Meet In The Middle - II

Special class

Vivek Chauhan • Jan 17, 2021

Vivek Chauhan

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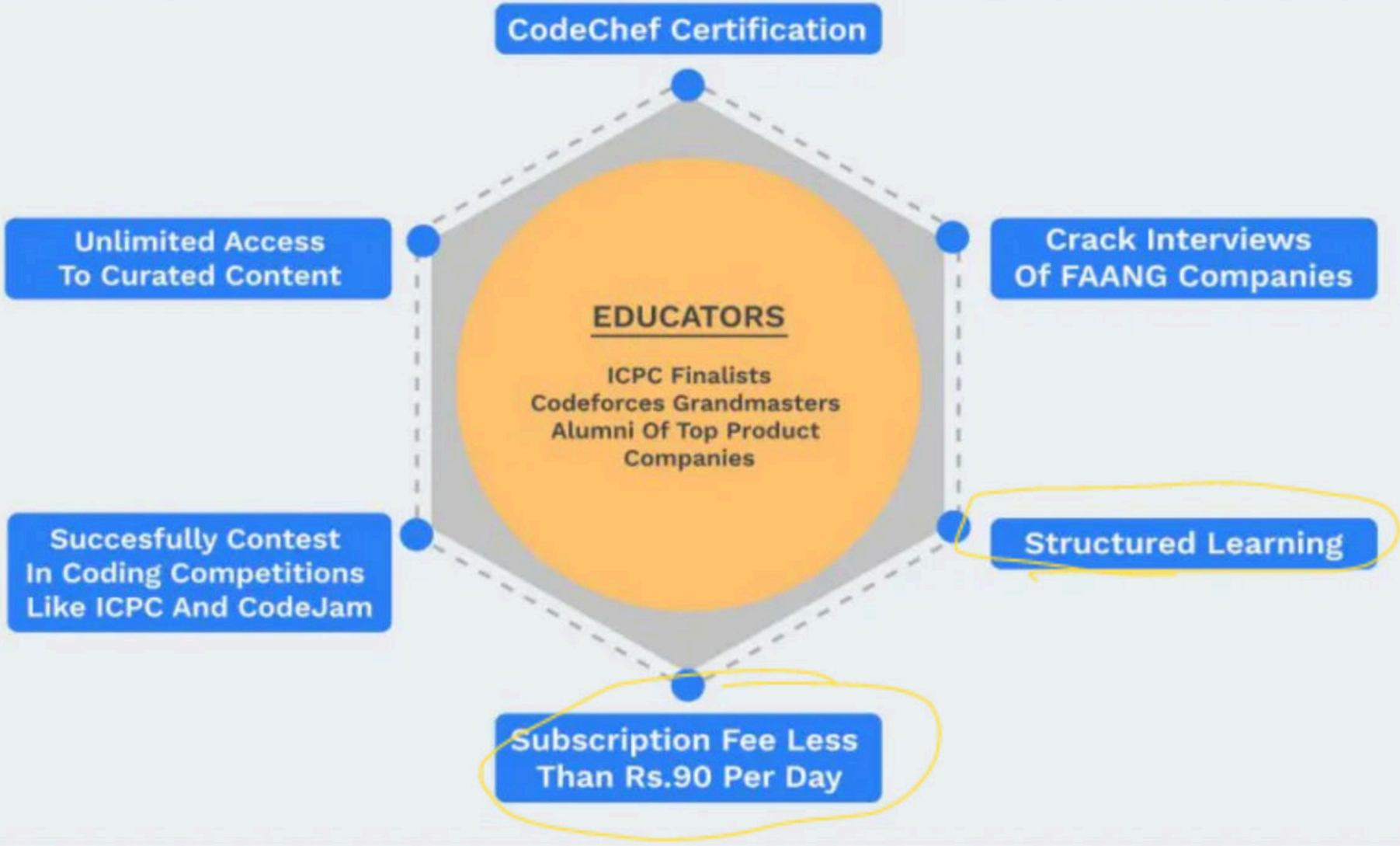

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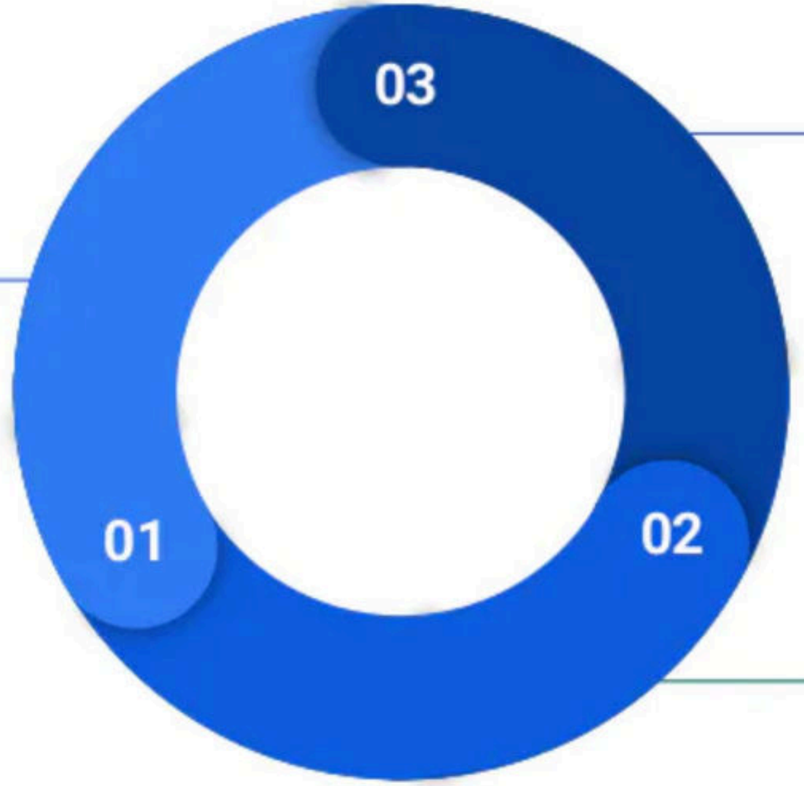

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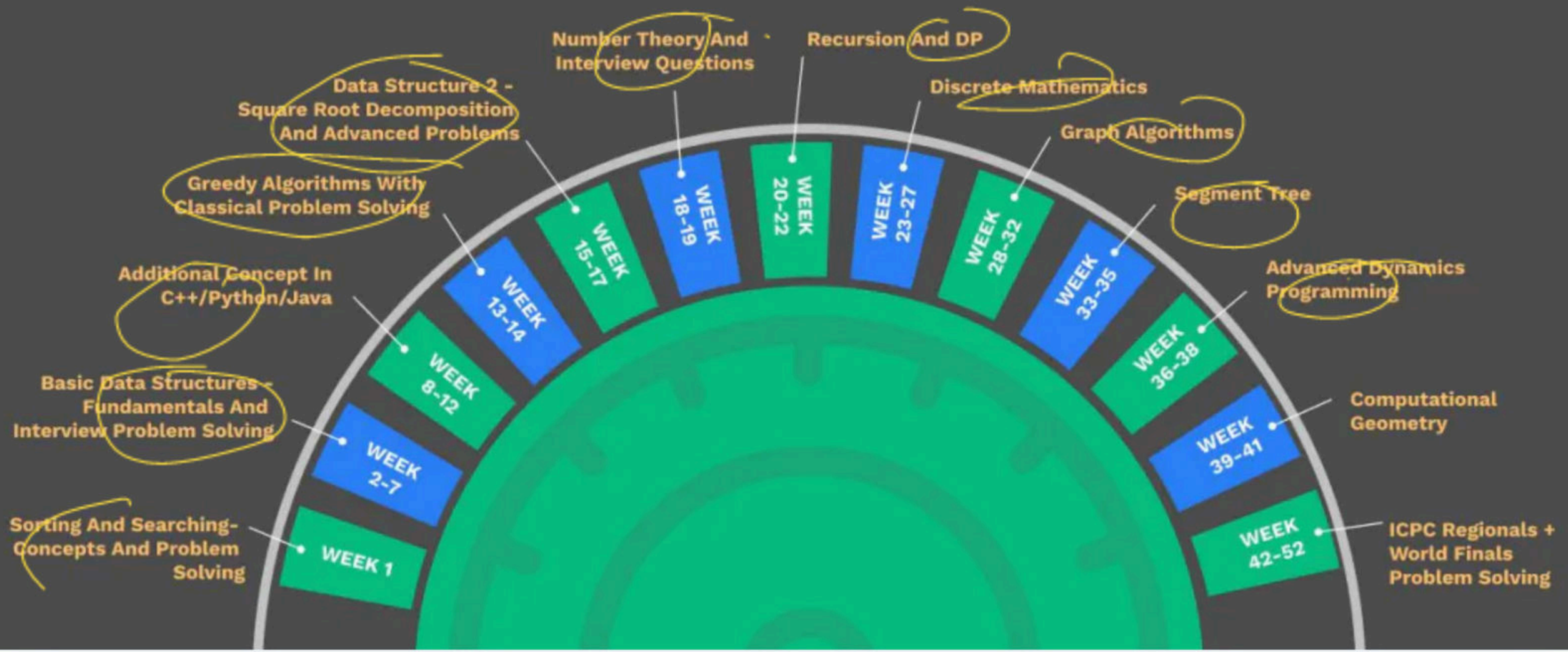

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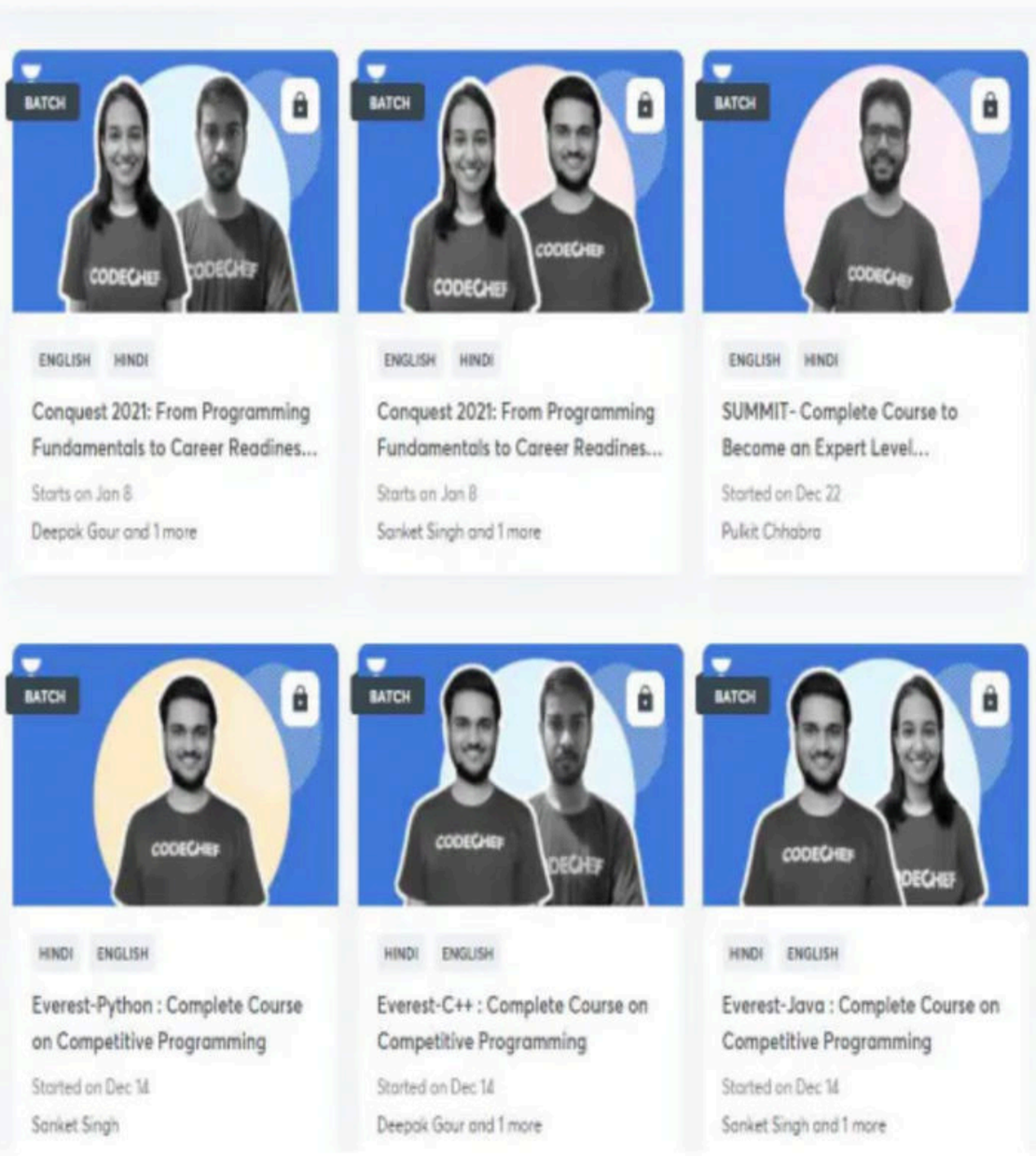

Educators

Tanuj Khattar

ACM ICPC World Finalist - 2017, 2018. Indian IOI Team Trainer 2016-2018. Worked @ Google, Facebook, HFT. Quantum Computing Enthusiast.

Sanket Singh

Software Development Engineer @ LinkedIn | Former SDE @ Interviewbit | Google Summer of Code 2019 @ Harvard University | Former Intern @ISRO

Pulkit Chhabra

Codeforces: 2246 | Codechef: 2416 | Former SDE Intern @CodeNation | Former Intern @HackerRank

Riya Bansal

Software Engineer at Flipkart | Former SDE and Instructor @ InterviewBit | Google Women TechMakers Scholar 2018

Triveni Mahatha

Qualified ICPC 2016 World Final. Won multiple Codechef Long Challenges (India). ICPC Onsite Regionals' Problem setter and Judge. IIT Kanpur.

Deepak Gour

ICPC World Finalist 2020 | Former Instructor @InterviewBit | Software Engineer at AppDynamics

Educators

Himanshu Singh

World Finalist ICPC 2020, Winner Techgig Code Gladiators 2020, Winner TCC '19, 2020 CSE Graduate from IIT BHU, Works at Nutanix

Nishchay Manwani

Hey I am Nishchay Manwani from CSE, IIT Guwahati and I'm a Seven star on Codechef and International Grandmaster on Codeforces.

Murugappan S

Software engineer at Google. Have won many programming contests. Max Rating of 2192 in codeforces and 2201 in codechef.

Vivek Chauhan

Codechef: 7 stars (2612) India Rank 6, Codeforces: MASTER (2279), Won Codechef Long Challenges(India), TCO20 Southern Asia Runner up

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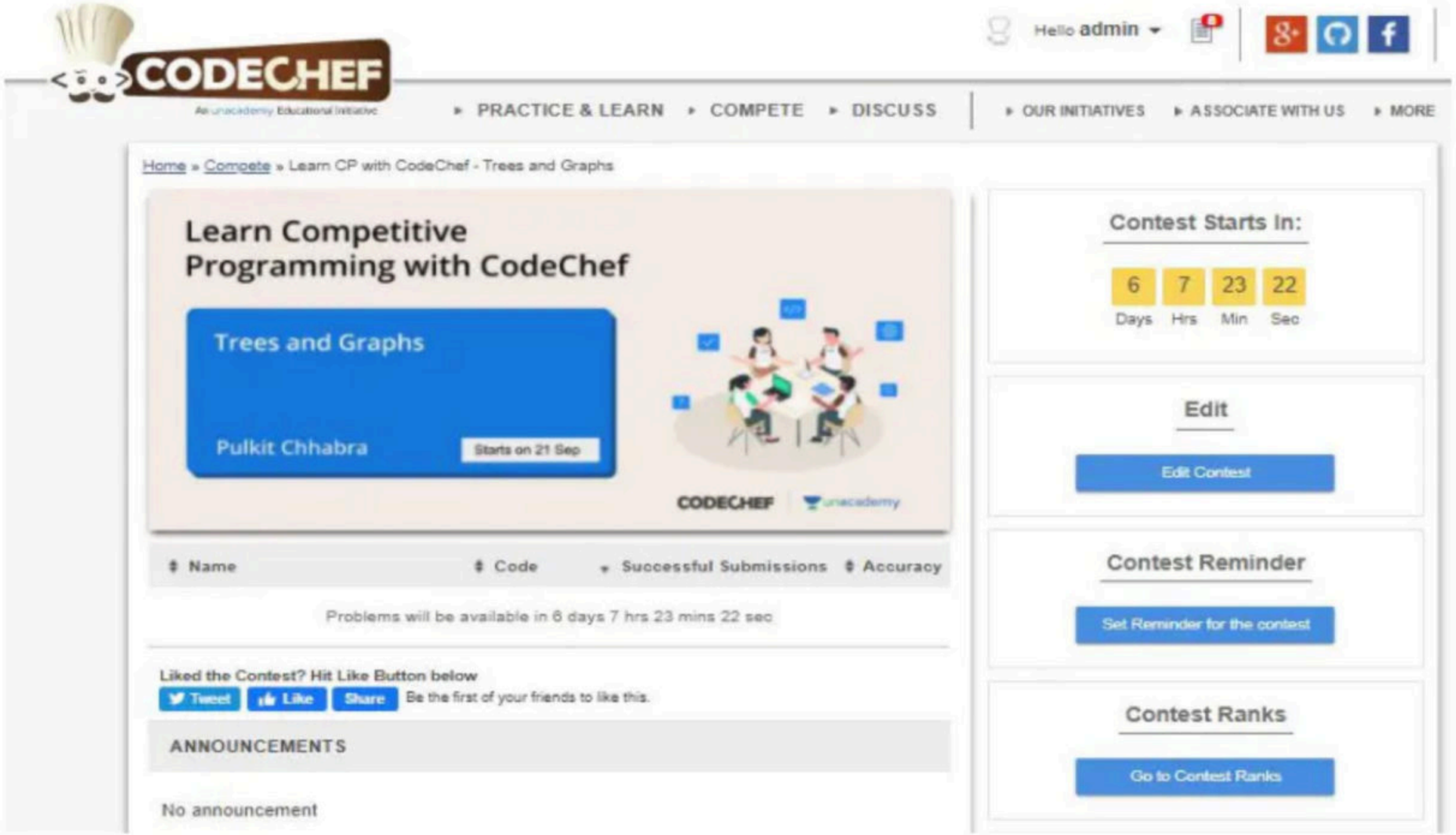
Course-wise Practice Problems



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Proceed to pay

Meet in the Middle

Vivek Chauhan
(vivek_1998299)

Prerequisites

1. Basics of graph theory
2. Basics of bit manipulation

1) Easy - med

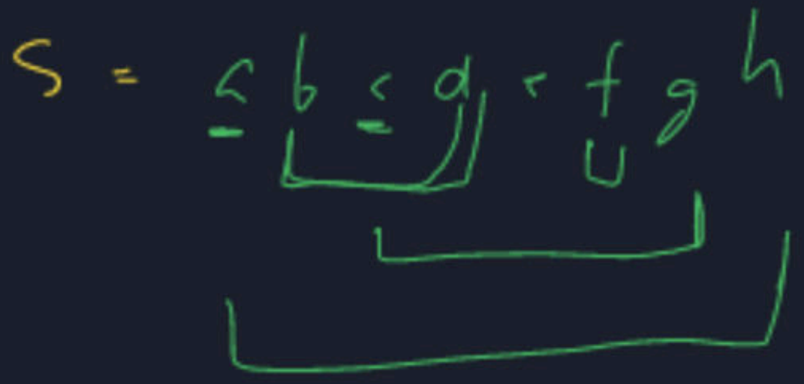
2) Hard

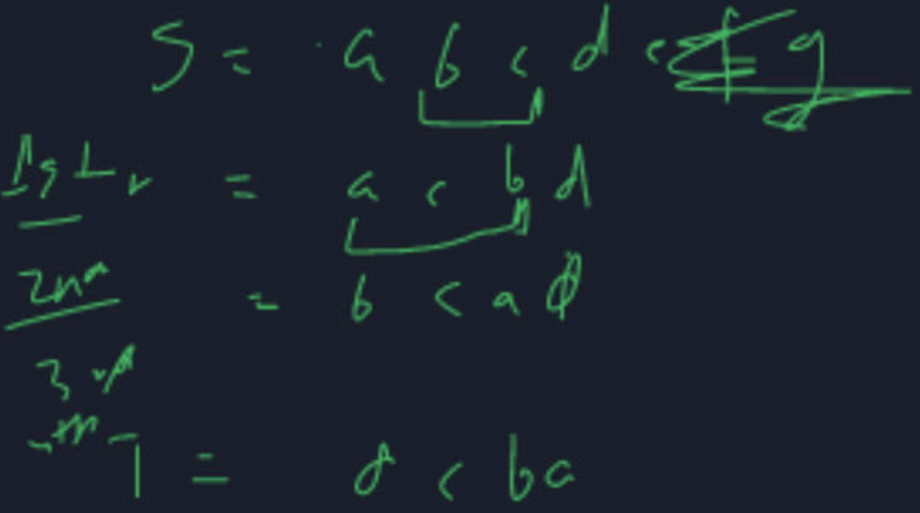
You are given two strings **S** and **T** of length **N**.
Figure out if we can get string **T** starting from string **S** and applying 4 substring reversal operations.

Constraints:

1 <= **N** <= ~~300~~

S and **T** consists of lowercase English alphabets only





N = 4
S = aaba
T = aaab

Yes :

S = a a b a

1st :

a a b a

2nd :

b a a a

3rd :

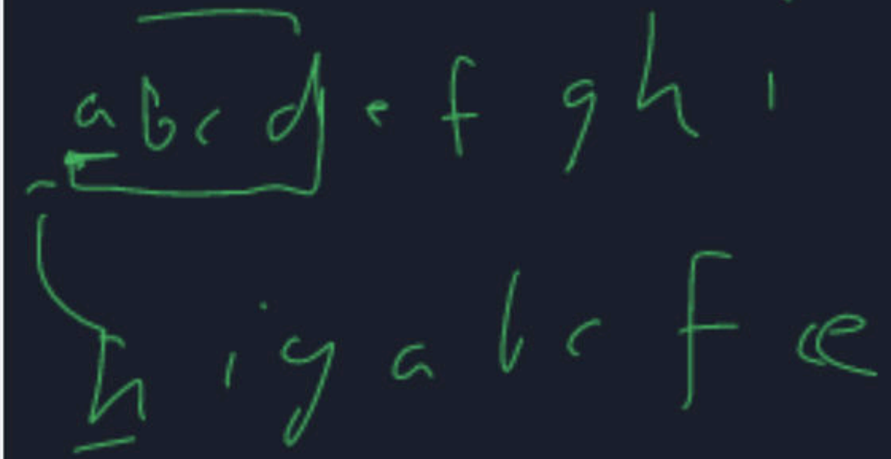
a a a b

4th

a a a b

T = a a a b

N = 4
S = abcd
T = cdba



N = 4

A = abcd

B = dcab

What will be the answer?

N = 4
S = abcd
T = cdba

```
for(L1=0; L1<N; L1++) { O(N)
  for(R1=L1; R1<N; R1++) { O(N)
    for(L2=0; L2<N; L2++) { O(N)
      for(R2=L2; R2<N; R2++) {
        for(L3=0; L3<N; L3++) {
          for(R3=L3; R3<N; R3++) {
            for(L4=0; L4<N; L4++) {
              for(R4=L4; R4<N; R4++) {
```

L1 R1

L2 R2

L3 R3 $O(n^8)$

L4 R4

a l c r

2

L4 R1

N = 4
S = abcd
T = cdba

```
string *temp = S;                    O(N)
reverse(temp, L1, R1);               O(N)
reverse(temp, L2, R2);               O(N)
reverse(temp, L3, R3);               O(N)
reverse(temp, L4, R4);
if(temp == T)                        O(N)
    return Yes;
```

$O(N!) \times O(N)$

$O(N^7)$

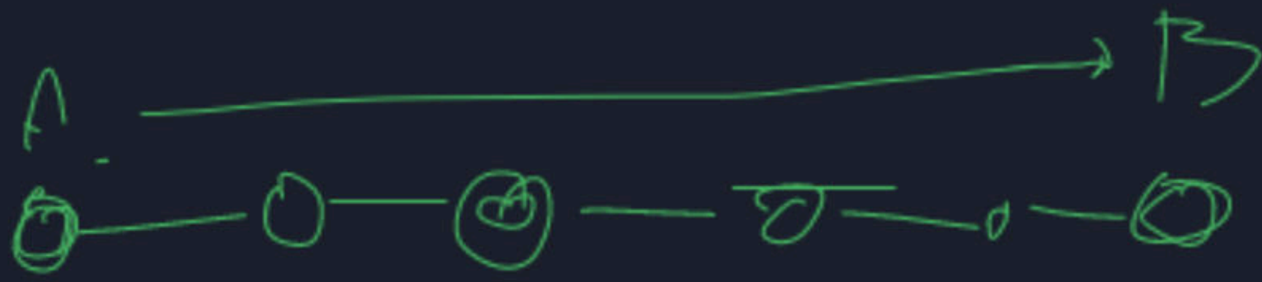
$(20)^9 = 10^{\text{T}_5}$

333

}

return No;

N = 4
S = abcd
T = cdba



S1 S2 . I2 T1

P

[0,2] [1,3]

abcd ⟹ cbad ⟹ cdab

S

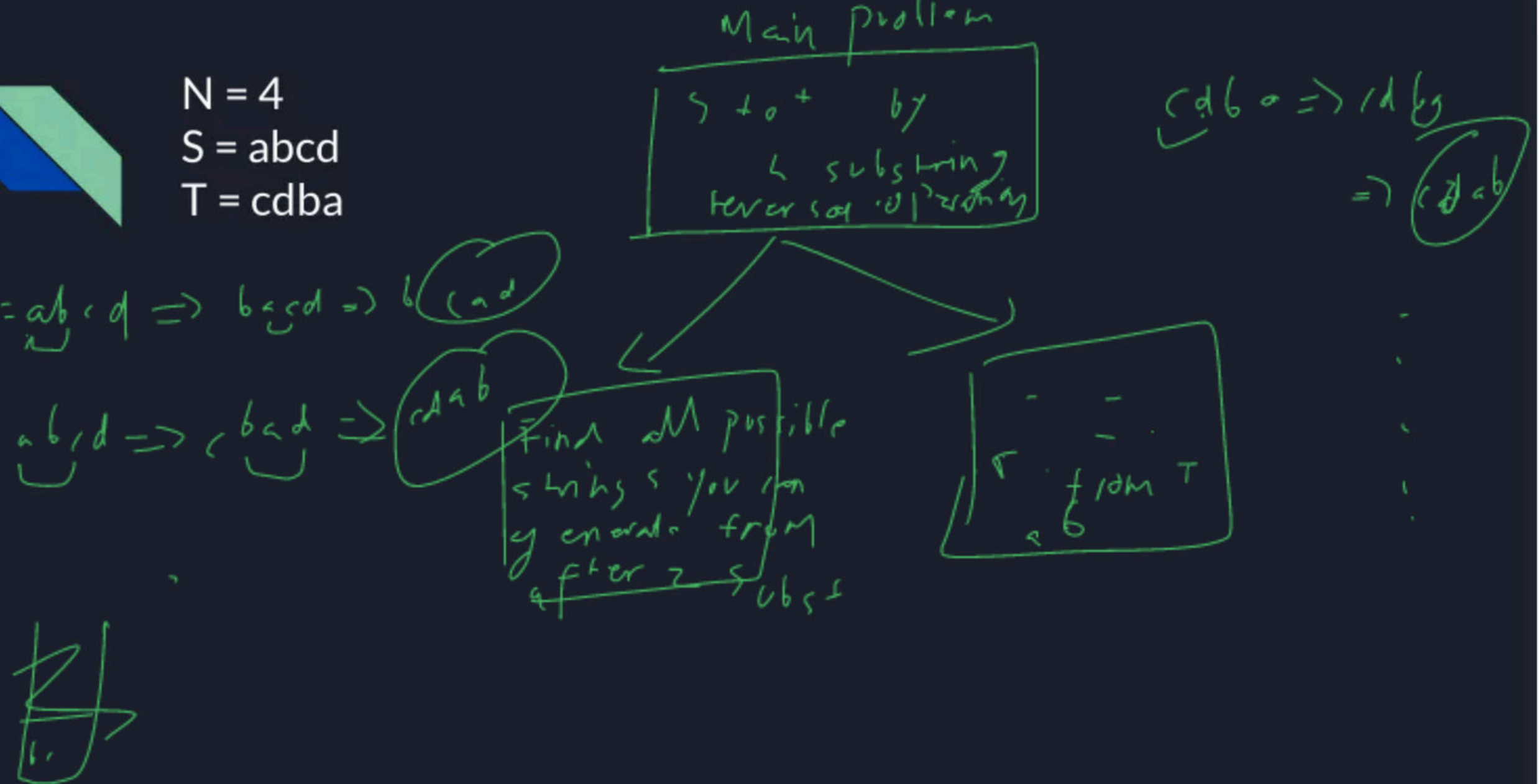
P

cdab ⟸ [0,0] cdab

cdab ⟸ [2,3] cdab

T

N = 4
S = abcd
T = cdba



N = 4
S = abcd
T = cdba

T =>

SoA

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

N = 4
S = abcd
T = cdba

```cpp
bool solve(string S, string T, int N) {
  set<string> mySet;
  for (int L1 = 0; L1 < N; L1++) {
    for (int R1 = L1; R1 < N; R1++) {
      for (int L2 = 0; L2 < N; L2++) {
        for (int R2 = L2; R2 < N; R2++) {
          string tempS = S;
          reverse(tempS.begin() + L1, tempS.begin() + R1 + 1);
          reverse(tempS.begin() + L2, tempS.begin() + R2 + 1);
          mySet.insert(tempS);
        }
      }
    }
  }

  for (int L3 = 0; L3 < N; L3++) {
    for (int R3 = L3; R3 < N; R3++) {
      for (int L4 = 0; L4 < N; L4++) {
        for (int R4 = L4; R4 < N; R4++) {
          string tempT = T;
          reverse(tempT.begin() + L3, tempT.begin() + R3 + 1);
          reverse(tempT.begin() + L4, tempT.begin() + R4 + 1);
          if (mySet.find(tempT) != mySet.end()) {
            return true;
          }
        }
      }
    }
  }
  return false;
}
```

left

right

```cpp
bool solve(string S, string T, int N) {
  set<string> mySet;
  for (int L1 = 0; L1 < N; L1++) {
    for (int R1 = L1; R1 < N; R1++) {
      for (int L2 = 0; L2 < N; L2++) {
        for (int R2 = L2; R2 < N; R2++) {
          string tempS = S;
          reverse(tempS.begin() + L1, tempS.begin() + R1 + 1);
          reverse(tempS.begin() + L2, tempS.begin() + R2 + 1);
          mySet.insert(tempS);
        }
      }
    }
  }

  for (int L3 = 0; L3 < N; L3++) {
    for (int R3 = L3; R3 < N; R3++) {
      for (int L4 = 0; L4 < N; L4++) {
        for (int R4 = L4; R4 < N; R4++) {
          string tempT = T;
          reverse(tempT.begin() + L3, tempT.begin() + R3 + 1);
          reverse(tempT.begin() + L4, tempT.begin() + R4 + 1);
          if (mySet.find(tempT) != mySet.end()) {
            return true;
          }
        }
      }
    }
  }
  return false;
}
```

S

L1 R1

L2 R2

```cpp
bool solve(string S, string T, int N) {
  set<string> mySet;
  for (int L1 = 0; L1 < N; L1++) {
    for (int R1 = L1; R1 < N; R1++) {
      for (int L2 = 0; L2 < N; L2++) {
        for (int R2 = L2; R2 < N; R2++) {
          string tempS = S;
          reverse(tempS.begin() + L1, tempS.begin() + R1 + 1);
          reverse(tempS.begin() + L2, tempS.begin() + R2 + 1);
          mySet.insert(tempS);
        }
      }
    }
  }

  for (int L3 = 0; L3 < N; L3++) {
    for (int R3 = L3; R3 < N; R3++) {
      for (int L4 = 0; L4 < N; L4++) {
        for (int R4 = L4; R4 < N; R4++) {
          string tempT = T;
          reverse(tempT.begin() + L3, tempT.begin() + R3 + 1);
          reverse(tempT.begin() + L4, tempT.begin() + R4 + 1);
          if (mySet.find(tempT) != mySet.end()) {
            return true;
          }
        }
      }
    }
  }
  return false;
}
```

Assume the time-complexity of set.insert and set.find are O(N*logN), what will the be the time complexity of solution?

A. O(N^4)
B. O(N^4*logN)
C. O(N^5)
D. O(N^5*logN)

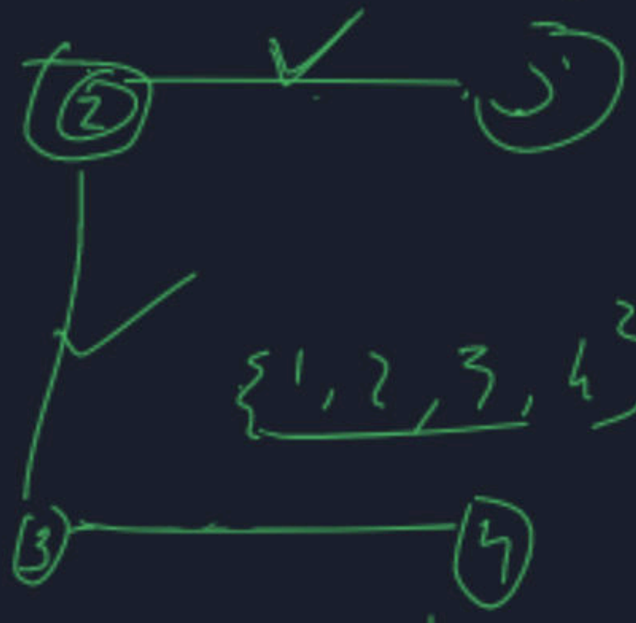
```
bool solve(string S, string T, int N) {
  set<string> mySet;
  for (int L1 = 0; L1 < N; L1++) {
    for (int R1 = L1; R1 < N; R1++) {
      for (int L2 = 0; L2 < N; L2++) {
        for (int R2 = L2; R2 < N; R2++) {
          string tempS = S;
          reverse(tempS.begin() + L1, tempS.begin() + R1 + 1);
          reverse(tempS.begin() + L2, tempS.begin() + R2 + 1);
          mySet.insert(tempS);
        }
      }
    }
  }

  for (int L3 = 0; L3 < N; L3++) {
    for (int R3 = L3; R3 < N; R3++) {
      for (int L4 = 0; L4 < N; L4++) {
        for (int R4 = L4; R4 < N; R4++) {
          string tempT = T;
          reverse(tempT.begin() + L3, tempT.begin() + R3 + 1);
          reverse(tempT.begin() + L4, tempT.begin() + R4 + 1);
          if (mySet.find(tempT) != mySet.end()) {
            return true;
          }
        }
      }
    }
  }
  return false;
}
```

{1, 2, 3} Minimum vertex cover => {2, 3} => 2

Vertex cover

Vertex cover of size



A set of vertices is called as a vertex cover if and only if for each edge at least one endpoint lies in the set

vertex cover => 2

You are given an undirected graph with **N** vertices and **M** edges. Find the size of the minimum vertex cover of the graph.

Constraints:

3 <= **N** <= 30

1 <= **M** <= 50

Vertex cover : Set of vertices is called as vertex cover if and only if for each edge Atleast one endpoint lies in the set

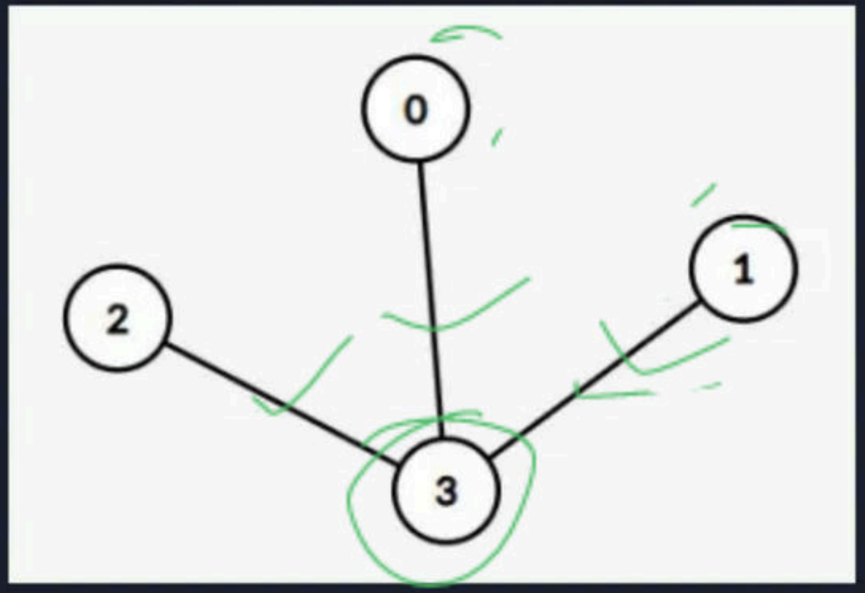
Min vertex cover : vertex cover of minimum size

N = 4
M = 3

{0, 1, 2} => vertex cover

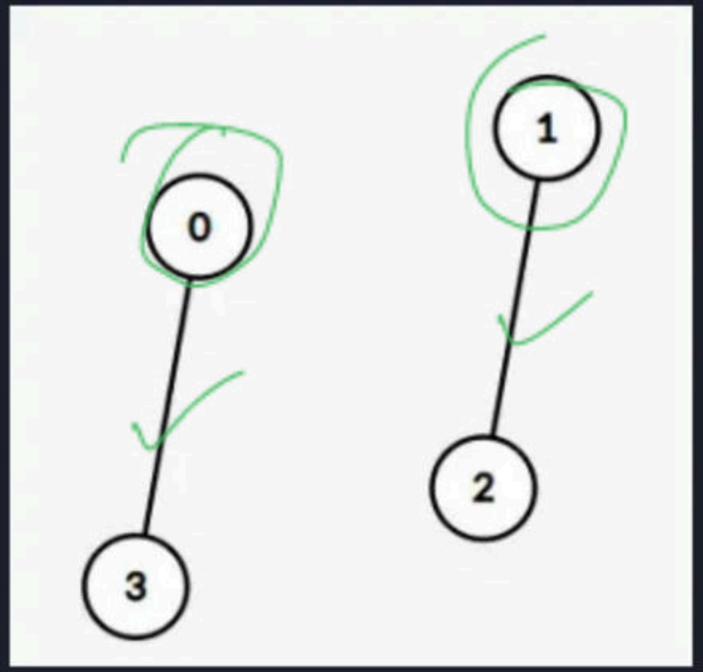
=> 3

~~{0, 1, 2}~~ {3} => 1



N = 4
M = 2

{0, 1} => 2



N = 6
M = 6

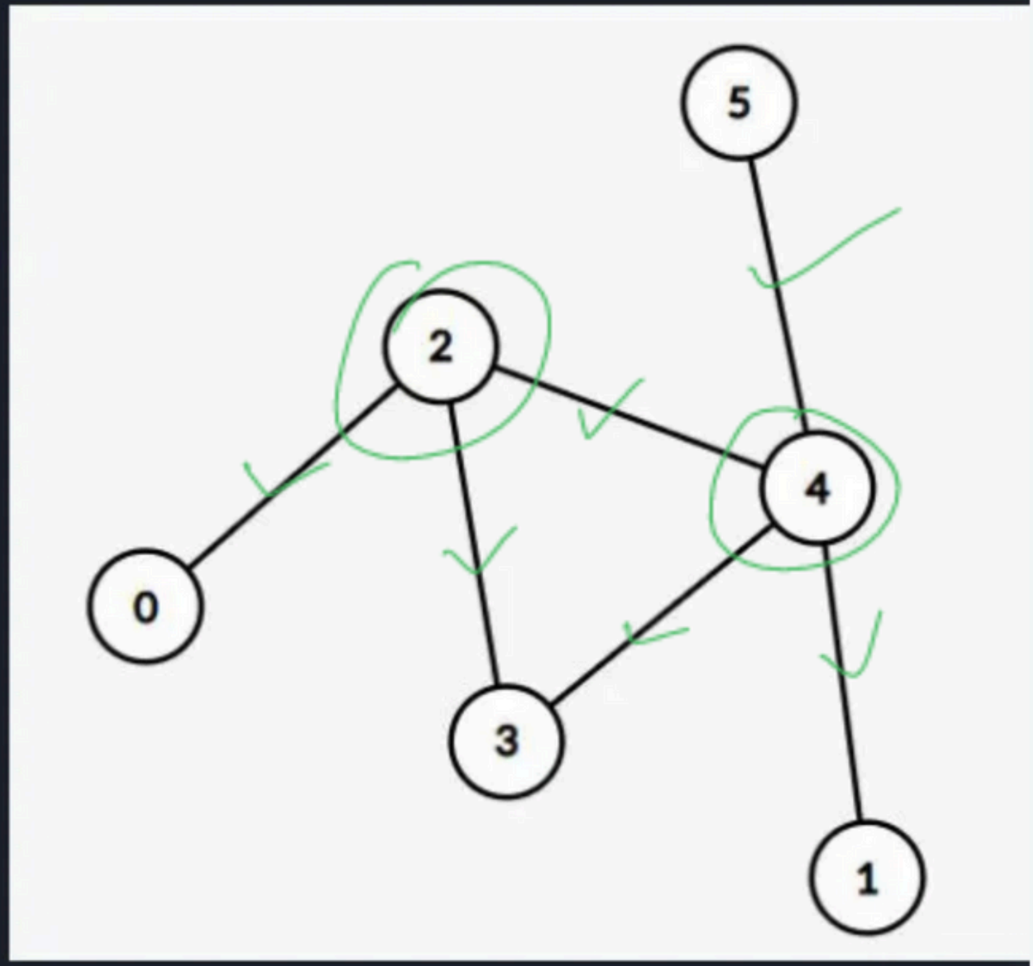
What will be the answer?

A. 1

B. 2

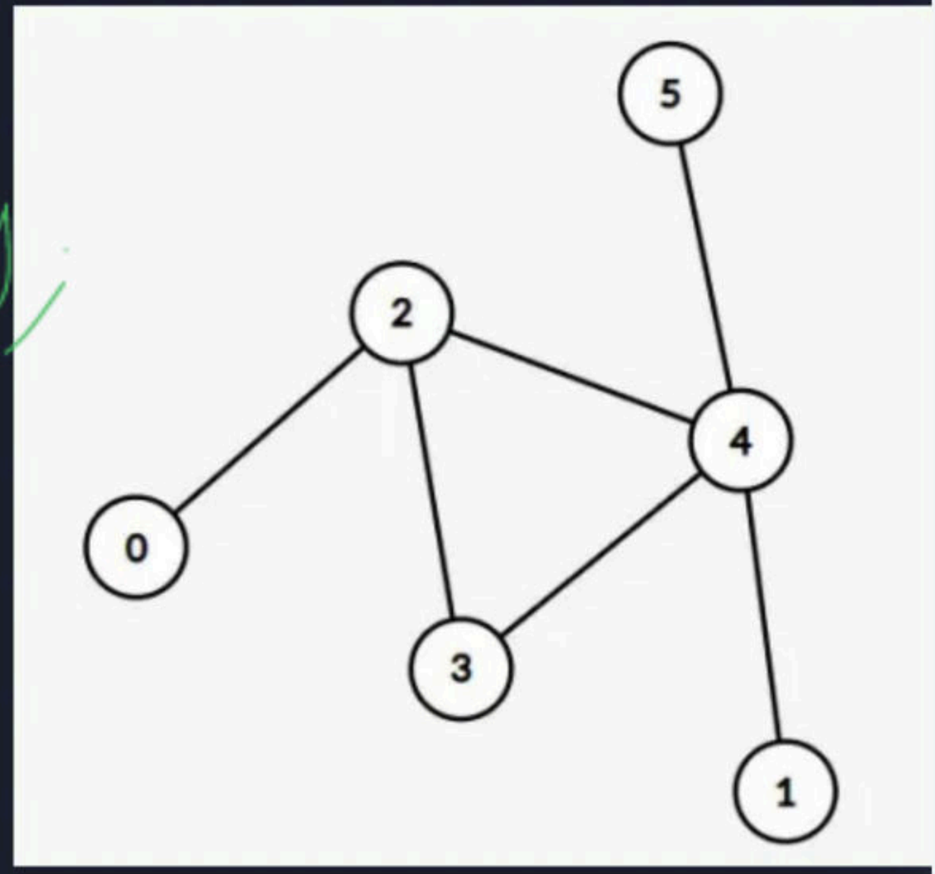
C. 3

D. 4



N = 6
M = 6

```
res = inf
for(each vertex cover Vc of graph) {
    res = min(res, Vc.size());
}
```



N = 6
M = 6

{0, 1, 4, 5}

{0, 2}

S = {0, 1, 2, ... N-1}

res = inf

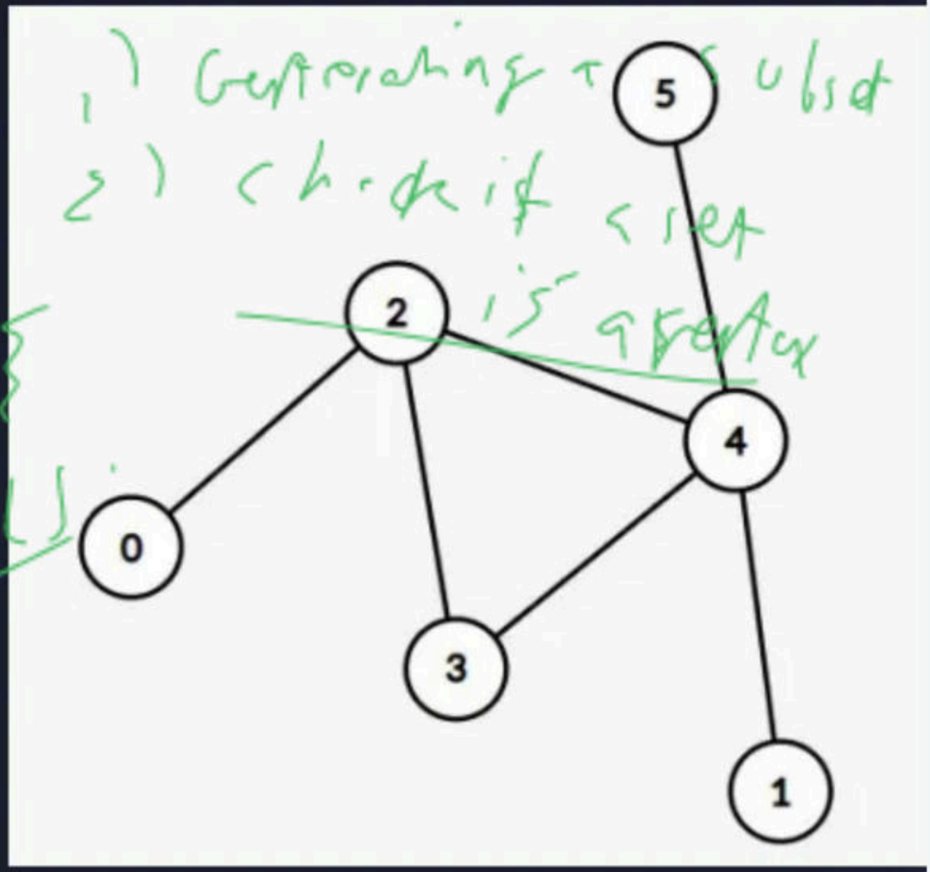
for (each subset S1 of S) {

if (S1 is a vertex cover) {

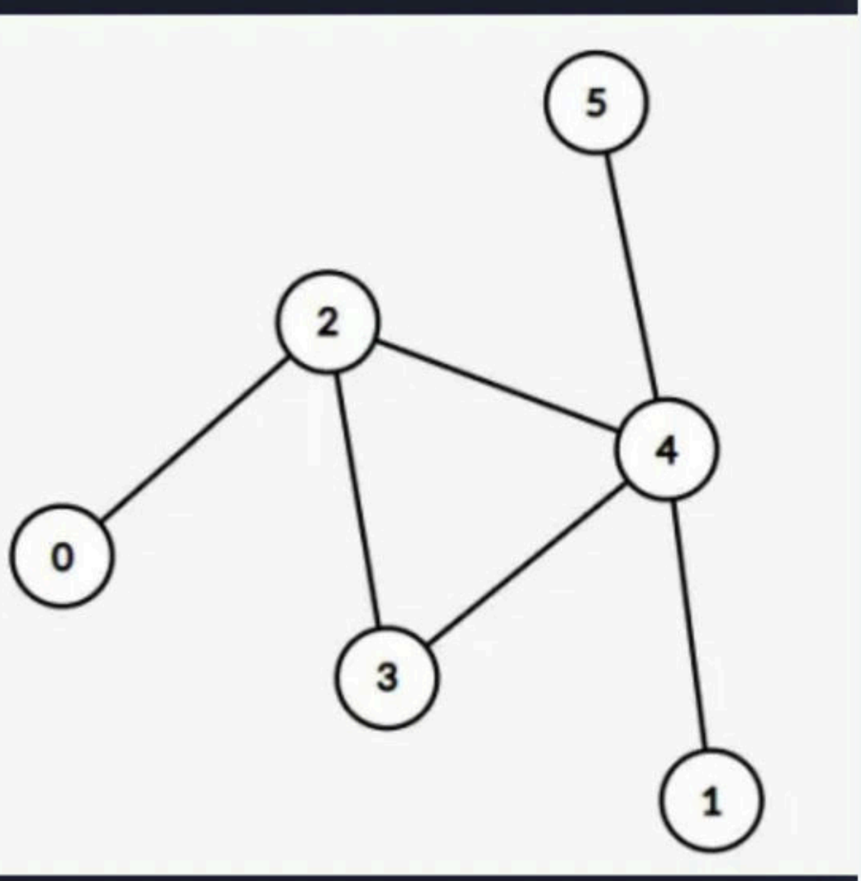
res = min(res, S1.size())

}

}



N = 6
M = 6



N = 6
M = 6

$O(2^N \times M)$

too high

10^4

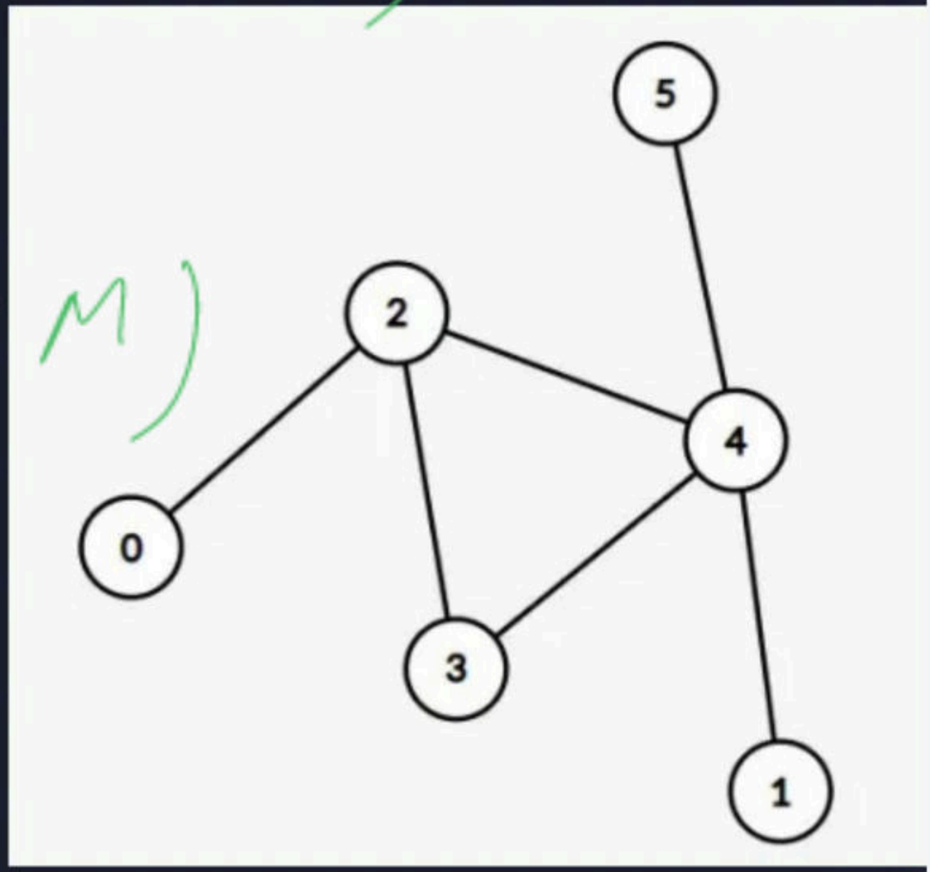
for (mask = 0; mask < 2^N ; mask++) { $O(2^N)$

S_1 = {set bits in mask}

if (S_1 is a vertex cover) → $O(M)$

res = min(res, S_1.size())

}



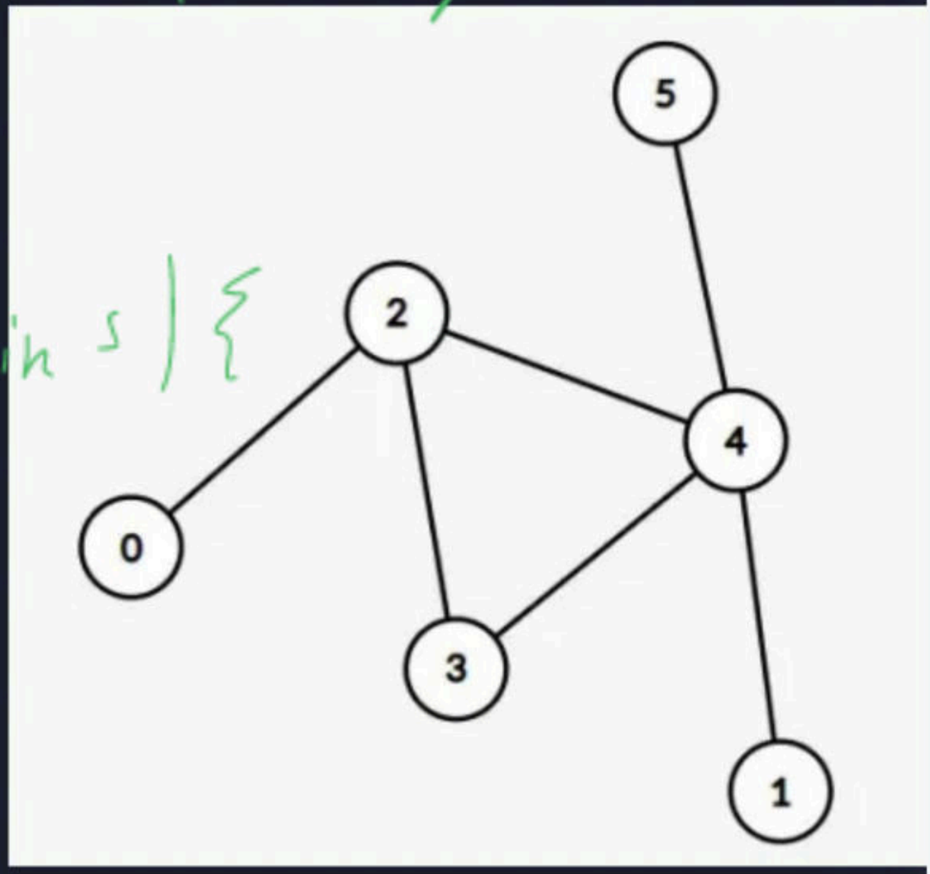
N = 6
M = 6

S = {0, 1, 4, 6}

O(M)

O(M x logN)

```
for (i=1; i<=M; i++) {
    a, b
    if (a is not in S && b is not in S) {
        return false;
    }
}
return true;
```



N = 6
M = 6

$S_{Left} = \{1, 2\} \cup \{0\}$

$S_{Left} = \{1, 2, 0\}$

$< \frac{N}{2}$

$\{0, 1, 2\}$

$> = \frac{N}{2}$

$\{3, 4, 5\}$

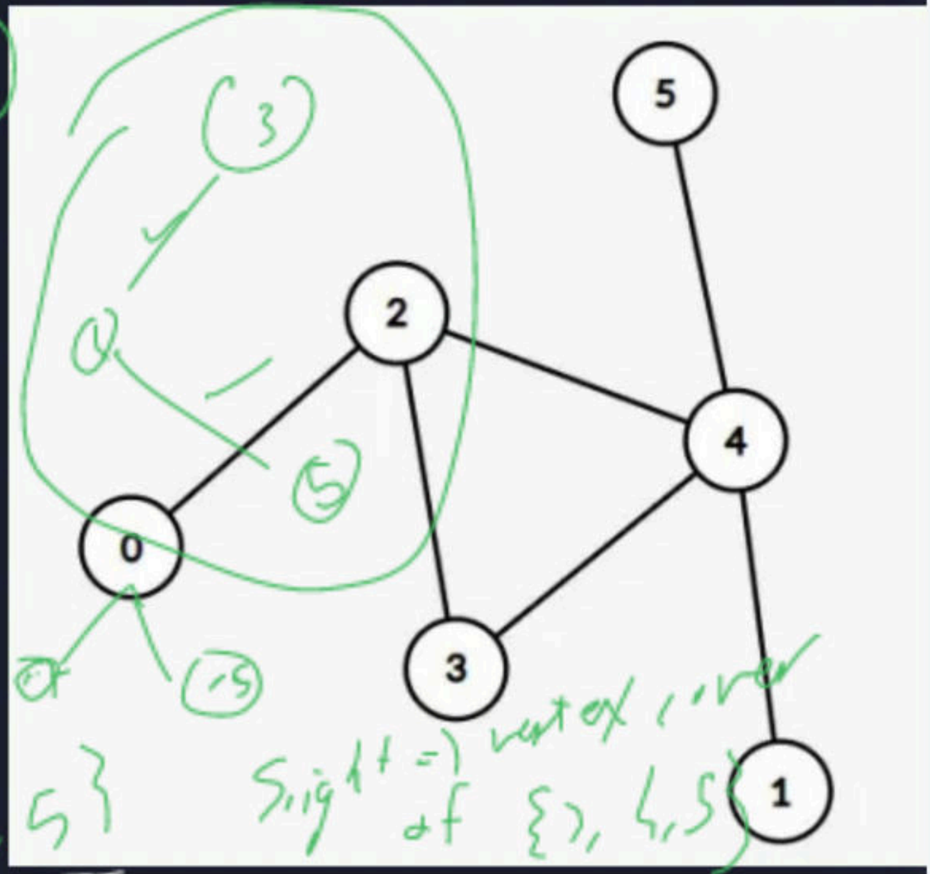
A

B

S_{Left}

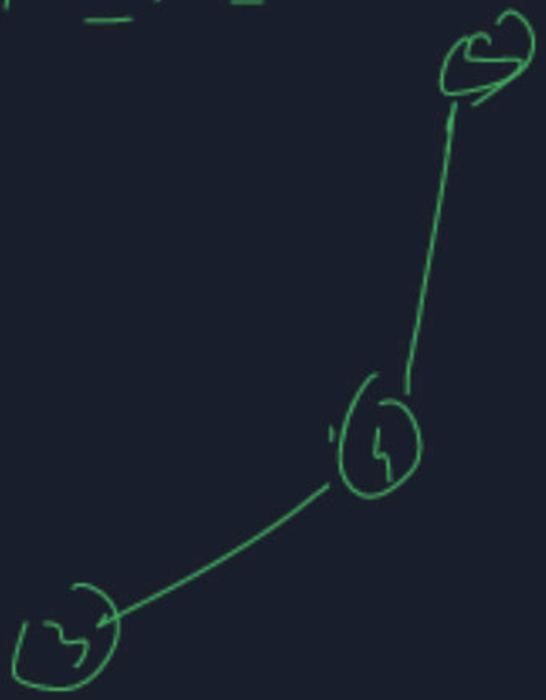
$S_{Right} = \{3,$

1) Edges inside A
2) Edges inside B
3) Edges between A and B

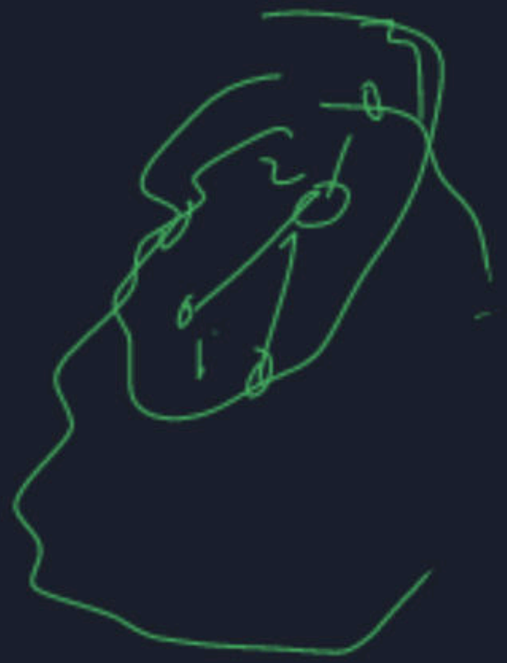


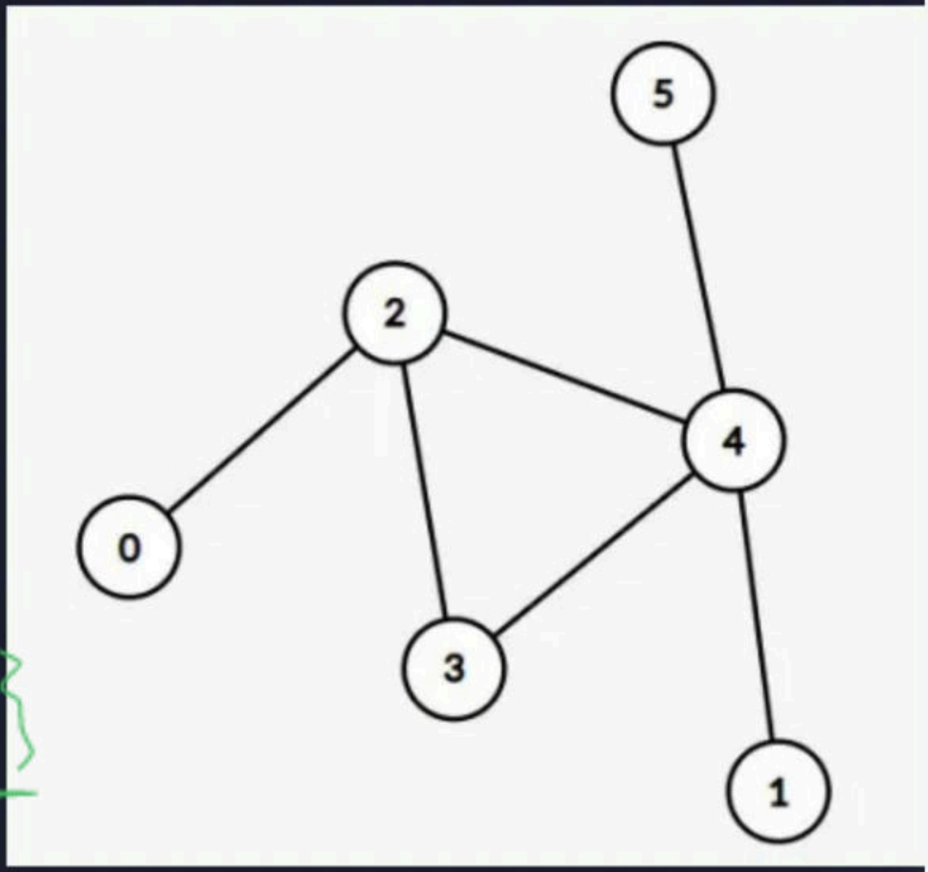
N = 6
M = 6

{3, 1, 5}



N = 6
M = 6





$O(3^{n/3} \times m)$

N = 6

M = 6

{0, 1, {4, 5}} ⇒

$V_{13} = \{4\}$

rem_{13} {3, 5}

$O(2^{n/3} \times m)$

1) Go through all vertex covers V_B of B

a) $S_{right} = \{V_3\}$ ✗

b) $rem_{13} = B - V_{13}$ ✓

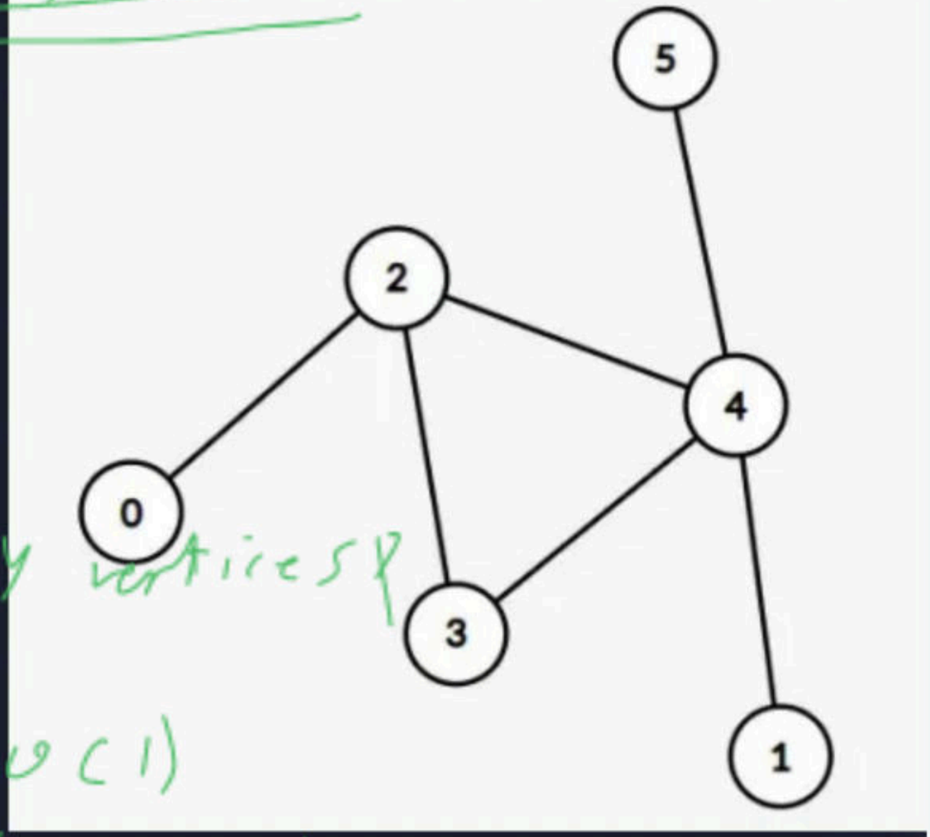
c) $adj_A = adj(rem_B)$ ✗

d) $S_{left} = \{adj_A\}$ # compulsory vertices ✗

e) $rem_A = A - S_{left}$

f) V_A = min vertex cover of rem_A $O(1)$

g) $S_{left} = \{adj_A\} \cup \{$min vert cover$\}$



N = 6
M = 6

Main problem

Min vertex cover of graph

A

Find min vertex cover for all subgraphs of A

B

Find all vertex covers of B

$O(3^{n/2} \times m)$

$O(3^{n/2} \times m + 2^{n/2} \times m)$

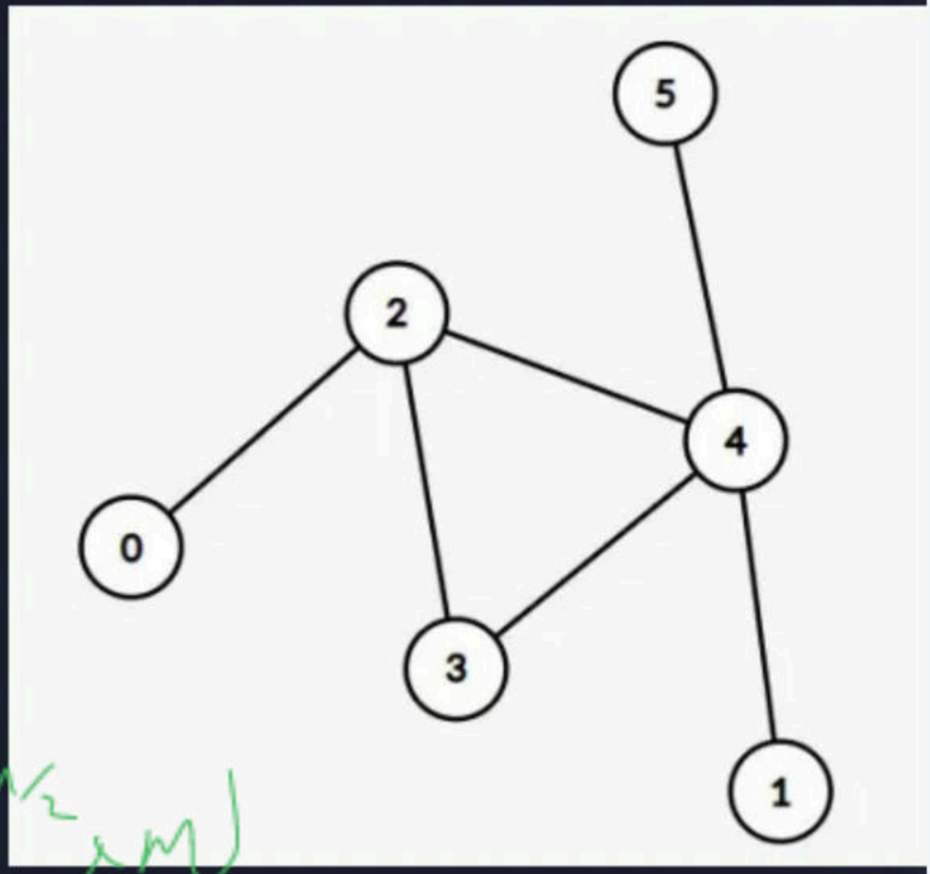
$O(2^{n/2} \times m)$

$O(3^{n/2} \times m)$

{0, 1}

{0, 2}

{1, 2}



N = 6
M = 6

B

$2^n \times M$

$2^{n/2} \times M$

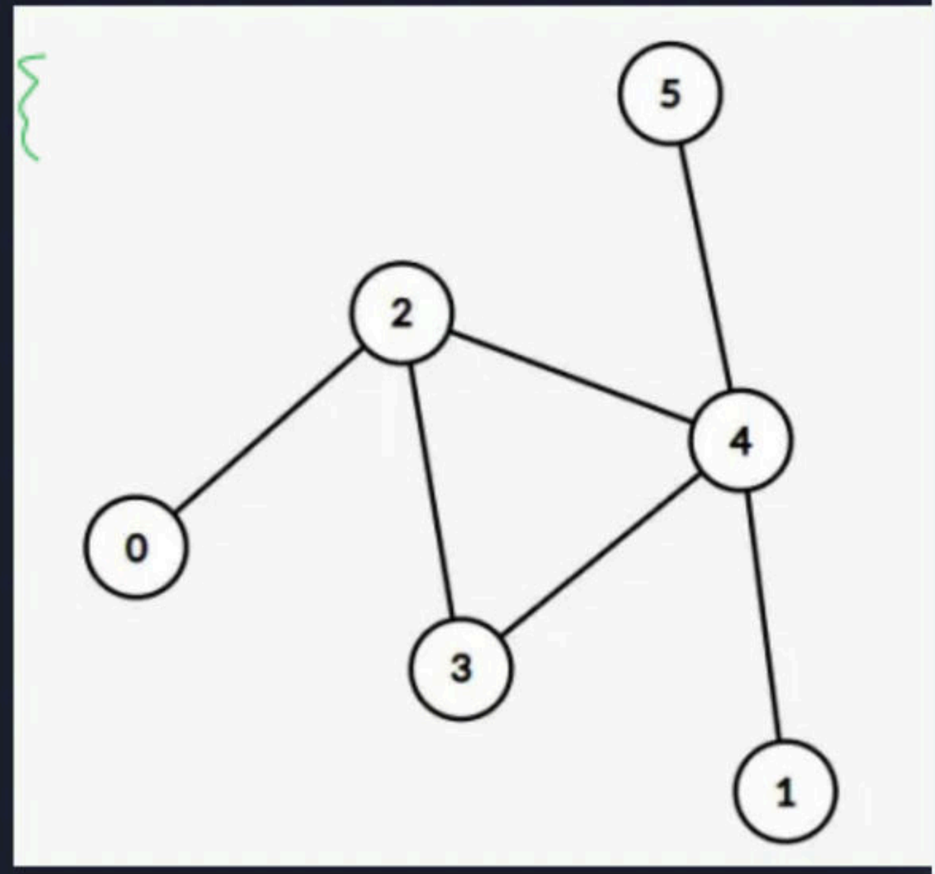
for each vertex cover V_{13} of B)

{

res.append(V_{13})

}

for(ma



$2^0 \times M + 2^1 \times M + 2^1 \times M + 2^2 \times M + 2^1 \times M$

N = 6

M = 6

$2^2 \times M + 2^2 \times M + 2^3 \times M$

$2^n \times M$

0 0 0 => 0

0 0 1 => 1

0 1 0 => 1

0 1 1 => 2

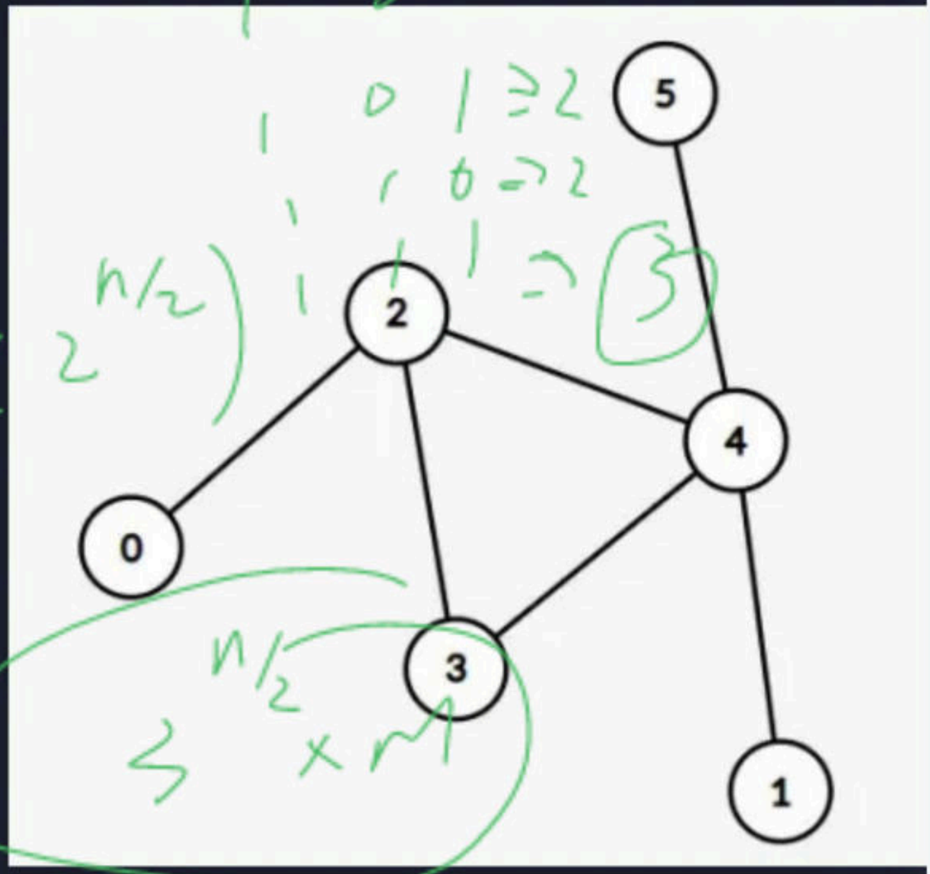
1 0 0 => 1

G with n vertex : cover = $2^n \times M$

for (each subgraph A' of A) { O(

dp[A'] = min vertex of A')

}



N = 6
M = 6

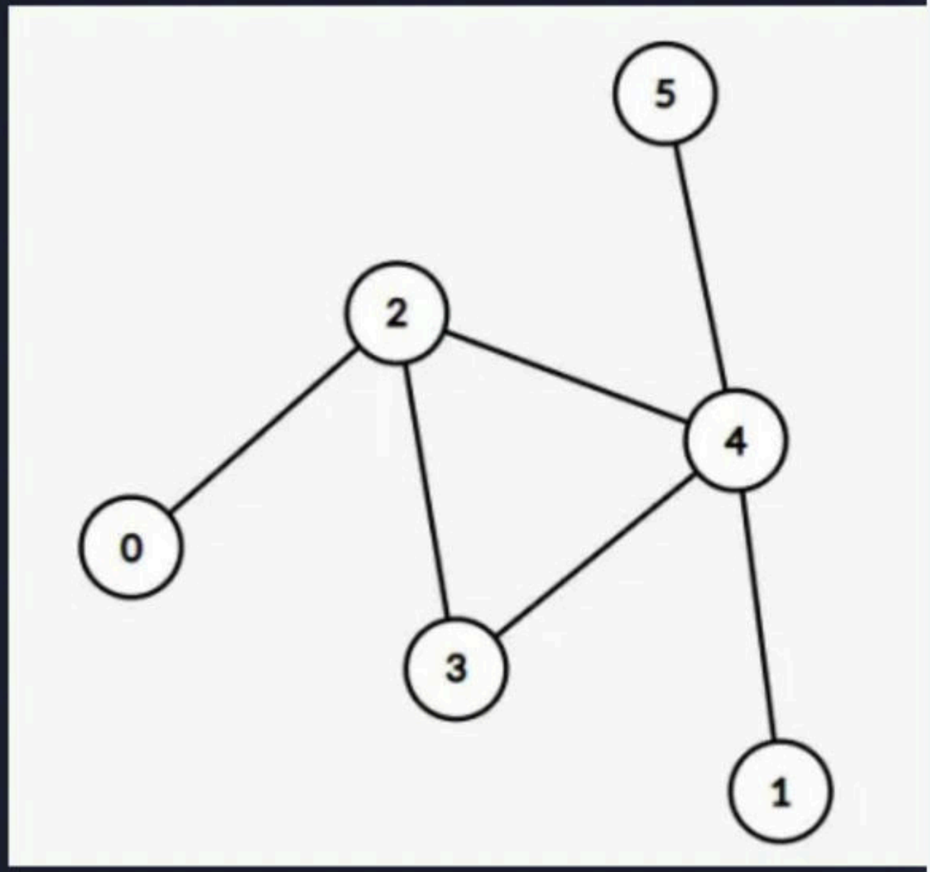
$n = 30$

$3^{15} \times 50$

$$\left(\sum_{i=0}^{2^n - 1} 2^{\#\text{set bits in } i} \right) \times M$$

$$\frac{}{N_r}$$

$3^{} \times M$



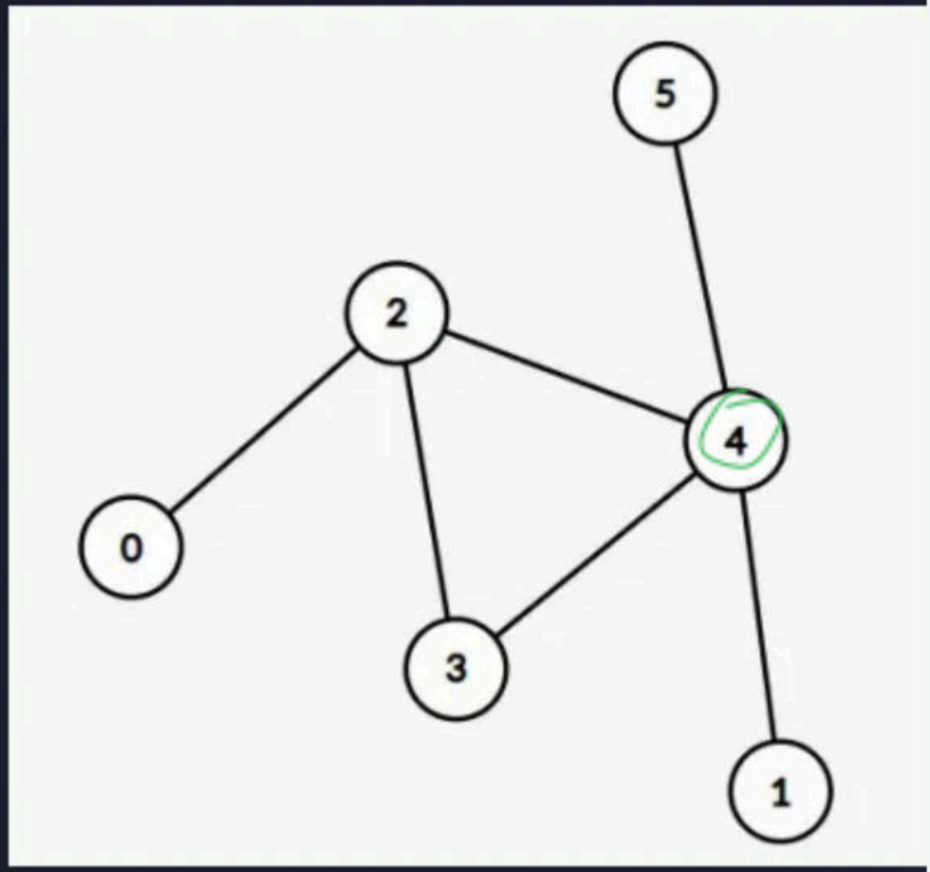
N = 6
M = 6

{0, 1, 2, 3, 4, 5}

5 4 3 2 1 0

1 0 0 1 1 1

O(1)



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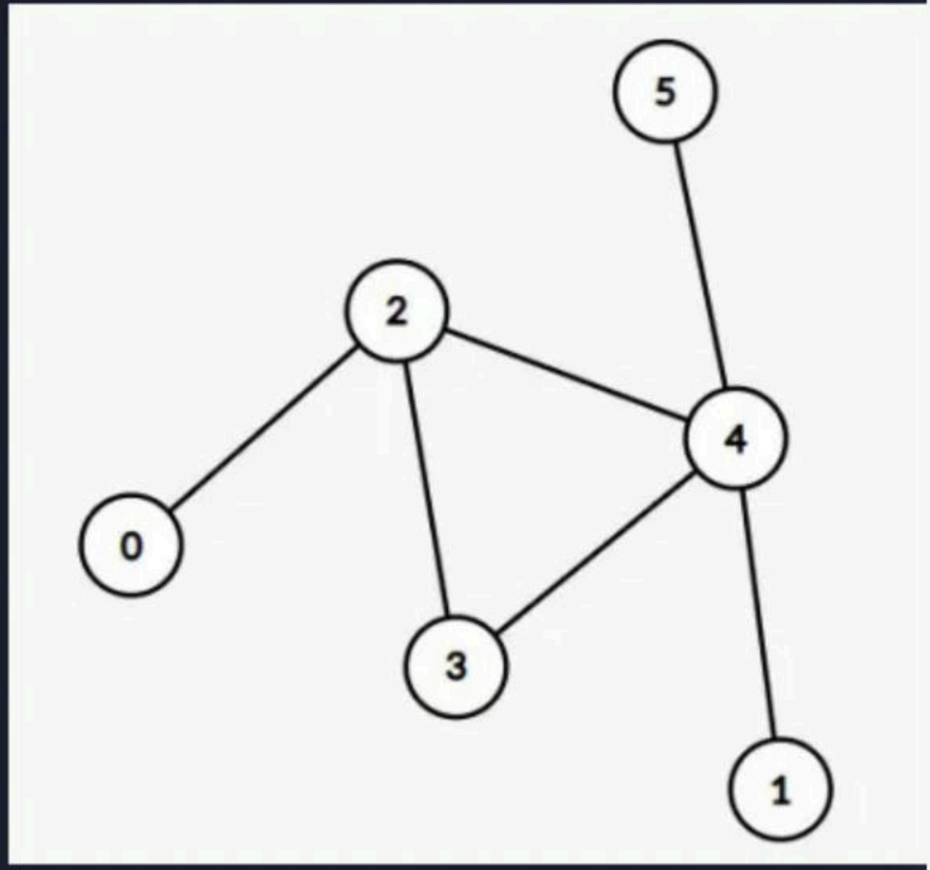

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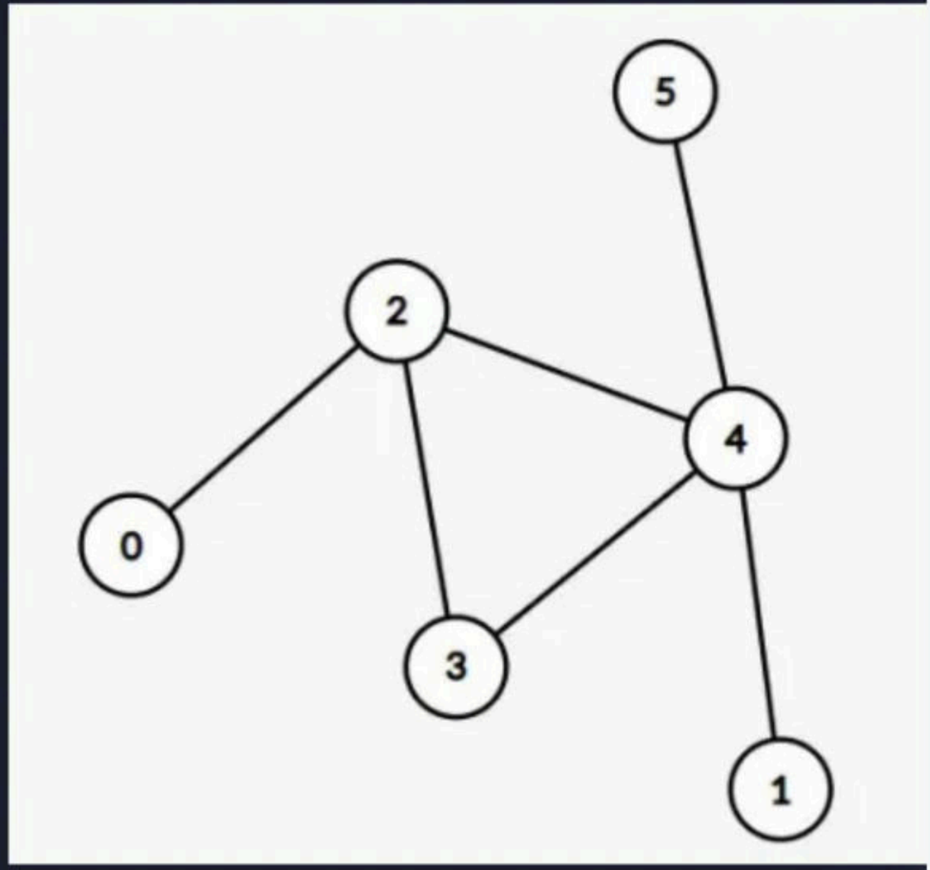

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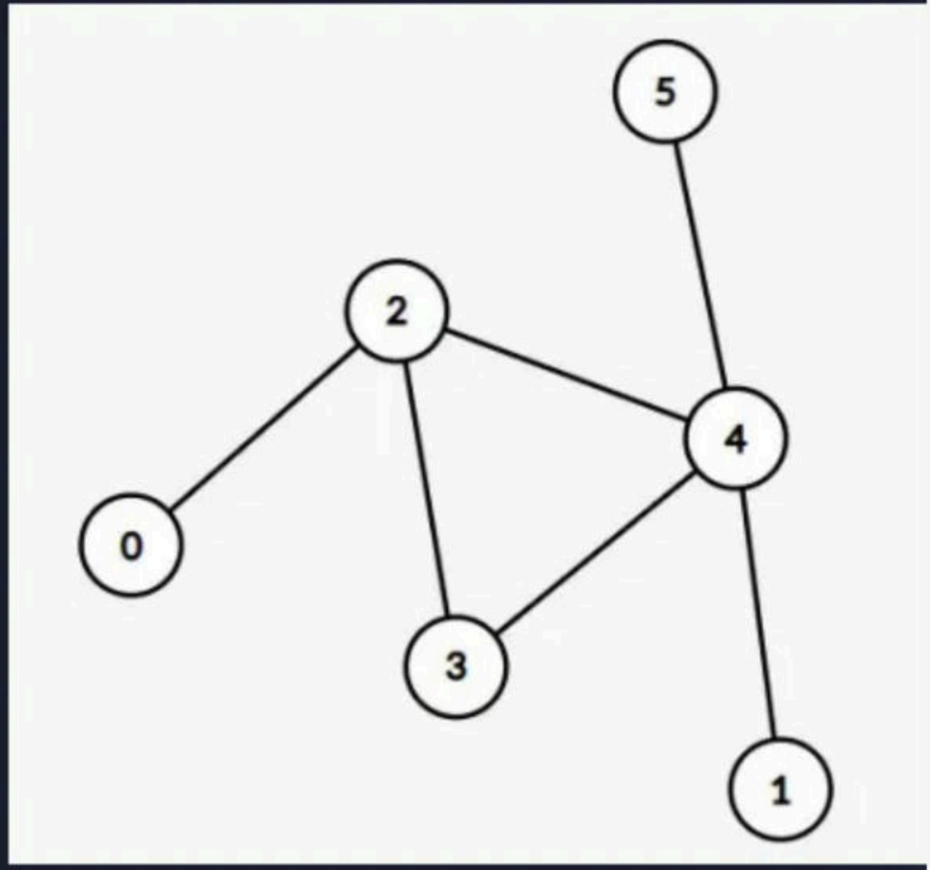

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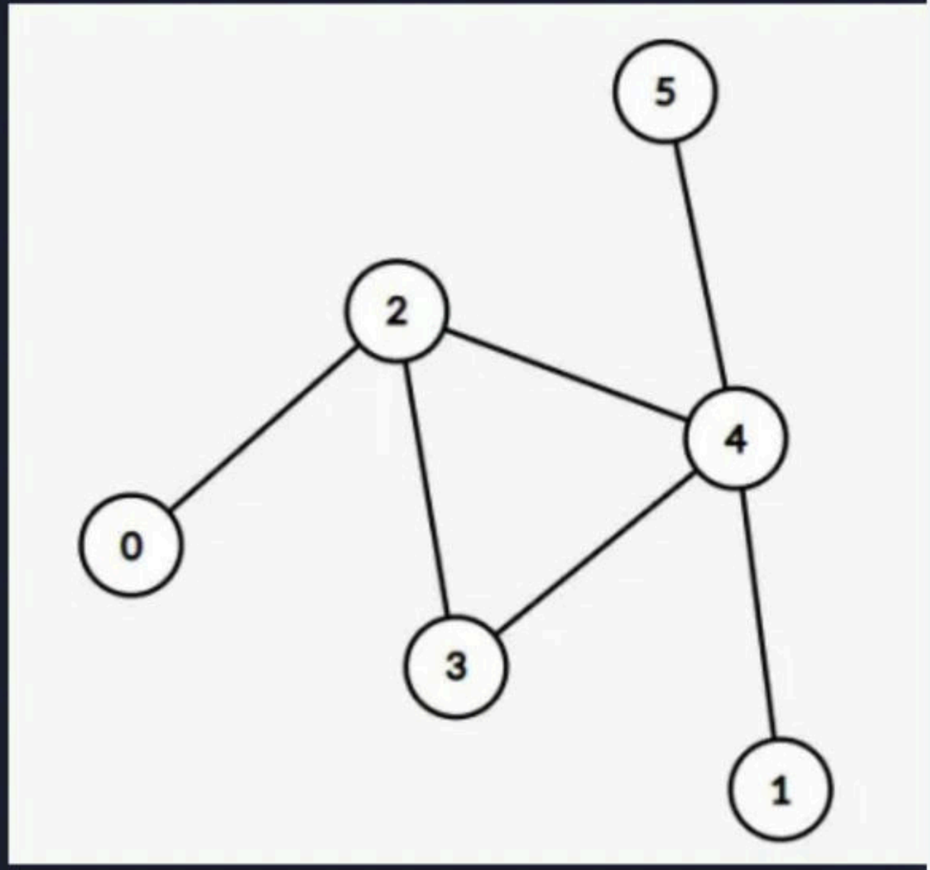

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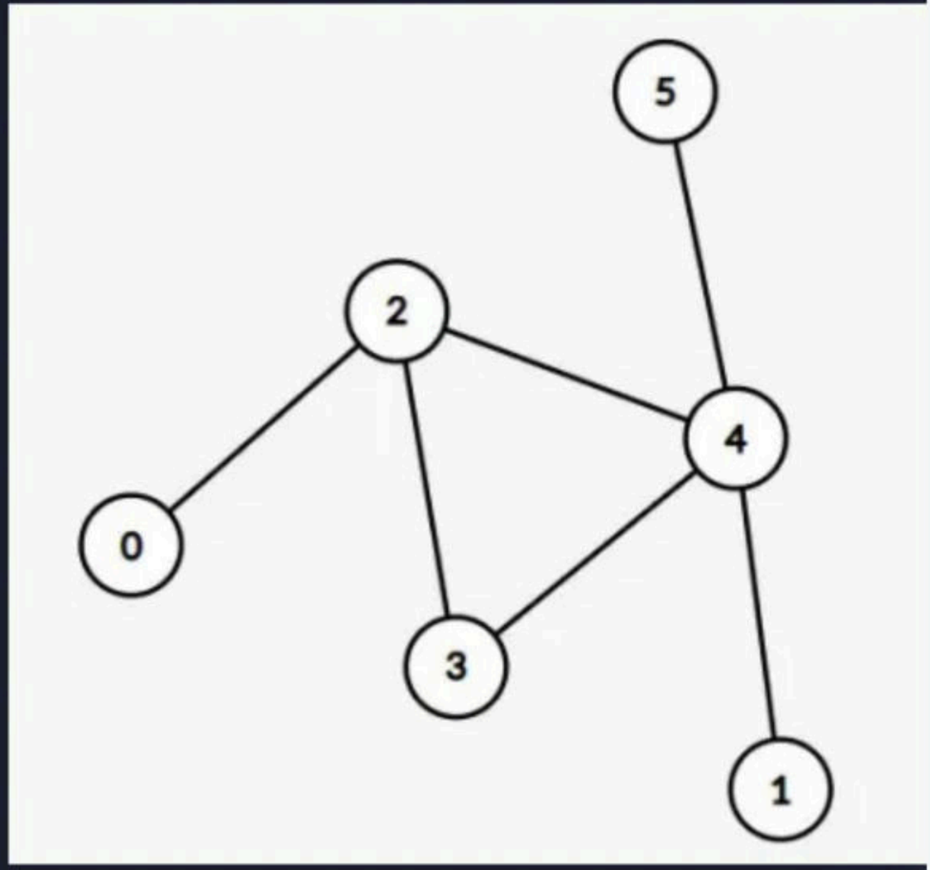

N = 6
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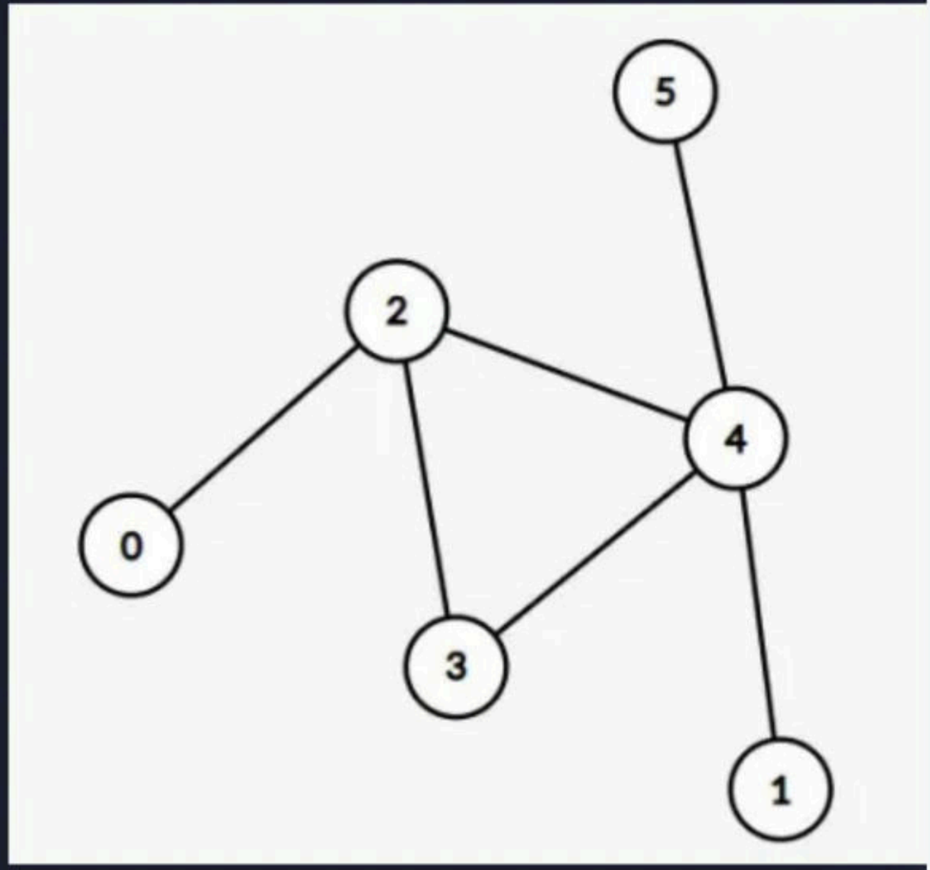

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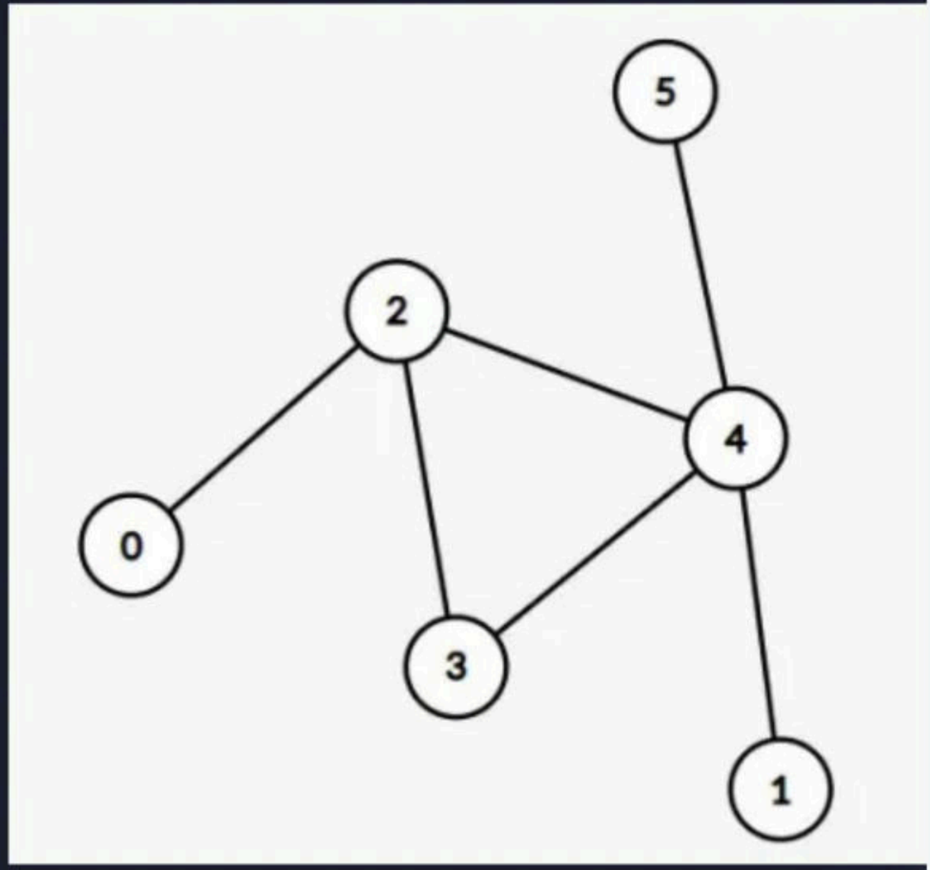

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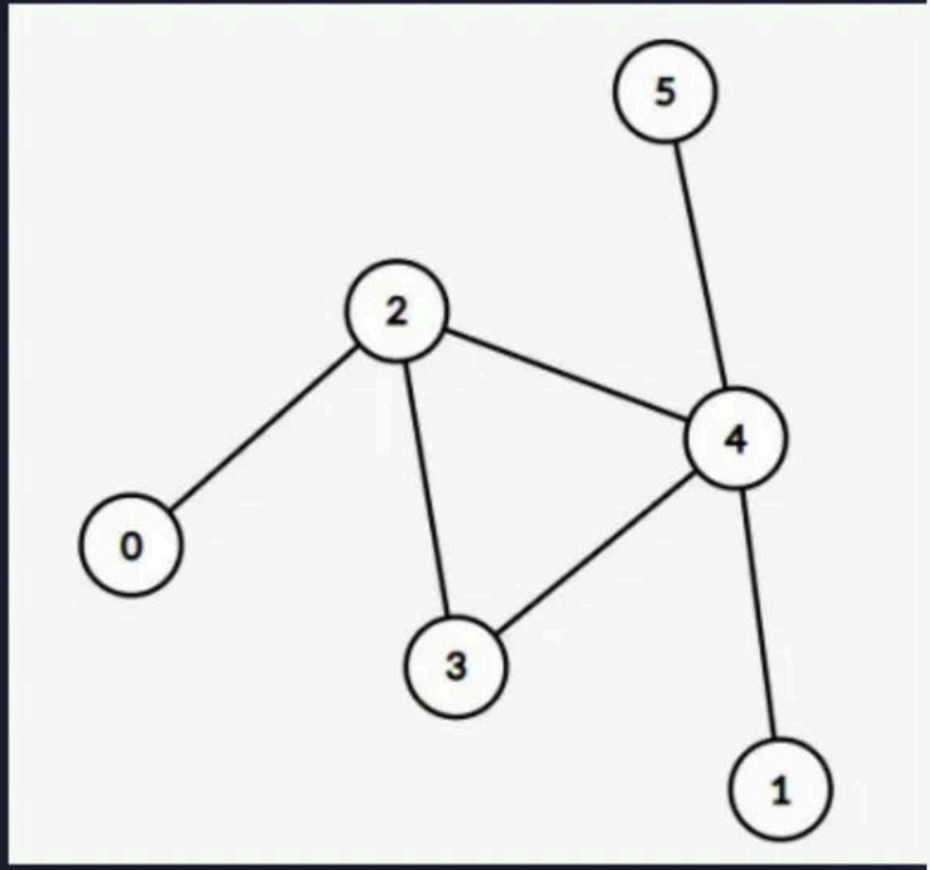

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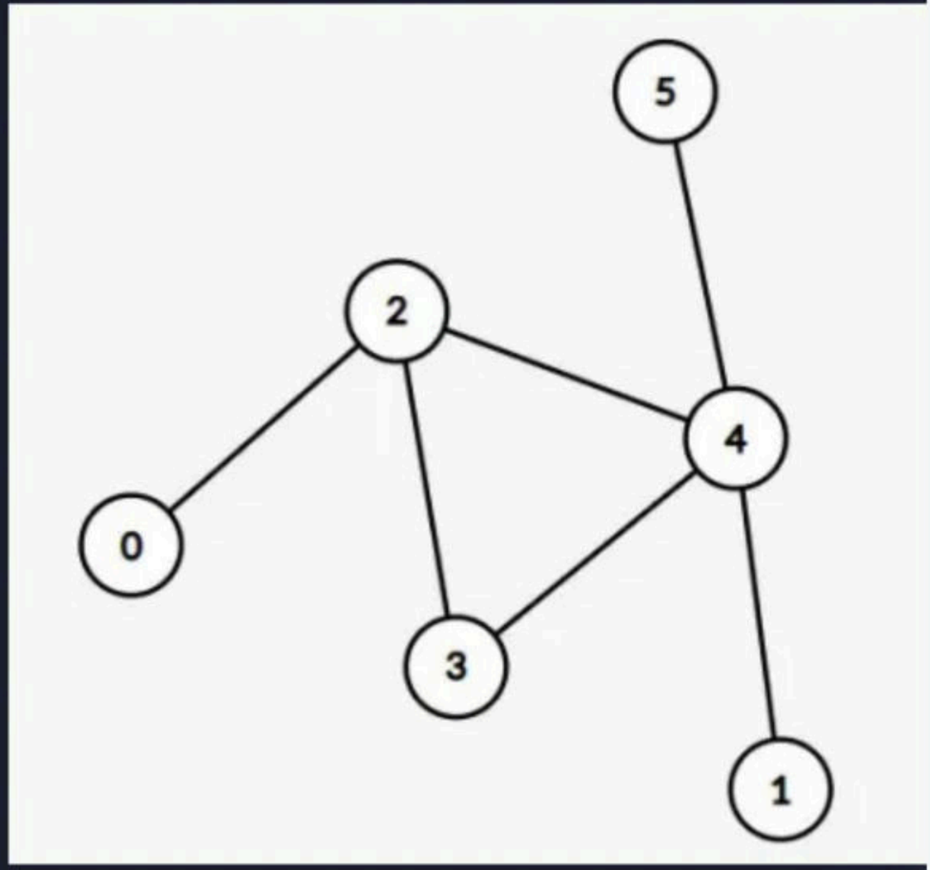

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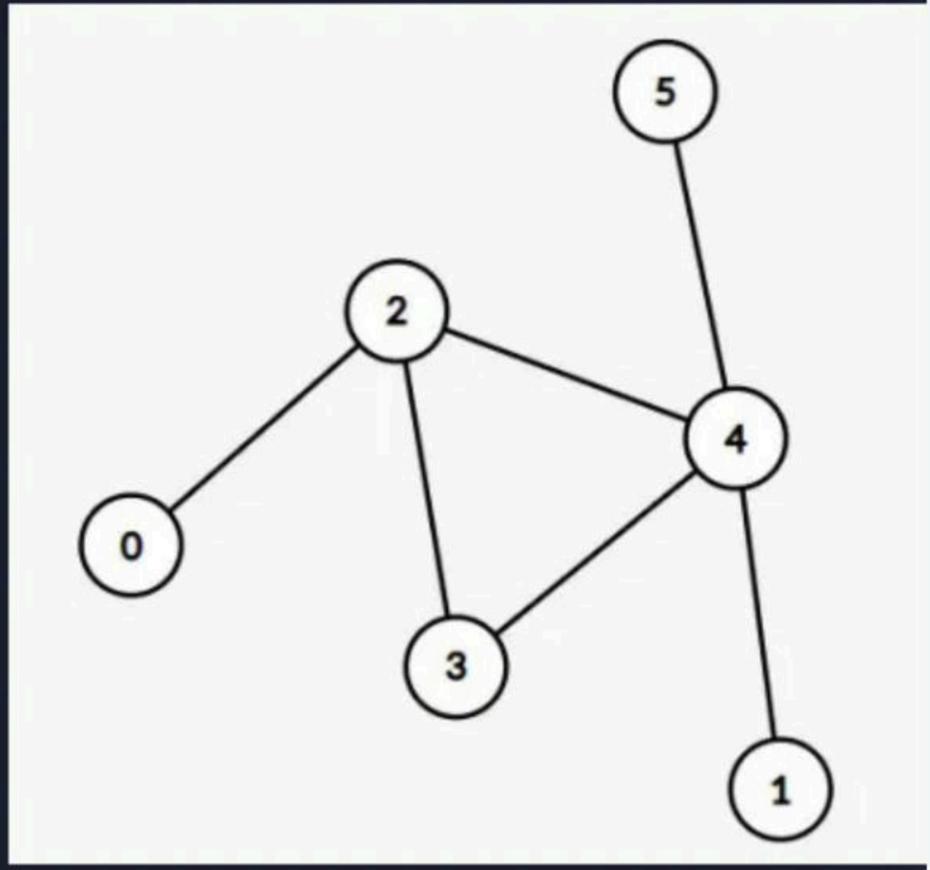
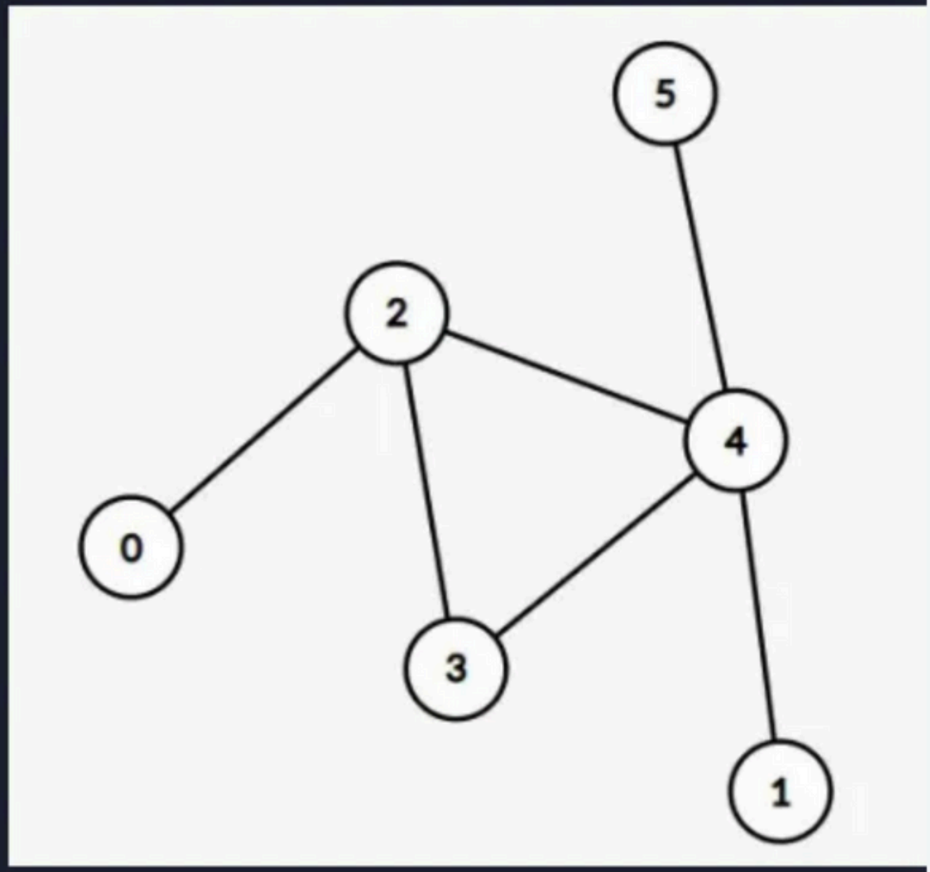


N = 6
M = 6

```
int res = A[0];
for (int i = mask; i > 0; i = (i - 1) & mask) {
  res += A[i];
}
```



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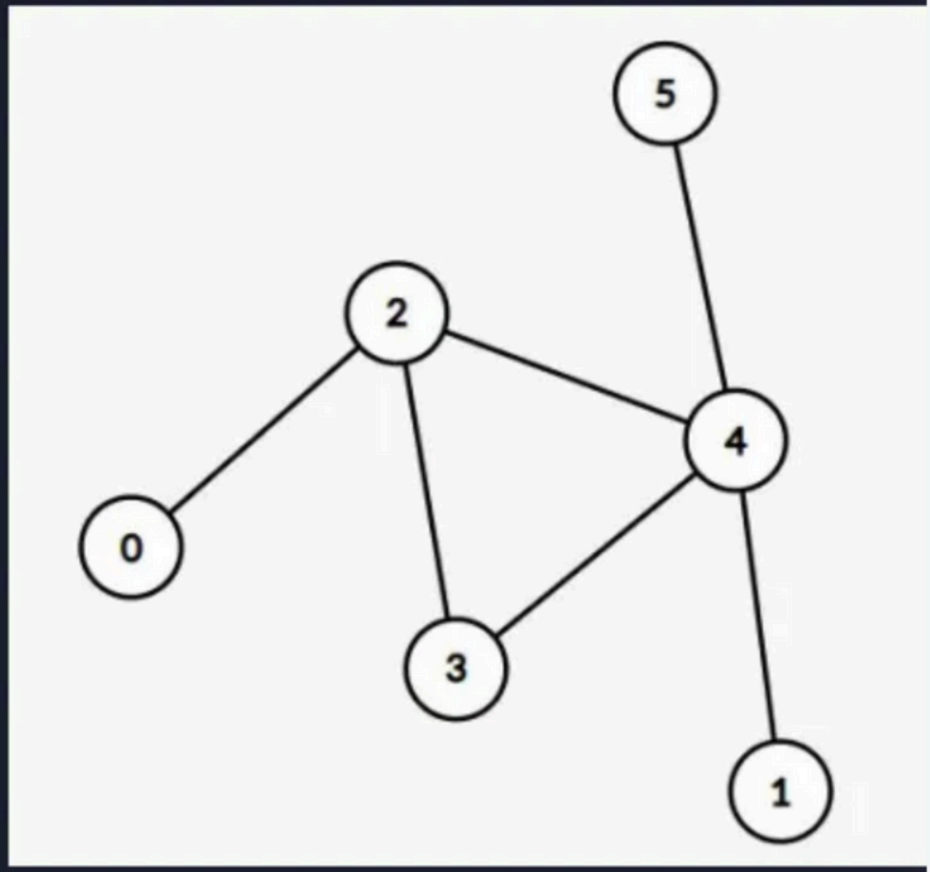

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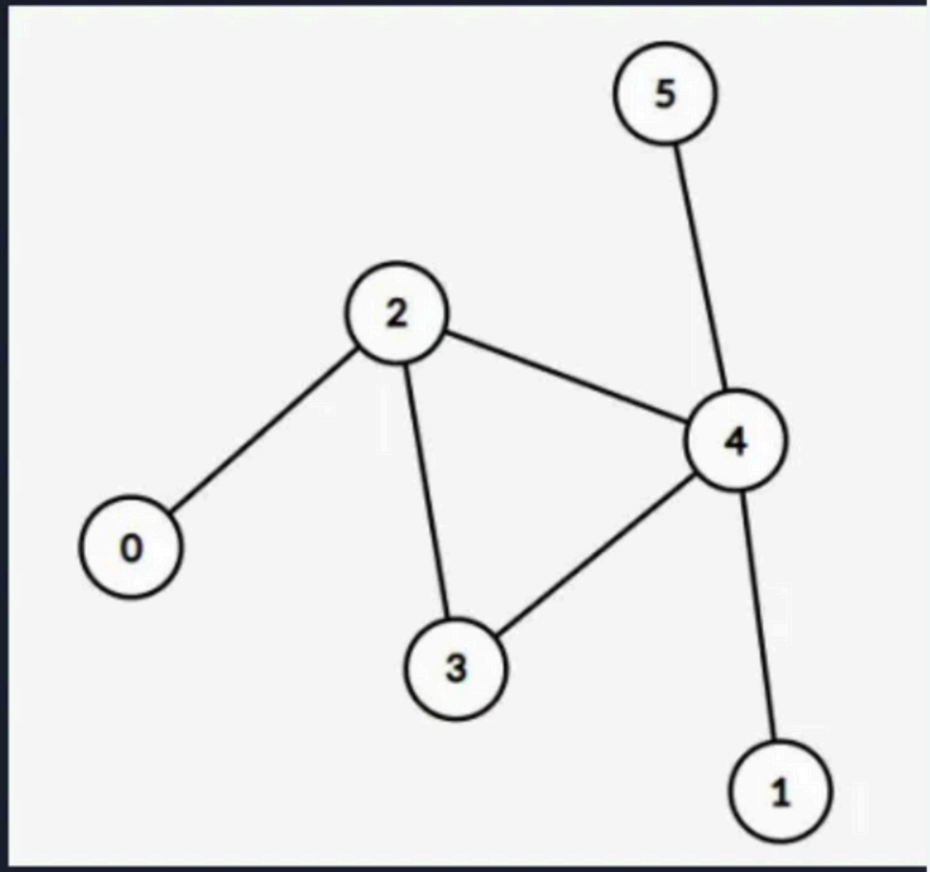

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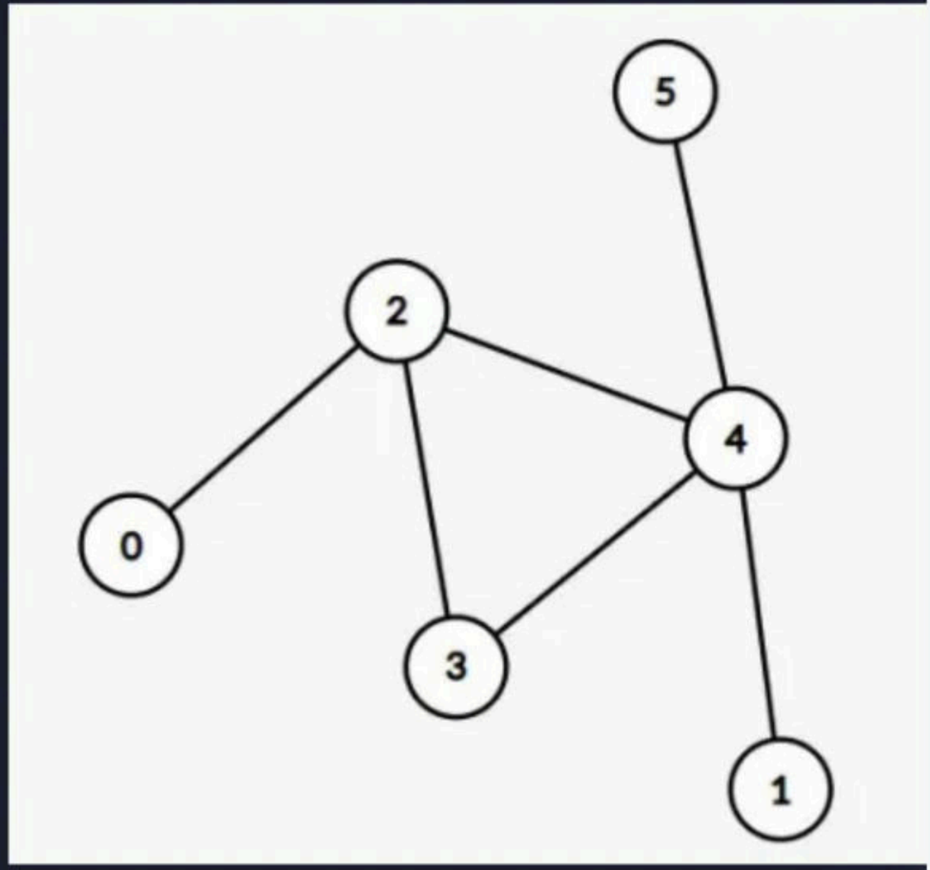

N = 6
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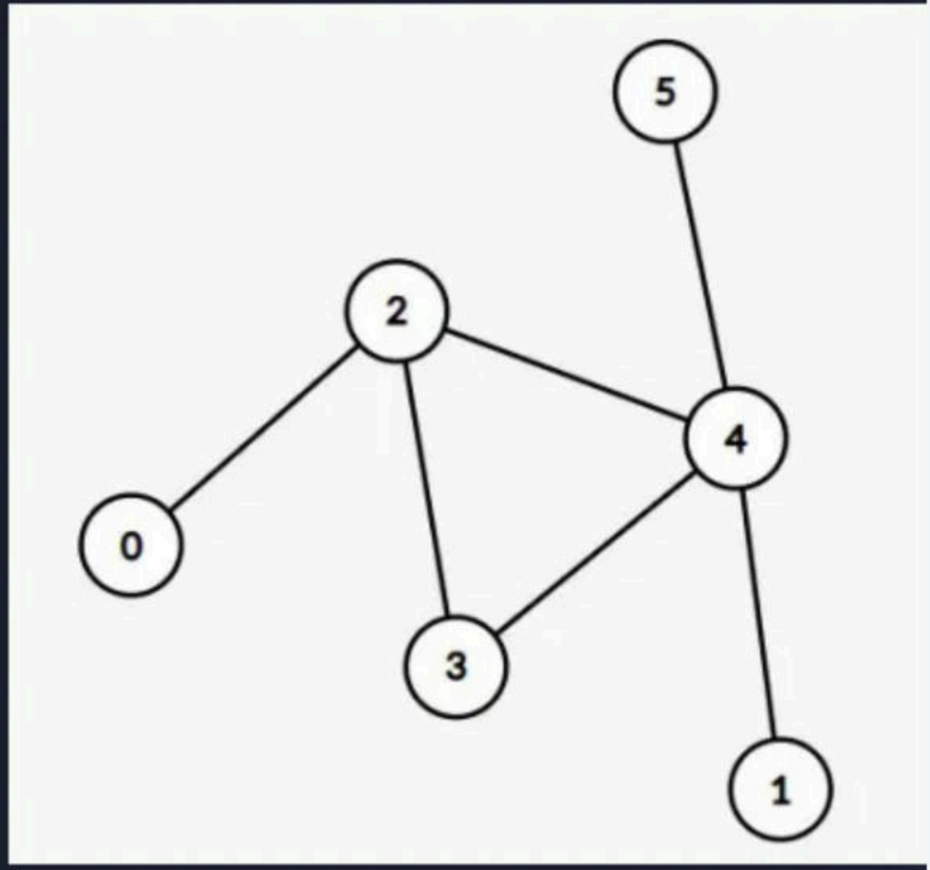
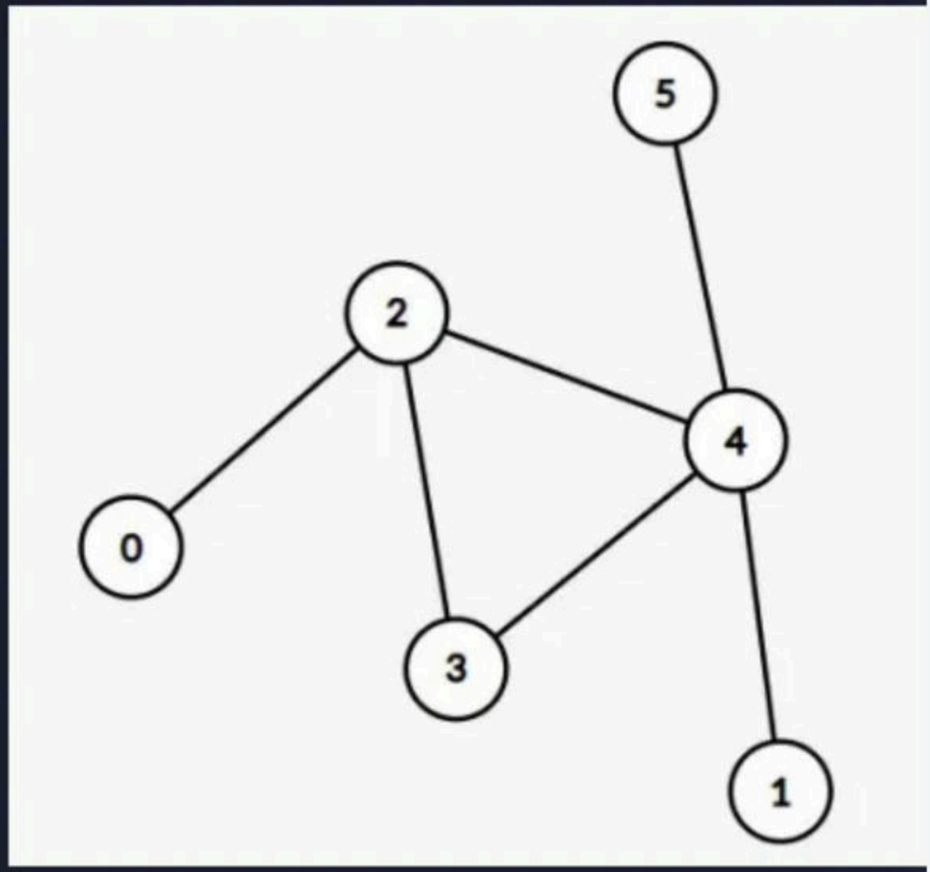
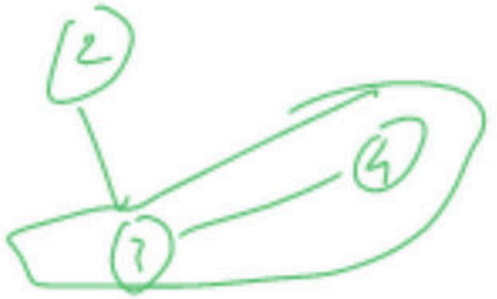


N = 6
M = 6

{2, 3}



```cpp
// this function checks whether <vertextCover> is the vertex cover of graph
// <graph>
bool check(int graph, int vertexCover, int edges[][2], int M) {
    for (int i = 1; i <= M; i++) {
        int a = edges[i][0];
        int b = edges[i][1];
        if (((graph >> a) & 1) == 0 or ((graph >> b) & 1) == 0) {
            // this edge doesn't lie in graph
            continue;
        }
        if (((vertexCover >> a) & 1) == 0 && ((vertexCover >> b) & 1) == 0) {
            // no edge vertex lies in vertex cover
            return false;
        }
    }
    return true;
}
```



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    int b = edges[i][1];
    if (((graph >> a) & 1) == 0 or ((graph >> b) & 1) == 0) {
      // this edge doesn't lie in graph
      continue;
    }
    if (((vertexCover >> a) & 1) == 0 && ((vertexCover >> b) & 1) == 0) {
      // no edge vertex lies in vertex cover
      return false;
    }
  }
  return true;
}
```

```
int solve(int edges[][2], int N, int M) {
  const int inf = 1e9;
  int leftSize = N / 2;
  int rightSize = N - leftSize;

  vector<int> adj[N + 5];
  for (int i = 1; i <= M; i++) {
    adj[edges[i][0]].push_back(edges[i][1]);
    adj[edges[i][1]].push_back(edges[i][0]);
  }

  int dp[(1 << leftSize) + 5];

  for (int graph = 0; graph < (1 << leftSize); graph++) {
    int minVertexConver = inf;

    if (check(graph, 0, edges, M))
      minVertexConver = 0;
    for (int vertexCover = graph; vertexCover > 0;
         vertexCover = (vertexCover - 1) & graph) {
      if (check(graph, vertexCover, edges, M)) {
        minVertexConver = min(minVertexConver, countSetBits(vertexCover));
      }
    }
    dp[graph] = minVertexConver;
  }

  int res = inf;
  for (int vertexCover = 0; vertexCover < (1 << rightSize); vertexCover++) {
    int graph = (1 << rightSize) - 1;
    if (!check(graph << leftSize, vertexCover, edges, M))
      continue;

    int rightVertexCover = countSetBits(vertexCover);
    int remGraph = graph ^ vertexCover;

    int leftVerticesToTake = 0;

    for (int remVertex = 0; remVertex < rightSize; remVertex++) {
      if ((remGraph >> remVertex) & 1) {
        int actualVertex = remVertex + leftSize;
        for (int &leftVertex : adj[actualVertex]) {
          if (leftVertex < leftSize)
            leftVerticesToTake |= (1 << leftVertex);
        }
      }
    }

    int leftVertexCover = countSetBits(leftVerticesToTake) +
                          dp[((1 << leftSize) - 1) ^ leftVerticesToTake];
    res = min(res, leftVertexCover + rightVertexCover);
  }
  return res;
}
```

```
int solve(int edges[][2], int N, int M) {
  const int inf = 1e9;
  int leftSize = N / 2;
  int rightSize = N - leftSize;

  vector<int> adj[N + 5];
  for (int i = 1; i <= M; i++) {
    adj[edges[i][0]].push_back(edges[i][1]);
    adj[edges[i][1]].push_back(edges[i][0]);
  }

  int dp[(1 << leftSize) + 5];

  for (int graph = 0; graph < (1 << leftSize); graph++) {
    int minVertexConver = inf;

    if (check(graph, 0, edges, M))
      minVertexConver = 0;
    for (int vertexCover = graph; vertexCover > 0;
         vertexCover = (vertexCover - 1) & graph) {
      if (check(graph, vertexCover, edges, M)) {
        minVertexConver = min(minVertexConver, countSetBits(vertexCover));
      }
    }
    dp[graph] = minVertexConver;
  }
  int res = inf;
  for (int vertexCover = 0; vertexCover < (1 << rightSize); vertexCover++) {
    int graph = (1 << rightSize) - 1;
    if (!check(graph << leftSize, vertexCover, edges, M))
      continue;

    int rightVertexCover = countSetBits(vertexCover);
    int remGraph = graph ^ vertexCover;

    int leftVerticesToTake = 0;

    for (int remVertex = 0; remVertex < rightSize; remVertex++) {
      if ((remGraph >> remVertex) & 1) {
        int actualVertex = remVertex + leftSize;
        for (int &leftVertex : adj[actualVertex]) {
          if (leftVertex < leftSize)
            leftVerticesToTake |= (1 << leftVertex);
        }
      }
    }

    int leftVertexCover = countSetBits(leftVerticesToTake) +
                          dp[((1 << leftSize) - 1) ^ leftVerticesToTake];
    res = min(res, leftVertexCover + rightVertexCover);
  }
  return res;
}
```

Summary