Breadth First Search or BFS for a Graph

*The **Breadth First Search (BFS)** algorithm is used to search a graph data structure for a node that meets a set of criteria. It starts at the root of the graph and visits all nodes at the current depth level before moving on to the nodes at the next depth level.*

Relation between BFS for Graph and Tree traversal:

Breadth-First Traversal (or Search) for a graph is similar to the Breadth-First Traversal of a tree.

The only catch here is, that, unlike trees, graphs may contain cycles, so we may come to the same node again. To avoid processing a node more than once, we divide the vertices into two categories:

- Visited and
- Not visited.

A boolean visited array is used to mark the visited vertices. For simplicity, it is assumed that all vertices are reachable from the starting vertex. BFS uses a **queue data structure** for traversal.

How does BFS work?

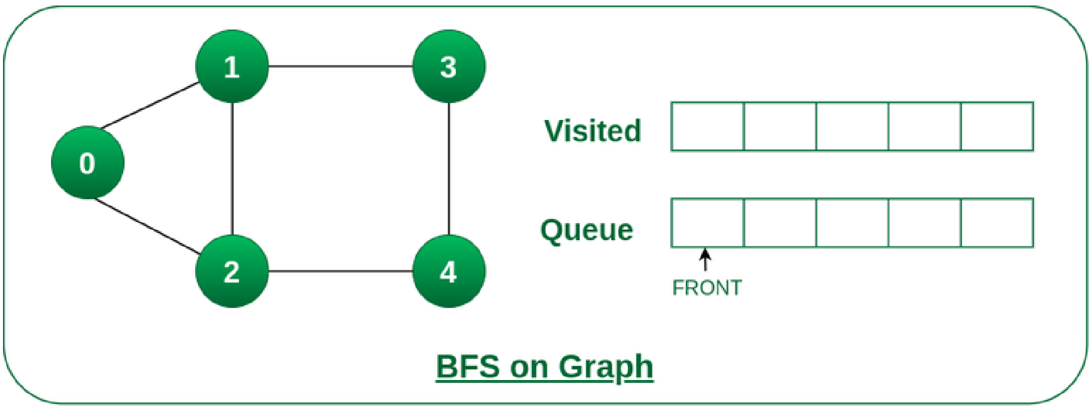
Starting from the root, all the nodes at a particular level are visited first and then the nodes of the next level are traversed till all the nodes are visited.

To do this a queue is used. All the adjacent unvisited nodes of the current level are pushed into the queue and the nodes of the current level are marked visited and popped from the queue.

Illustration:

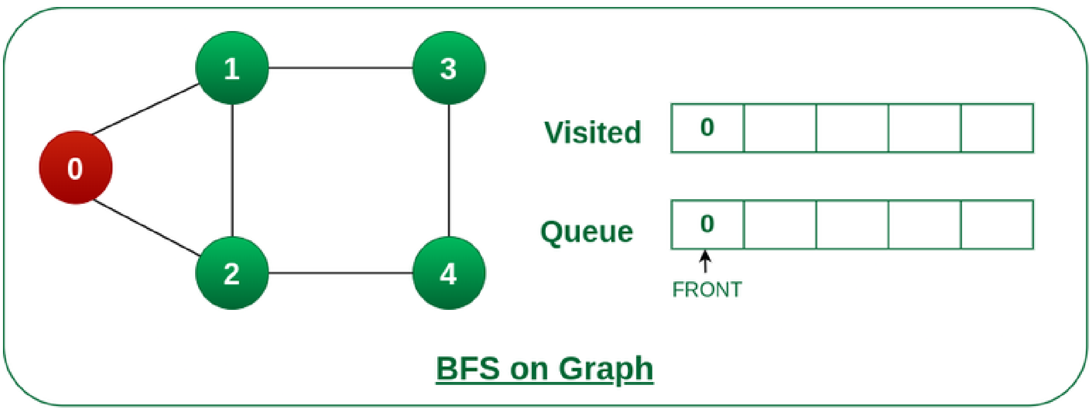
Let us understand the working of the algorithm with the help of the following example.

Step1: *Initially queue and visited arrays are empty.*



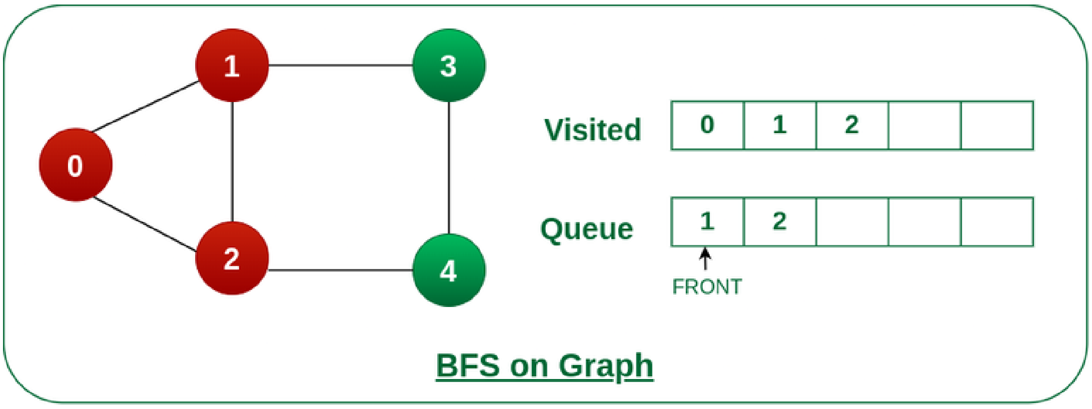
Queue and visited arrays are empty initially.

Step2: *Push node 0 into queue and mark it visited.*



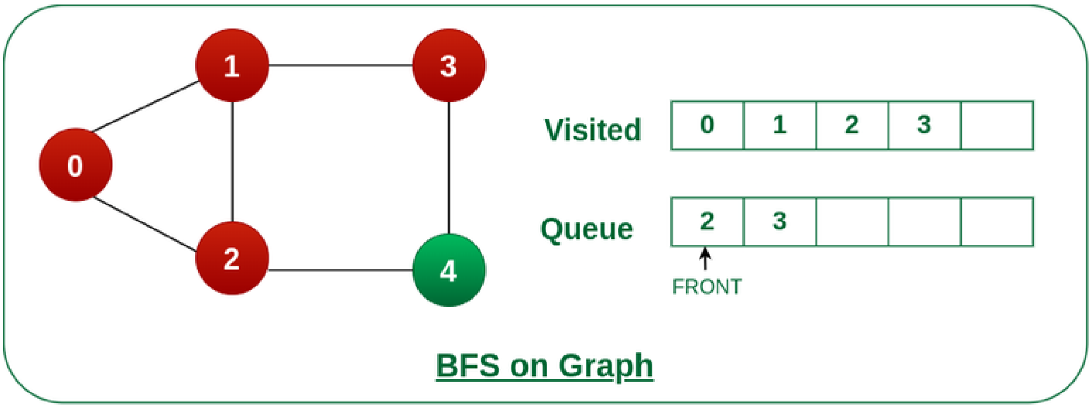
Push node 0 into queue and mark it visited.

Step 3: *Remove node 0 from the front of queue and visit the unvisited neighbours and push them into queue.*



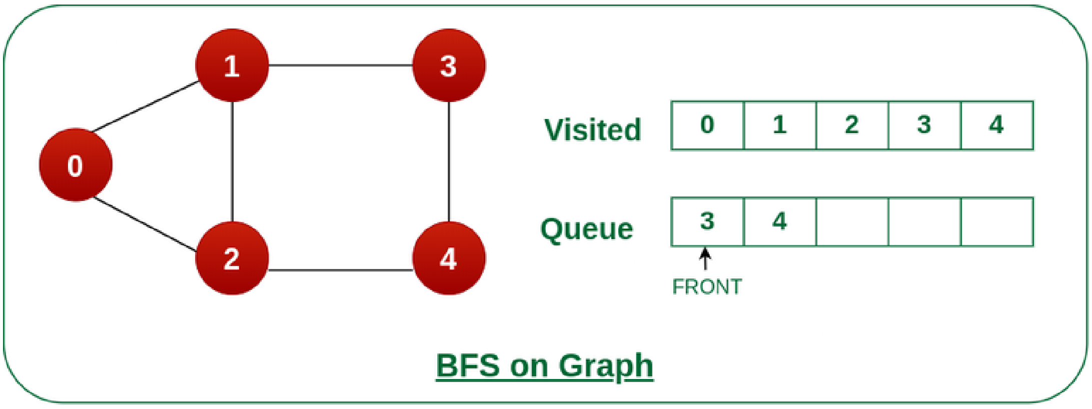
Remove node 0 from the front of queue and visited the unvisited neighbours and push into queue.

Step 4: *Remove node 1 from the front of queue and visit the unvisited neighbours and push them into queue.*



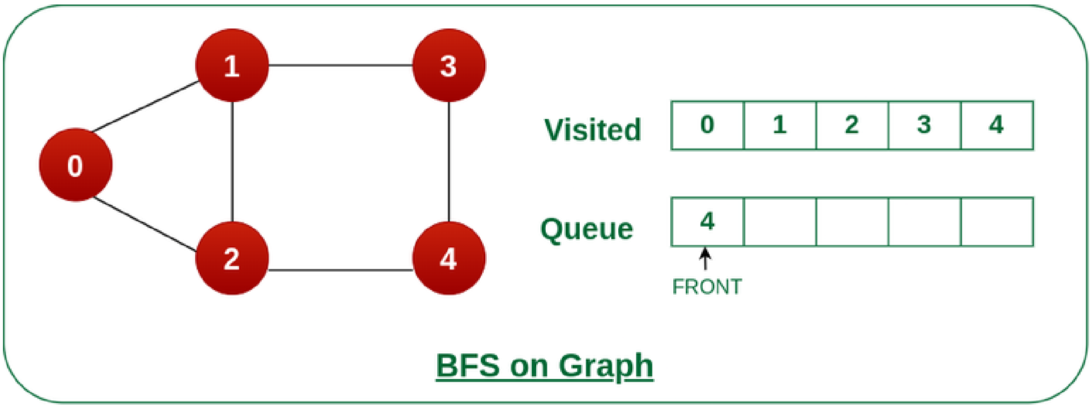
Remove node 1 from the front of queue and visited the unvisited neighbours and push

Step 5: *Remove node 2 from the front of queue and visit the unvisited neighbours and push them into queue.*



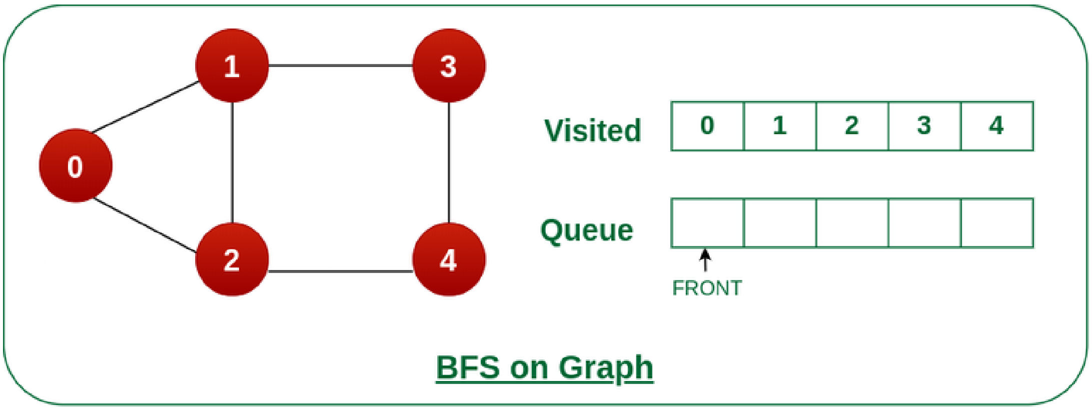
Remove node 2 from the front of queue and visit the unvisited neighbours and push them into queue.

Step 6: Remove node 3 from the front of queue and visit the unvisited neighbours and push them into queue.
As we can see that every neighbours of node 3 is visited, so move to the next node that are in the front of the queue.



Remove node 3 from the front of queue and visit the unvisited neighbours and push them into queue.

Steps 7: *Remove node 4 from the front of queue and visit the unvisited neighbours and push them into queue.*
As we can see that every neighbours of node 4 are visited, so move to the next node that is in the front of the queue.



Remove node 4 from the front of queue and visit the unvisited neighbours and push them into queue.

Now, Queue becomes empty, So, terminate these process of iteration.

Implementation of BFS for Graph using Adjacency List:

C

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

#define MAX_VERTICES 50

// This struct represents a directed graph using
// adjacency list representation
typedef struct Graph_t {

    // No. of vertices
    int V;
    bool adj[MAX_VERTICES][MAX_VERTICES];
} Graph;

// Constructor
Graph* Graph_create(int V)
{
    Graph* g = malloc(sizeof(Graph));
    g->V = V;

    for (int i = 0; i < V; i++) {
        for (int j = 0; j < V; j++) {
            g->adj[i][j] = false;
        }
    }

    return g;
}

// Destructor
void Graph_destroy(Graph* g) { free(g); }

// Function to add an edge to graph
void Graph_addEdge(Graph* g, int v, int w)
{
    // Add w to v’s list.
    g->adj[v][w] = true;
}

// Prints BFS traversal from a given source s
void Graph_BFS(Graph* g, int s)
{
    // Mark all the vertices as not visited
    bool visited[MAX_VERTICES];
    for (int i = 0; i < g->V; i++) {
```

```c
        visited[i] = false;
    }

    // Create a queue for BFS
    int queue[MAX_VERTICES];
    int front = 0, rear = 0;

    // Mark the current node as visited and enqueue it
    visited[s] = true;
    queue[rear++] = s;

    while (front != rear) {

        // Dequeue a vertex from queue and print it
        s = queue[front++];
        printf("%d ", s);

        // Get all adjacent vertices of the dequeued
        // vertex s.
        // If an adjacent has not been visited,
        // then mark it visited and enqueue it
        for (int adjacent = 0; adjacent < g->V;
             adjacent++) {
            if (g->adj[s][adjacent] && !visited[adjacent]) {
                visited[adjacent] = true;
                queue[rear++] = adjacent;
            }
        }
    }
}

// Driver code
int main()
{
    // Create a graph
    Graph* g = Graph_create(4);
    Graph_addEdge(g, 0, 1);
    Graph_addEdge(g, 0, 2);
    Graph_addEdge(g, 1, 2);
    Graph_addEdge(g, 2, 0);
    Graph_addEdge(g, 2, 3);
    Graph_addEdge(g, 3, 3);

    printf("Following is Breadth First Traversal "
           "(starting from vertex 2) \n");
    Graph_BFS(g, 2);
    Graph_destroy(g);

    return 0;
```

```
}
```

C++

```cpp
// C++ code to print BFS traversal from a given
// source vertex

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

// This class represents a directed graph using
// adjacency list representation
class Graph {

    // No. of vertices
    int V;

    // Pointer to an array containing adjacency lists
    vector<list<int> > adj;

public:
    // Constructor
    Graph(int V);

    // Function to add an edge to graph
    void addEdge(int v, int w);

    // Prints BFS traversal from a given source s
    void BFS(int s);
};

Graph::Graph(int V)
{
    this->V = V;
    adj.resize(V);
}

void Graph::addEdge(int v, int w)
{
    // Add w to v’s list.
    adj[v].push_back(w);
}

void Graph::BFS(int s)
{
    // Mark all the vertices as not visited
    vector<bool> visited;
    visited.resize(V, false);
```

```
    // Create a queue for BFS
    list<int> queue;

    // Mark the current node as visited and enqueue it
    visited[s] = true;
    queue.push_back(s);

    while (!queue.empty()) {

        // Dequeue a vertex from queue and print it
        s = queue.front();
        cout << s << " ";
        queue.pop_front();

        // Get all adjacent vertices of the dequeued
        // vertex s.
        // If an adjacent has not been visited,
        // then mark it visited and enqueue it
        for (auto adjacent : adj[s]) {
            if (!visited[adjacent]) {
                visited[adjacent] = true;
                queue.push_back(adjacent);
            }
        }
    }
}

// Driver code
int main()
{
    // Create a graph given in the above diagram
    Graph g(4);
    g.addEdge(0, 1);
    g.addEdge(0, 2);
    g.addEdge(1, 2);
    g.addEdge(2, 0);
    g.addEdge(2, 3);
    g.addEdge(3, 3);

    cout << "Following is Breadth First Traversal "
         << "(starting from vertex 2) \n";
    g.BFS(2);

    return 0;
}
```

Java

```java
// Java program to print BFS traversal from a given source
// vertex. BFS(int s) traverses vertices reachable from s.

import java.io.*;
import java.util.*;

// This class represents a directed graph using adjacency
// list representation
class Graph {

    // No. of vertices
    private int V;

    // Adjacency Lists
    private LinkedList<Integer> adj[];

    // Constructor
    Graph(int v)
    {
        V = v;
        adj = new LinkedList[v];
        for (int i = 0; i < v; ++i)
            adj[i] = new LinkedList();
    }

    // Function to add an edge into the graph
    void addEdge(int v, int w) { adj[v].add(w); }

    // prints BFS traversal from a given source s
    void BFS(int s)
    {
        // Mark all the vertices as not visited(By default
        // set as false)
        boolean visited[] = new boolean[V];

        // Create a queue for BFS
        LinkedList<Integer> queue
            = new LinkedList<Integer>();

        // Mark the current node as visited and enqueue it
        visited[s] = true;
        queue.add(s);

        while (queue.size() != 0) {

            // Dequeue a vertex from queue and print it
            s = queue.poll();
            System.out.print(s + " ");
```

```
            // Get all adjacent vertices of the dequeued
            // vertex s.
            // If an adjacent has not been visited,
            // then mark it visited and enqueue it
            Iterator<Integer> i = adj[s].listIterator();
            while (i.hasNext()) {
                int n = i.next();
                if (!visited[n]) {
                    visited[n] = true;
                    queue.add(n);
                }
            }
        }
    }

    // Driver code
    public static void main(String args[])
    {
        Graph g = new Graph(4);
        g.addEdge(0, 1);
        g.addEdge(0, 2);
        g.addEdge(1, 2);
        g.addEdge(2, 0);
        g.addEdge(2, 3);
        g.addEdge(3, 3);

        System.out.println(
            "Following is Breadth First Traversal "
            + "(starting from vertex 2)");

        g.BFS(2);
    }
}

// This code is contributed by Aakash Hasija
```

Python3

```
# Python3 Program to print BFS traversal
# from a given source vertex. BFS(int s)
# traverses vertices reachable from s.

from collections import defaultdict


# This class represents a directed graph
# using adjacency list representation
```

```python
class Graph:

    # Constructor
    def __init__(self):

        # Default dictionary to store graph
        self.graph = defaultdict(list)

    # Function to add an edge to graph
    def addEdge(self, u, v):
        self.graph[u].append(v)

    # Function to print a BFS of graph
    def BFS(self, s):

        # Mark all the vertices as not visited
        visited = [False] * (max(self.graph) + 1)

        # Create a queue for BFS
        queue = []

        # Mark the source node as
        # visited and enqueue it
        queue.append(s)
        visited[s] = True

        while queue:

            # Dequeue a vertex from
            # queue and print it
            s = queue.pop(0)
            print(s, end=" ")

            # Get all adjacent vertices of the
            # dequeued vertex s.
            # If an adjacent has not been visited,
            # then mark it visited and enqueue it
            for i in self.graph[s]:
                if visited[i] == False:
                    queue.append(i)
                    visited[i] = True


# Driver code
if __name__ == '__main__':

    # Create a graph given in
    # the above diagram
    g = Graph()
```

```
    g.addEdge(0, 1)
    g.addEdge(0, 2)
    g.addEdge(1, 2)
    g.addEdge(2, 0)
    g.addEdge(2, 3)
    g.addEdge(3, 3)

    print("Following is Breadth First Traversal"
          " (starting from vertex 2)")
    g.BFS(2)

# This code is contributed by Neelam Yadav
```

C#

```
// C# program to print BFS traversal from a given source
// vertex. BFS(int s) traverses vertices reachable from s.

using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;

// This class represents a directed graph
// using adjacency list representation
class Graph {

    // No. of vertices
    private int _V;

    // Adjacency Lists
    LinkedList<int>[] _adj;

    public Graph(int V)
    {
        _adj = new LinkedList<int>[ V ];
        for (int i = 0; i < _adj.Length; i++) {
            _adj[i] = new LinkedList<int>();
        }
        _V = V;
    }

    // Function to add an edge into the graph
    public void AddEdge(int v, int w)
    {
        _adj[v].AddLast(w);
    }
```

```
// Prints BFS traversal from a given source s
public void BFS(int s)
{

    // Mark all the vertices as not
    // visited(By default set as false)
    bool[] visited = new bool[_V];
    for (int i = 0; i < _V; i++)
        visited[i] = false;

    // Create a queue for BFS
    LinkedList<int> queue = new LinkedList<int>();

    // Mark the current node as
    // visited and enqueue it
    visited[s] = true;
    queue.AddLast(s);

    while (queue.Any()) {

        // Dequeue a vertex from queue
        // and print it
        s = queue.First();
        Console.Write(s + " ");
        queue.RemoveFirst();

        // Get all adjacent vertices of the
        // dequeued vertex s.
        // If an adjacent has not been visited,
        // then mark it visited and enqueue it
        LinkedList<int> list = _adj[s];

        foreach(var val in list)
        {
            if (!visited[val]) {
                visited[val] = true;
                queue.AddLast(val);
            }
        }
    }
}

// Driver code
static void Main(string[] args)
{
    Graph g = new Graph(4);
    g.AddEdge(0, 1);
    g.AddEdge(0, 2);
    g.AddEdge(1, 2);
```

```
        g.AddEdge(2, 0);
        g.AddEdge(2, 3);
        g.AddEdge(3, 3);

        Console.Write("Following is Breadth First "
                      + "Traversal(starting from "
                      + "vertex 2) \n");
        g.BFS(2);
    }
}

// This code is contributed by anv89
```

Javascript

```
// Javacript Program to print BFS traversal from a given
// source vertex. BFS(int s) traverses vertices
// reachable from s.


// This class represents a directed graph using
// adjacency list representation
class Graph
{
    // Constructor
    constructor(v)
    {
        this.V = v;
        this.adj = new Array(v);
        for(let i = 0; i < v; i++)
            this.adj[i] = [];
    }

    // Function to add an edge into the graph
    addEdge(v, w)
    {
        // Add w to v's list.
        this.adj[v].push(w);
    }

    // Prints BFS traversal from a given source s
    BFS(s)
    {
        // Mark all the vertices as not visited(By default
        // set as false)
        let visited = new Array(this.V);
        for(let i = 0; i < this.V; i++)
            visited[i] = false;
```

```
        // Create a queue for BFS
        let queue=[];

        // Mark the current node as visited and enqueue it
        visited[s]=true;
        queue.push(s);

        while(queue.length>0)
        {
            // Dequeue a vertex from queue and print it
            s = queue[0];
            console.log(s+" ");
            queue.shift();

            // Get all adjacent vertices of the dequeued
            // vertex s.
            // If an adjacent has not been visited,
            // then mark it visited and enqueue it
            this.adj[s].forEach((adjacent,i) => {
                if(!visited[adjacent])
                {
                    visited[adjacent]=true;
                    queue.push(adjacent);
                }
            });
        }
    }
}

// Driver program to test methods of graph class

    // Create a graph given in the above diagram
    g = new Graph(4);
    g.addEdge(0, 1);
    g.addEdge(0, 2);
    g.addEdge(1, 2);
    g.addEdge(2, 0);
    g.addEdge(2, 3);
    g.addEdge(3, 3);

    console.log("Following is Breadth First Traversal " +
                "(starting from vertex 2) ");

    g.BFS(2);

// This code is contributed by Aman Kumar.
```

Output

```
Following is Breadth First Traversal (starting from vertex
2)
2 0 3 1
```

Time Complexity: O(V+E), where V is the number of nodes and E is the number of edges.
Auxiliary Space: O(V)

Problems related to BFS:

S.no	Problems	Practice
1.	Find the level of a given node in an Undirected Graph	Link
2.	Minimize maximum adjacent difference in a path from top-left to bottom-right	Link
3.	Minimum jump to the same value or adjacent to reach the end of an Array	Link
4.	Maximum coin in minimum time by skipping K obstacles along the path in Matrix	Link
5.	Check if all nodes of the Undirected Graph can be visited from the given Node	Link
6.	Minimum time to visit all nodes of a given Graph at least once	Link
7.	Minimize moves to the next greater element to reach the end of the Array	Link
8.	Shortest path by removing K walls	Link

S.no	Problems	Practice
9.	Minimum time required to infect all the nodes of the Binary tree	Link
10.	Check if destination of given Matrix is reachable with required values of cells	Link

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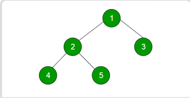

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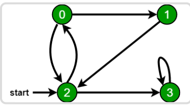

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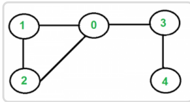

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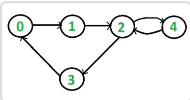

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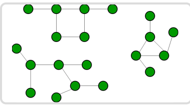

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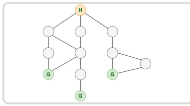

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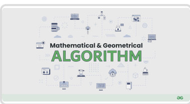

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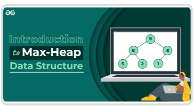

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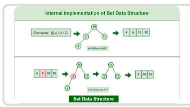

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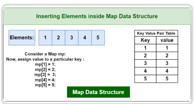

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