```
/*
    Program-1
    Implement  Queue  using  two  stacks.  (Note:  the  functions  such  as  E
nqueue,
Dequeue and Display need to be implemented.)
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

class Queue
{
    public:

    stack<int> S1; // first stack
    stack<int> S2; // second stack

    // Enqueue a number into the queue
    void enqueue(int n)
    {
        S1.push(n); // push element onto stack
        cout << "Enqueue " << n << " operation : SUCCESS";
    }

    // Dequeue the frontmost element from the queue
    void dequeue()
    {
        if (S1.empty())
        {
            cout << "Error : QUEUE UNDERFLOW";
            return;
        }

        while (!S1.empty())
        {
            int top = S1.top();
            S2.push(top);
            S1.pop();
        }

        S2.pop(); // pop topmost
        cout << "Dequeue : SUCCESS";

        while (!S2.empty())
        {
            int top = S2.top();
            S1.push(top);
```

```cpp
            S2.pop();
        }
    }

    // Display the queue
    void display()
    {
        cout << "Your Queue : ";

        if (S1.empty())
        {
            cout << "EMPTY";
            return;
        }

        while (!S1.empty())
        {
            int top = S1.top();
            S2.push(top);
            S1.pop();
        }

        while (!S2.empty())
        {
            int top = S2.top();
            cout << top << " ";
            S1.push(top);
            S2.pop();
        }
    }
};

// Main Function
int main()
{
    cout << "Welcome to C++ Queue using Stacks !" << endl;
    cout << "'E' stands for enqueue, 'D' for dequeue, 'd' for display and 'e'
for exit." << endl << endl;

    bool flag = true;
    Queue Q; // queue object

    while (flag)
    {
        int n; // number

        char ch; // choice
        cout << "Enter your choice : ";
        cin >> ch;

        switch(ch)
        {
            case 'E': // enqueue
                cout << "Enter the element you wish to enqueue : ";
                cin >> n;
                Q.enqueue(n); // perform enqueue
                break;

            case 'D': // dequeue
                Q.dequeue();
                break;

            case 'd': // display
                Q.display();
                break;

            case 'e': // exit
                flag = false;
                cout << "Program Execution Terminated.";
                break;

            default:
                cout << "Invalid Choice.";
        }

        cout << endl << endl;
    }

    cout << "Thank you for using C++ Queue using Stacks. Bye Bye !";
}
```

```
/*
    Program-2
    Implement  circular  descending  priority  queue.  (Note:  the  functions
 such  as
Enqueue, Dequeue and Display need to be implemented.)
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Circular Descending Order Priority Queue
class CDPQ
{
    public:

    int C; // capacity
    int F, R; // front and rear pointers
    int * Q; // queue

    CDPQ(int n) // constructor
    {
        C = n; // initialize capacity
        F = R = -1; // initialize pointers
        Q = new int [C]; // initialize queue
    }

    void enqueue(int n) // enqueue an element n
    {
        if (((F == 0) && (R == C-1)) || (R+1 == F)) // overflow
        {
            cout << "Error : QUEUE OVERFLOW";
            return;
        }
        else if ((F == -1) && (R == -1)) // first element enqueue
            F = R = 0;
        else if (R == C-1) // circle cross enqueue
            R = 0;
        else // normal enqueue
            R++;

        Q[R] = n; // enqueue
        cout << "Enqueue " << n << " : SUCCESS";

        sort();
    }

    void dequeue() // dequeue frontmost element
    {
        if ((F == -1) && (R == -1))
        {
            cout << "Error : QUEUE UNDERFLOW";
            return;
        }

        cout << "Dequeue " << Q[F] << " : SUCCESS";

        if (F == R) // last element dequeue
            F = R = -1;
        else if (F == C-1) // circle cross dequeue
            F = 0;
        else // normal dequeue
            F++;
    }

    void display()
    {
        cout << "QUEUE : ";

        if ((F == -1) && (R == -1)) // empty
            cout << "EMPTY";
        else if (F <= R) // normal display
            for (int i = F; i <= R; i++) cout << Q[i] << " ";
        else // circle cross display
        {
            for (int i = F; i < C; i++) cout << Q[i] << " ";
            for (int i = 0; i <= R; i++) cout << Q[i] << " ";
        }
    }

    void sort() // sort in descending order using insertion sort
    {
        bool flag = (F <= R);
        if (!flag) R += C;

        int P = R, elem = Q[R%C];
        while ((P > F) && (Q[(P-1)%C] < Q[P%C]))
        {
            swap(Q[P%C], Q[(P-1)%C]); // swap
            P--; // decrement pointer
        }
        Q[P%C] = elem;

        if (!flag) R -= C;
    }
};
```

```cpp
// Main Function
int main()
{
    cout << "Welcome to C++ Circular Descending Order Priority Queue !" <<
endl;
    cout << "'E' stands for enqueue, 'D' for dequeue, 'd' for display and 'e'
for exit." << endl << endl;

    int n; // capacity
    cout << "Enter the maximum capcity of your queue : ";
    cin >> n;
    cout << endl;

    bool flag = true;
    CDPQ Q(n); // queue object

    while (flag)
    {
        int n; // number

        char ch; // choice
        cout << "Enter your choice : ";
        cin >> ch;

        switch(ch)
        {
            case 'E': // enqueue
                cout << "Enter the element you wish to enqueue : ";
                cin >> n;
                Q.enqueue(n); // perform enqueue
                break;

            case 'D': // dequeue
                Q.dequeue();
                break;

            case 'd': // display
                Q.display();
                break;

            case 'e': // exit
                flag = false;
                cout << "Program Execution Terminated.";
                break;

            default:
                cout << "Invalid Choice.";
        }

        cout << endl << endl;
    }

    cout << "Thank you for using C++ Circular Descending Order Priority Queue. 
Bye Bye !";
}
```

```cpp
/*
    Program-3
    Given two unordered circular doubly linked lists, write a program for the
printing
common elements of them.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Node
struct Node
{
    int data; // data
    struct Node * prev; // address of previous node
    struct Node * next; // address of next node

    Node(int n) // constructor
    {
        data = n; // set data
        prev = next = NULL;
    }
};

// Get a list as user input
struct Node * input()
{
    int n; // size
    cout << "Enter the list size : ";
    cin >> n;

    struct Node * head = NULL; // head pointer
    struct Node * ptr = head; // pointer

    cout << "Enter your list : ";
    for (int i = 0; i < n; i++)
    {
        int tmp; cin >> tmp; // get the number
        struct Node * node = new Node(tmp); // node

        if (i == 0) // first number
        {
            head = node; // set head
            head->next = head->prev = head; // set links
            ptr = head;
        }
        else // general case
        {
            ptr->next = node;
            node->prev = ptr; // doubly links
            node->next = head;
            head->prev = node; // circular links
            ptr = node; // update last node
        }
    }

    return head;
}

// Main Function
int main()
{
    cout << "Welcome to C++ Circular Doubly Linked Lists !" << endl << endl;

    cout << "LIST-I :" << endl;
    struct Node * headA = input();

    cout << endl << "LIST-II :" << endl;
    struct Node * headB = input();

    struct Node * ptrA = headA;
    struct Node * ptrB = headB; // pointers to lists
    int c = 0; // number of common elements

    cout << endl << "COMMON ELEMENTS : " << endl;
    do
    {
        do
        {
            if (ptrA->data == ptrB->data)
            {
                c++;
                cout << ptrA->data << " ";
            }
            ptrB = ptrB->next; // increment pointerB
        } while (ptrB != headB);
        ptrA = ptrA->next; // increment pointerA
    } while (ptrA != headA);

    if (!c) cout << "NONE";
    cout << endl << endl << "Thank you for using C++ Circular Doubly Linked
Lists. Bye Bye !";
}
```

```
/*
    Program-4
    Given a singly linked list, write a program to find
        (i) the last element from the beginning whose n%k == 0,
        (ii)  the first from the end whose n%k == 0,
    where n is the number of  elements in the list and k is an integer
constant. For example,
    if n = 19 and k = 3 then  (i) 18th node should be returned. (ii) 16th node
should be returned.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Linked List Node
struct Node
{
    int data; // data
    struct Node * next; // address to next node

    Node(int n) // constructor
    {
        data = n; // set data
        next = NULL; // set next pointer as NULL
    }
};

// Reverse a Linked List
struct Node * rev(struct Node * head)
{
    if (!head) return NULL;

    struct Node * prev = NULL;
    struct Node * curr = head;
    struct Node * next = NULL; // 3 pointer approach

    while (curr)
    {
        next = curr->next;
        curr->next = prev; // reverse link

        prev = curr;
        curr = next; // update pointers
    }

    return prev; // new head
}
```

```cpp
// Main Function
int main()
{
    cout << "Welcome to C++ Singly Linked Lists !" << endl << endl;

    int n; // number of elements
    cout << "Enter the number of elements in your linked list : ";
    cin >> n;

    struct Node * head = NULL; // head of linked list
    struct Node * ptr = head; // pointer to head
    cout << "Enter your linked list : ";

    for (int i = 0; i < n; i++)
    {
        int tmp; cin >> tmp;
        struct Node * node = new Node(tmp);

        if (ptr)
        {
            ptr->next = node;
            ptr = node; // update pointer
        }

        else
        {
            head = node; // set head
            ptr = head; // set pointer
        }
    }

    int k; // divisor
    cout << "Enter k : ";
    cin >> k;

    head = rev(head); // reverse the linked list
    bool flag = false;
    ptr = head;

    while (ptr)
    {
        if (!(ptr->data % k)) // remainder 0 obtained
        {
            flag = true;
            cout << "Element " << ptr->data << " satisfies n % k = 0";
            break;
        }
        ptr = ptr->next; // move forward
    }

    if (!flag) cout << "No element in your linked list satisfies the given
condition.";
    cout << endl << endl << "Thank you for using C++ Singly Linked Lists. Bye
Bye !";
}
```

```cpp
/*
    Program-5
    Given a circular linked list with even and odd numbers, write a program
to  make
changes to the list in such a way that all even numbers appear at the
beginning.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Linked List Node
struct Node
{
    int data; // data
    struct Node * next; // link to next node

    Node(int n) // constructor
    {
        data = n; // set data
        next = NULL;
    }
};

// Modify list such that all even numbers appear first
struct Node * modify(struct Node * head)
{
    struct Node * odd = NULL;
    struct Node * oddPtr = odd; // odd numbers

    struct Node * even = NULL;
    struct Node * evenPtr = even; // even numbers

    struct Node * ptr = head;
    do
    {
        if (ptr->data % 2) // odd number encountered
        {
            if (odd)
            {
                oddPtr->next = ptr;
                oddPtr = ptr; // increment odd pointer
            }

            else // first odd number
                oddPtr = oddPtr = ptr;
        }
        else // even number encountered
        {
            if (even)
            {
                evenPtr->next = ptr;
                evenPtr = ptr; // increment even pointer
            }

            else // first even number
                even = evenPtr = ptr;
        }

        ptr = ptr->next;
    } while (ptr != head);

    if (even && odd) // at least one of both odd and even exist
    {
        evenPtr->next = odd;
        oddPtr->next = even;
        return even; // even comes first
    }

    else if (even) // only even numbers exist
    {
        evenPtr->next = even; // circular link
        return even;
    }

    else if (odd) // only odd numbers exist
    {
        oddPtr->next = odd; // circular link
        return odd;
    }

    else // no numbers at all
        return NULL;
}

// Display Circular Linked List
void display(struct Node * head)
{
    if (!head)
    {
        cout << "EMPTY";
        return;
    }
    struct Node * ptr = head;
    do
    {
        cout << ptr->data << " ";
        ptr = ptr->next;
    } while (ptr != head);
}

// Main Function
int main()
{
    cout << "Welcome to C++ Circular Linked Lists !" << endl << endl;

    int n; // size of linked list
    cout << "Enter the number of elements in your linked list : ";
    cin >> n;

    struct Node * head = NULL; // head of linked list
    struct Node * ptr = head; // pointer

    cout << "Enter your list : ";
    for (int i = 0; i < n; i++)
    {
        int tmp; cin >> tmp;
        struct Node * node = new Node(tmp); // node

        if (ptr)
        {
            ptr->next = node; // insert
            ptr = node; // move pointer
        }

        else
        {
            head = node; // set head
            ptr = head; // set pointer
        }
    }

    ptr->next = head; // establish circular link
    head = modify(head); // perform modifications

    cout << "Modified List : ";
    display(head);
    cout << endl << endl << "Thank you for using C++ Circular Linked Lists.
Bye Bye !";
}
```

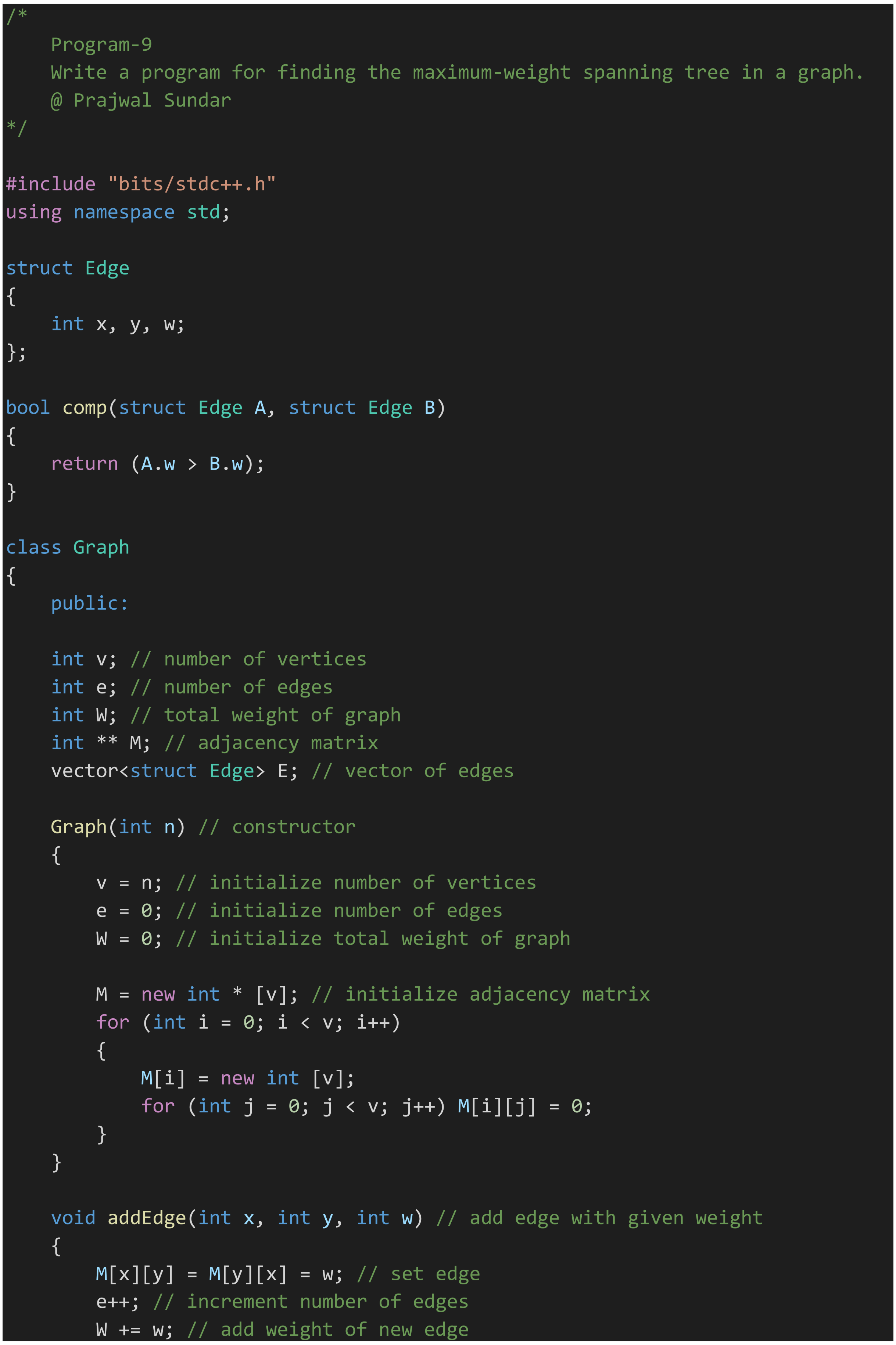
```
/*
    Program-6
    Given a BST and two integers (minimum and maximum integers) as parameters,
write a program to remove (prune) elements that are not within that range.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Binary Tree Node
struct Node
{
    int data; // data
    struct Node * left; // address of left child
    struct Node * right; // address of right child

    Node(int n) // constructor
    {
        data = n;
        left = right = NULL;
    }
};

struct Node * form()
{
    int n; cin >> n;
    struct Node * root = new Node(n);

    int l; // left child existence
    cout << "Does " << n << " have a left child ? Enter 0/1 : ";
    cin >> l;

    if (l)
    {
        cout << "Enter the left child of " << n << " : ";
        root->left = form(); // left subtree
    }

    int r; // right child existence
    cout << "Does " << n << " have a right child ? Enter 0/1 : ";
    cin >> r;

    if (r)
    {
        cout << "Enter the right child of " << n << " : ";
        root->right = form(); // right subtree
    }
```

```cpp
    return root;
}

// Prune a given BST
struct Node * prune(struct Node * root, int L, int U)
{
    if (!root) return NULL;

    root->left = prune(root->left, L, U); // prune left subtree
    root->right = prune(root->right, L, U); // prune right subtree

    // Now come to root

    if (root->data < L) // lesser than minimum element
    {
        struct Node * right = root->right;
        delete root;
        return right;
    }

    else if (root->data > U) // greater than maximum element
    {
        struct Node * left = root->left;
        delete root;
        return left;
    }

    else // in range
        return root;
}

// Binary Tree Display Function
void display(struct Node * root)
{
    if (!root) cout << "N ";
    else
    {
        cout << root->data << " "; // root
        display(root->left); // left
        display(root->right); // right
    }
}

// Main Function
int main()
{
    cout << "Welcome to C++ Binary Tree Pruner !" << endl << endl;
    cout << "Enter root value : ";
    struct Node * root = form(); // get binary tree as user input

    int L, U; // lower and upper limits
    cout << endl << "Enter the range you wish to retain : ";
    cin >> L >> U;

    root = prune(root, L, U); // prune BST
    cout << "Pruned BST : ";
    display(root);

    cout << endl << endl << "Thank you for using C++ Binary Tree Pruner. Bye 
Bye !";
}
```

```
/*
    Program-7
    Give an algorithm for checking the existence of path with given sum. That
means,
given a sum, check whether there exists a path from root to any of the nodes.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Binary Tree Node
struct Node
{
    int data; // data
    struct Node * left; // address of left child
    struct Node * right; // address of right child

    Node(int n) // constructor
    {
        data = n;
        left = right = NULL;
    }
};

void sum(struct Node * root, int s, string str, int * c)
{
    if (!root) return;

    s -= root->data; // reduce sum
    if (!s) // sum obtained
    {
        cout << "Sum Obtained in Path : " << str << endl;
        (*c)++; // increment count variable
    }

    sum(root->left, s, str+"L", c);
    sum(root->right, s, str+"R", c);
}

struct Node * form()
{
    int n; cin >> n;
    struct Node * root = new Node(n);

    int l; // left child existence
    cout << "Does " << n << " have a left child ? Enter 0/1 : ";
    cin >> l;
    if (l)
    {
        cout << "Enter the left child of " << n << " : ";
        root->left = form(); // left subtree
    }

    int r; // right child existence
    cout << "Does " << n << " have a right child ? Enter 0/1 : ";
    cin >> r;

    if (r)
    {
        cout << "Enter the right child of " << n << " : ";
        root->right = form(); // right subtree
    }

    return root;
}

int main()
{
    cout << "Welcome to C++ Binary Tree Path Sum Checker !" << endl << endl;

    cout << "Enter the root : ";
    struct Node * root = form();

    int s; // sum
    cout << endl << "Enter the sum you wish to obtain : ";
    cin >> s;

    int c = 0; // count variable
    sum(root, s, "", &c);

    if (!c) cout << "Path with given sum does not exist.";
    else cout << "Therefore, number of paths with given sum = " << c;

    cout << endl << endl << "Thank you for using C++ Binary Tree Path Sum
Checker. Bye Bye !";
}
```

```
/*
    Program-8
    Given a tree with a special property where leaves are represented with ‘L’
and
internal node with ‘I’. Also, assume that each node has either 0 or 2
children. Given
preorder traversal of this tree, write a program to construct the tree and
display it
in the tree format as shown below.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Structure of a Binary Tree Node
struct Node
{
    string data; // data
    struct Node * left; // address of left child
    struct Node * right; // address of right child

    Node(string ch) // constructor
    {
        data = ch; // set data
        left = right = NULL;
    }
};

// Return tree of a given string
struct Node * form(string str)
{
    struct Node * root = new Node("-");
    bool mode = false; // left = false, right = true
    stack<struct Node *> S; // stack
    S.push(root);

    int len = str.size();
    for (int i = 0; i < len; i++)
    {
        if (str[i] == 'I')
        {
            struct Node * node = new Node("I");

            if (!mode) S.top()->left = node;
            else S.top()->right = node; // push based on mode

            S.push(node); // push newly formed internal node
            mode = false; // reset mode
        }

        else if (str[i] == 'L')
        {
            if (!mode)
            {
                S.top()->left = new Node("L");
                mode = true; // change mode to right
            }

            else
            {
                S.top()->right = new Node("L");
                S.pop(); // pop topmost node
            }
        }
    }

    return root->left;
}

// Get height of the binary tree
int height(struct Node * root)
{
    if (!root) return -1;
    else return 1 + max(height(root->left), height(root->right));
}

// Fill Matrix Function
void fill(string ** M, struct Node * root, int r, int c, int h)
{
    M[r][c] = root->data;
    int n = pow(2, h-1);

    if (root->left) // recursion in left-subtree
    {
        int i, j, x;
        for (i = r+1, j = c-1, x = 0; x < n; i++, j--, x++) M[i][j] = "/";
        fill(M, root->left, i, j, h-1);
    }

    if (root->right) // recursion in right-subtree
    {
        int i, j, x;
        for (i = r+1, j = c+1, x = 0; x < n; i++, j++, x++) M[i][j] = "\\";
        fill(M, root->right, i, j, h-1);
    }
```

```cpp
}

// Display a tree
void display(struct Node * root)
{
    int h = height(root);

    int r = pow(2, h) + h; // number of rows in matrix
    int c = pow(2, h+1) + (2*h) - 1; // number of columns in matrix

    string ** M = new string * [r]; // string matrix to store tree
    for (int i = 0; i < r; i++)
    {
        M[i] = new string [c];
        for (int j = 0; j < c; j++) M[i][j] = " "; // empty string by default
    }

    fill(M, root, 0, r-1, h); // fill matrix function
    for (int i = 0; i < r; i++)
    {
        for (int j = 0; j < c; j++) cout << M[i][j];
        cout << endl; // next line
    }
}

// Main Function
int main()
{
    cout << "Welcome to C++ Trees !" << endl << endl;

    string str;
    cout << "Enter your pre-order string : ";
    cin >> str;

    struct Node * root = form(str); // form tree
    cout << "Your Tree is : " << endl;
    display(root);

    cout << endl << "Thank you for using C++ Trees. Bye Bye !";
}
```



```cpp
/*
    Program-9
    Write a program for finding the maximum-weight spanning tree in a graph.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

struct Edge
{
    int x, y, w;
};

bool comp(struct Edge A, struct Edge B)
{
    return (A.w > B.w);
}

class Graph
{
    public:

    int v; // number of vertices
    int e; // number of edges
    int W; // total weight of graph
    int ** M; // adjacency matrix
    vector<struct Edge> E; // vector of edges

    Graph(int n) // constructor
    {
        v = n; // initialize number of vertices
        e = 0; // initialize number of edges
        W = 0; // initialize total weight of graph

        M = new int * [v]; // initialize adjacency matrix
        for (int i = 0; i < v; i++)
        {
            M[i] = new int [v];
            for (int j = 0; j < v; j++) M[i][j] = 0;
        }
    }

    void addEdge(int x, int y, int w) // add edge with given weight
    {
        M[x][y] = M[y][x] = w; // set edge
        e++; // increment number of edges
        W += w; // add weight of new edge
        E.push_back({x, y, w});
    }

    void displayGraph() // display all graph edges
    {
        for (int i = 0; i < e; i++)
            cout << "Edge of weight " << E[i].w << " between (" << E[i].x <<
"," << E[i].y << ")" << endl;
    }
};

// Absolute Parents Function
int getAbsParent(int * parents, int v)
{
    if (parents[v] < 0) return v;
    else return getAbsParent(parents, parents[v]);
}

// Return MST of maximum weight
Graph Kruskal(Graph G)
{
    sort(G.E.begin(), G.E.end(), comp); // arrange edges in descending order
of weight

    Graph MST(G.v); // maximum spanning tree
    int parents[G.v]; // array pointing to parents
    memset(parents, -1, sizeof(parents));

    for (int i = 0; (i < G.e && MST.e < G.v-1); i++)
    {
        int xp = getAbsParent(parents, G.E[i].x);
        int yp = getAbsParent(parents, G.E[i].y);

        if (xp == yp) continue; // cycle formation
        else if (parents[xp] < parents[yp]) // make x the parent of y
        {
            parents[xp] += parents[yp];
            parents[yp] = xp;
        }
        else // make y the parent of x
        {
            parents[yp] += parents[xp];
            parents[xp] = yp;
        }

        MST.addEdge(G.E[i].x, G.E[i].y, G.E[i].w); // add edge to graph
    }
    return MST;
}

// Main Function
int main()
{
    cout << "Welcome to C++ Maximum Spanning Trees !" << endl << endl;

    int v; // number of vertices
    cout << "Enter the number of vertices : ";
    cin >> v;

    int e; // number of edges
    cout << "Enter the number of edges : ";
    cin >> e;

    Graph G(v);
    cout << "Enter each edge as (vertex1 vertex2 weight) :-" << endl;
    for (int i = 0; i < e; i++)
    {
        int x, y, w;
        cin >> x >> y >> w;
        G.addEdge(x, y, w); // add edge to graph object
    }

    Graph MST = Kruskal(G); // get maximum spanning tree using Kruskal's
algorithm
    cout << endl << "The maximum Spanning Tree has the following edges :" <<
endl;
    MST.displayGraph();
    cout << "Weight of MST : " << MST.W;

    cout << endl << endl << "Thank you for using C++ Maximum Spanning Trees.
Bye Bye !";
}
```

```cpp
/*
    Program-10
    Write a program to return the reverse of the directed graph (each edge
from v to w
is replaced by an edge from w to v).
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

class Graph
{
    public:

    int v; // number of vertices
    int e; // number of edges
    int ** M; // adjacency matrix

    Graph(int n) // constructor
    {
        v = n; // initialize number of vertices
        e = 0; // initialize number of edges
        M = new int * [v];
        for (int i = 0; i < v; i++)
        {
            M[i] = new int [v];
            for (int j = 0; j < v; j++) M[i][j] = 0; // no edge present
initially
        }
    }

    void addEdge(int x, int y)
    {
        M[x][y] = 1; // add edge to graph
    }

    void printEdges() // print all edges present in graph
    {
        for (int i = 0; i < v; i++)
            for (int j = 0; j < v; j++)
                if (M[i][j]) cout << "(" << i << "," << j << ") ";
    }

    void transpose() // reverse the graph
    {
        for (int i = 0; i < v; i++)
            for (int j = 0; j < i; j++)
```

```
                swap(M[i][j], M[j][i]);
    }
};

// Main Function
int main()
{
    cout << "Welcome to C++ Graph Reverser !" << endl << endl;

    int v; // vertices
    cout << "Enter the number of vertices : ";
    cin >> v;

    int e; // edges
    cout << "Enter the number of edges : ";
    cin >> e;

    Graph G(v); // graph
    cout << "Enter each edge as (source destination) :-" << endl;
    for (int i = 0; i < e; i++)
    {
        int x, y;
        cin >> x >> y;
        G.addEdge(x, y);
    }

    G.transpose(); // reverse direction of all edges
    cout << endl << "Reversed Graph :" << endl;
    G.printEdges();

    cout << endl << endl << "Thank you for using C++ Graph Reverser. Bye Bye
!";

}
```

```
/*
    Program-11
    Write a program to implement Warshall’s algorithm on weighted as well as
unweighted graphs.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Floyd-Warshall Algorithm on given Matrix
int ** warshall(int ** M, int n)
{
    for (int k = 0; k < n; k++)
    {
        int ** T = new int * [n];
        for (int i = 0; i < n; i++)
        {
            T[i] = new int [n];
            for (int j = 0; j < n; j++)
                T[i][j] = min(M[i][j], M[i][k] + M[k][j]);
        }
        M = T;
    }
    return M;
}

// Main Function
int main()
{
    cout << "Welcome to C++ Floyd Warshall Algorithm !" << endl << endl;

    int v; // number of vertices
    cout << "Enter the number of vertices : ";
    cin >> v;

    int e; // number of edges
    cout << "Enter the number of edges : ";
    cin >> e;

    int ** M = new int * [v]; // adjacency matrix
    for (int i = 0; i < v; i++)
    {
        M[i] = new int [v];
        for (int j = 0; j < v; j++)
        {
            if (i == j) M[i][j] = 0;
            else M[i][j] = INT_MAX;
```

```cpp
        }
    }

    cout << "Enter each edge as (source destination weight) :-" << endl;
    int maxW = INT_MIN;

    for (int i = 0; i < e; i++)
    {
        int x, y, w; cin >> x >> y >> w;
        M[x][y] = w; // set value in adjacency matrix
        maxW = max(maxW, w);
    }

    for (int i = 0; i < v; i++)
        for (int j = 0; j < v; j++)
            if (M[i][j] == INT_MAX) M[i][j] = maxW+1;

    M = warshall(M, v); // apply shortest path algorithm
    cout << endl << "All Pair Shortest Paths are :-" << endl;

    cout << "\t";
    for (int i = 0; i < v; i++) cout << "V" << i << "\t";
    cout << endl;

    for (int i = 0; i < v; i++)
    {
        cout << "V" << i << "\t";
        for (int j = 0; j < v; j++)
        {
            if (M[i][j] == maxW+1) cout << "-" << "\t";
            else cout << M[i][j] << "\t";
        }
        cout << endl;
    }

    cout << endl << "Thank you for using C++ Floyd Warshall Algorithm. Bye Bye
!";
}
```

```
/*
    Program-12
    Given an array A[] consisting of 0’s, 1’s and 2’s, Write a program to sort
this array
A[] using Quick Sort.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Partition Function
int partition(int * A, int L, int U)
{
    int i = L-1, j; // pointers
    for (j = L; j < U; j++)
    {
        if (A[j] < A[U])
        {
            i++; // increment pivot positioner
            swap(A[i], A[j]); // swap
        }
    }
    i++; // final pivot positioner
    swap(A[i], A[U]); // swap with pivot
    return i; // return pivot position
}

// Quick Sort Function
void sort(int * A, int L, int U)
{
    if (L < U)
    {
        int P = partition(A, L, U); // get partition
        sort(A, L, P-1); // sort elements left of partition
        sort(A, P+1, U); // sort elements right of partition
    }
}

// Main Function
int main()
{
    cout << "Welcome to C++ Quick Sort !" << endl << endl;

    int n; // number of elements of array
    cout << "Enter the size of your array : ";
    cin >> n;
    int A[n]; // array
    cout << "Enter your array : ";
    for (int i = 0; i < n; i++) cin >> A[i];

    sort(A, 0, n-1); // quick sort function
    cout << "Sorted Array : ";
    for (int i = 0; i < n; i++) cout << A[i] << " ";

    cout << endl << endl << "Thank you for using C++ Quick Sort. Bye Bye !";
}
```

```cpp
/*
    Program-13
    Write a program for finding the kth smallest element in min-heap.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

struct Element
{
    int num;
    int pos;
};

bool comp(struct Element A, struct Element B)
{
    return (A.num < B.num);
}

// Get kth smallest element from a min-heap
int kSmall(vector<int> MH, int k)
{
    int n = MH.size(); // size of min-heap

    vector<struct Element> V; // candidates for smallest node property
    V.push_back({MH[0], 0});

    int ans = INT_MAX;
    for (int i = 1; i <= k; i++)
    {
        sort(V.begin(), V.end(), comp); // sort vector
        ans = V[0].num; // smallest element currently

        int L = (2 * V[0].pos) + 1; // position of left child
        int R = (2 * V[0].pos) + 2; // position of right child

        if (L < n) V.push_back({MH[L], L});
        if (R < n) V.push_back({MH[R], R}); // push children

        V.erase(V.begin()); // remove first element
    }

    return ans;
}

// Main Function
int main()
```

```cpp
{
    cout << "Welcome to C++ Min Heaps !" << endl << endl;

    int n; // size of heap
    cout << "Enter the number of elements in your heap : ";
    cin >> n;

    vector<int> MH; // min heap vector
    cout << "Enter your min-heap : ";
    for (int i = 0; i < n; i++)
    {
        int tmp; cin >> tmp;
        MH.push_back(tmp);
    }

    int k; // kth smallest element
    cout << "Enter k to get kth smallest element : ";
    cin >> k;

    if ((k >= 1) && (k <= n)) cout << "The kth smallest element in your min-
heap is : " << kSmall(MH, k);
    else cout << "k should be in the range [1,n].";
    cout << endl << endl << "Thank you for using C++ Min Heaps. Bye Bye !";
}
```

```
/*
    Program-14
    Implement TSP problem using Dynamic Programming approach.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Graph Class
class Graph
{
    public:

    int v, e; // number of vertices and edges
    int ** M; // adjacency matrix

    Graph(int n) // constructor
    {
        v = n; // set number of vertices
        e = 0; // no edges initially

        M = new int * [v];
        for (int i = 0; i < v; i++)
        {
            M[i] = new int [v];
            for (int j = 0; j < v; j++) M[i][j] = 0;
        }
    }

    void addEdge(int x, int y, int w)
    {
        if (!M[x][y]) e++; // increment number of edges
        M[x][y] = w; // set edge with given weight
    }

    int getWeight(int x, int y)
    {
        return M[x][y];
    }
};

// Travelling Salesman Problem using Dynamic Programming
// Graph G and Starting Vertex s
void TSP(Graph G, int s)
{
    int r = G.v; // number of rows of matrix
    int c = pow(2, G.v); // number of columns of matrix
    int ** C = new int * [r]; // cost matrix
    int ** N = new int * [r]; // next matrix
    for (int i = 0; i < r; i++)
    {
        C[i] = new int [c]; N[i] = new int [c];
        for (int j = 0; j < c; j++)
        {
            C[i][j] = 0; // 0 cost
            N[i][j] = -1; // no where to go next
        }
    }

    vector<int> * V = new vector<int> [r+1]; // vector
    int * ones = new int [c]; // number of one's
    ones[0] = 0; V[0].push_back(0);
    for (int i = 1; i < c; i++)
    {
        ones[i] = ones[i/2] + (i%2);
        V[ones[i]].push_back(i);
    }

    // Base Cases
    for (int i = 0; i < G.v; i++)
    {
        C[i][c-1] = G.getWeight(i, s);
        N[i][c-1] = s;
    }

    // Recursive Cases
    for (int n = 1; n < r; n++)
    {
        // n - number of vertices remaining (number of zeros)
        for (int ptr = 0; ptr < V[r-n].size(); ptr++)
        {
            int j = V[r-n][ptr]; // column number
            for (int i = 0; i < r; i++)
            {
                int mincost = INT_MAX, next = -1; // minimum cost and next
vertex visited
                for (int x = 0; x < r; x++)
                {
                    if (!(j & (1 << x))) // xth vertex is unvisited
                    {
                        int cost = G.getWeight(i, x) + C[x][j+int(pow(2,x))];
// find cost
                        if (cost < mincost)
                        {
```

```cpp
                            mincost = cost;
                            next = x; // update minimum cost and next vertex
                        }
                    }
                }

                C[i][j] = mincost;
                N[i][j] = next; // record results
            }
        }
    }

    int ptrR = s, ptrC = (int) pow(2, s);
    cout << endl << "Minimum Cost : " << C[ptrR][ptrC] << endl;
    cout << "Path : ";

    do
    {
        cout << ptrR << " -> ";
        int next = N[ptrR][ptrC];

        ptrR = next;
        ptrC += (int) pow(2, next);

    } while (ptrR != s);

    cout << s;
}

// Main Function
int main()
{
    cout << "Welcome to C++ Travelling Salesman Problem !" << endl << endl;

    int v; // number of vertices
    cout << "Enter the number of vertices in your graph : ";
    cin >> v;

    int e; // number of edges
    cout << "Enter the number of edges in your graph : ";
    cin >> e;

    Graph G(v); // graph object
    cout << "Enter each edge as (source destination weight) :-" << endl;
    for (int i = 0; i < e; i++)
    {
        int x, y, w; cin >> x >> y >> w;
        G.addEdge(x, y, w);
    }

    int s; // start vertex
    cout << "Enter the start vertex : ";
    cin >> s;

    TSP(G, s);
    cout << endl << endl << "Thank you for using C++ Travelling Salesman
Problem. Bye Bye !";
}
```

```
/*
    Program-15
    Implement Strassen’s Matrix multiplication using Divide and Conquer
approach.
    @ Prajwal Sundar
*/

#include "bits/stdc++.h"
using namespace std;

// Padding Operation
int ** padding(int ** M, int r, int c, int n)
{
    int ** matrix = new int * [n];

    for (int i = 0; i < r; i++)
    {
        matrix[i] = new int [n];
        for (int j = 0; j < c; j++) matrix[i][j] = M[i][j];
        for (int j = c; j < n; j++) matrix[i][j] = 0;
    }

    for (int i = r; i < n; i++)
    {
        matrix[i] = new int [n];
        for (int j = 0; j < n; j++) matrix[i][j] = 0;
    }

    return matrix;
}

// Addition Operation
int ** Add(int ** A, int rA, int cA, int ** B, int rB, int cB, int n)
{
    int ** C = new int * [n];
    for (int i = 0; i < n; i++)
    {
        C[i] = new int [n];
        for (int j = 0; j < n; j++)
            C[i][j] = A[i+rA][j+cA] + B[i+rB][j+cB]; // addition operation
    }
    return C;
}

// Subtraction Operation
int ** Sub(int ** A, int rA, int cA, int ** B, int rB, int cB, int n)
{
    int ** C = new int * [n];
    for (int i = 0; i < n; i++)
    {
        C[i] = new int [n];
        for (int j = 0; j < n; j++)
            C[i][j] = A[i+rA][j+cA] - B[i+rB][j+cB]; // subtraction operation
    }
    return C;
}

// Strassen's Matrix Multiplication on two n x n matrices, where n is a power
of 2
int ** Mul(int ** A, int rA, int cA, int ** B, int rB, int cB, int n)
{
    int ** C = new int * [n];
    for (int i = 0; i < n; i++) C[i] = new int [n];

    if (n == 1)
    {
        C[0][0] = A[rA][cA] * B[rB][cB]; // perform multiplication
        return C; // return
    }

    // Temperory M matrices
    int ** M1 = Add(A, rA, cA, A, rA + n/2, cA + n/2, n/2); // A11 + A22
    int ** M2 = Add(B, rB, cB, B, rB + n/2, cB + n/2, n/2); // B11 + B22
    int ** M3 = Add(A, rA + n/2, cA, A, rA + n/2, cA + n/2, n/2); // A21 + A22
    int ** M4 = Sub(B, rB, cB + n/2, B, rB + n/2, cB + n/2, n/2); // B12 - B22
    int ** M5 = Sub(B, rB + n/2, cB, B, rB, cB, n/2); // B21 - B11
    int ** M6 = Add(A, rA, cA, A, rA, cA + n/2, n/2); // A11 + A12
    int ** M7 = Sub(A, rA + n/2, cA, A, rA, cA, n/2); // A21 - A11
    int ** M8 = Add(B, rB, cB, B, rB, cB + n/2, n/2); // B11 + B12
    int ** M9 = Sub(A, rA, cA + n/2, A, rA + n/2, cA + n/2, n/2); // A12 - A22
    int ** M10 = Add(B, rB + n/2, cB, B, rB + n/2, cB + n/2, n/2); // B21 +
B22

    // Intermediate Strassen's 7 Matrices
    int ** P = Mul(M1, 0, 0, M2, 0, 0, n/2);
    int ** Q = Mul(M3, 0, 0, B, rB, cB, n/2);
    int ** R = Mul(A, rA, cA, M4, 0, 0, n/2);
    int ** S = Mul(A, rA + n/2, cA + n/2, M5, 0, 0, n/2);
    int ** T = Mul(M6, 0, 0, B, rB + n/2, cB + n/2, n/2);
    int ** U = Mul(M7, 0, 0, M8, 0, 0, n/2);
    int ** V = Mul(M9, 0, 0, M10, 0, 0, n/2);

    // Some more intermediate matrices
    int ** M11 = Add(P, 0, 0, S, 0, 0, n/2);
    int ** M12 = Sub(V, 0, 0, T, 0, 0, n/2);
    int ** M13 = Add(P, 0, 0, R, 0, 0, n/2);
```

```cpp
    int ** M14 = Sub(U, 0, 0, Q, 0, 0, n/2);

    // Final Strassen's Results
    int ** C11 = Add(M11, 0, 0, M12, 0, 0, n/2);
    int ** C12 = Add(R, 0, 0, T, 0, 0, n/2);
    int ** C21 = Add(Q, 0, 0, S, 0, 0, n/2);
    int ** C22 = Add(M13, 0, 0, M14, 0, 0, n/2);

    // Copy Values into C Matrix
    for (int i = 0; i < n/2; i++)
    {
        for (int j = 0; j < n/2; j++)
        {
            C[i][j] = C11[i][j];
            C[i][j+n/2] = C12[i][j];
            C[i+n/2][j] = C21[i][j];
            C[i+n/2][j+n/2] = C22[i][j]; // copy
        }
    }

    return C; // return multiplied result
}

// Display a Matrix
void display(int ** M, int r, int c)
{
    for (int i = 0; i < r; i++)
    {
        for (int j = 0; j < c; j++) cout << M[i][j] << "\t";
        cout << endl;
    }
}

// Main Function
int main()
{
    cout << "Welcome to C++ Strassen's Matrix Multiplication !" << endl <<
endl;

    int rA, cA;
    cout << "Enter the dimensions of your first matrix : ";
    cin >> rA >> cA;

    int rB, cB;
    cout << "Enter the dimensions of your second matrix : ";
    cin >> rB >> cB;

    if (cA != rB) // multiplication not possible
```

```cpp
        cout << "Sorry, multiplication not possible as the number of columns
of the first matrix and number of rows of the second matrix are not equal." <<
endl;

    else
    {
        cout << endl << "Enter matrix A below :-" << endl;
        int ** A = new int * [rA];
        for (int i = 0; i < rA; i++)
        {
            A[i] = new int [cA];
            for (int j = 0; j < cA; j++) cin >> A[i][j];
        }

        cout << endl << "Enter matrix B below :-" << endl;
        int ** B = new int * [rB];
        for (int i = 0; i < rB; i++)
        {
            B[i] = new int [cB];
            for (int j = 0; j < cB; j++) cin >> B[i][j];
        }

        vector<int> D = {rA, cA, rB, cB}; int n = INT_MIN;
        for (int i = 0; i < 4; i++) n = max(n, D[i]); // get maximum dimension
        n = (int) pow(2, ceil(log(n)/log(2))); // convert to next nearest
power of 2

        int ** X = padding(A, rA, cA, n);
        int ** Y = padding(B, rB, cB, n); // convert to square matrices by
padding

        int ** C = Mul(X, 0, 0, Y, 0, 0, n); // strassen
        cout << endl << "Multiplied Result :-" << endl;
        display(C, rA, cB);
    }

    cout << endl << "Thank you for using C++ Strassen's Matrix Multiplication.
Bye Bye !";
}
```