recursive)
(4) Display its preorder, postorder and inorder traversals. (iterative)
(5) Display level-by-level traversal. (BFS)
(6) Create a mirror image of tree
(7) Count the non-leaf, leaf and total number of nodes
(8) Search for an element x in the BST and change its value to y
    and then place the node with value y at its appropriate position
(9) Display height of tree
(10) Perform deletion by merging
(11) Perform deletion by copying
(0) Exit
```

```
Enter Choice: 0

Press any key to continue...
```