

# ACM-ICPC-REFERENCE

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# 1 Coding Resources

## 1.1 C++

### 1.1.1 IOOptimizationCPP

```
int main() {
    ios_base::sync_with_stdio(0);
    cin.tie(0);
}
```

### 1.1.2 IntToBinary

```
typedef long long int lli;

lli bitsInInt(lli n) {
    return floor(log2(n) + 1LL);
}

vector<int> intToBitsArray(lli n) {
    n = abs(n);
    if (!n) {
        vector<int> v;
        return v;
    }
    int length = bitsInInt(n);
    int lastPos = length - 1;
    vector<int> v(length);
    for (lli i = lastPos, j = 0; i > -1LL;
         i--, j++) {
        lli aux = (n >> i) & 1LL;
        v[j] = aux;
    }
    return v;
}
```

### 1.1.3 MapValueToInt

```
typedef string Key;
unordered_map<Key, int> val;
unordered_map<int, Key> getKey;
int mapId = 0;

int Map(Key key) {
    getKey[mapId] = key;
    return val.count(key) ? val[key]
                          : val[key] = mapId++;
}

void initMapping() {
    mapId = 0;
    val.clear();
}
```

### 1.1.4 PrintVector

```
void printv(vector<int> v) {
    if (v.size() == 0) {
        cout << "[]" << endl;
        return;
    }
}
```

```
cout << "[" << v[0];
for (int i = 1; i < v.size(); i++) {
    cout << ", " << v[i];
}
cout << "]" << endl;
}
```

### 1.1.5 PriorityQueueOfClass

```
struct Object {
    char first;
    int second;
};

int main() {
    auto cmp = [](const Object& a,
                  const Object& b) {
        return a.second > b.second;
    };
    priority_queue<Object, vector<Object>,
                  decltype(cmp)>
        pq(cmp);
    vector<Object> v = {
        {'c', 3}, {'a', 1}, {'b', 2}};
    sort(v.begin(), v.end(), cmp);
    return 0;
}
```

### 1.1.6 ReadLineCpp

```
// when reading lines, don't mix 'cin' with
// 'getline' just use getline and split
string input() {
    string ans;
    // cin >> ws; // eats all whitespaces.
    getline(cin, ans);
    return ans;
}
```

### 1.1.7 SortPair

```
pair<int, int> p;
sort(p.begin(), p.end());
// sorts array on the basis of the first element
```

### 1.1.8 SortVectorOfClass

```
struct Object {
    char first;
    int second;
};

bool cmp(const Object& a, const Object& b) {
    return a.second > b.second;
}

int main() {
    vector<Object> v = {
        {'c', 3}, {'a', 1}, {'b', 2}};
    sort(v.begin(), v.end(), cmp);
}
```

```
    printv(v);
    return 0;
}
```

### 1.1.9 SplitString

```
vector<string> split(string str, char token) {
    stringstream test(str);
    string seg;
    vector<string> seglist;
    while (getline(test, seg, token))
        seglist.push_back(seg);
    return seglist;
}
```

## 1.2 Python

### 1.2.1 Combinations

```
import itertools
#from arr choose k => combinations(arr, k)
print(list(itertools.combinations([1, 2, 3], 3)))
```

### 1.2.2 Fast IO

```
from sys import stdin, stdout
```

```
N = 10
#Reads N chars from stdin(it counts '\n' as char)
stdin.read(N)
#Reads until '\n' or EOF
line = stdin.readline()
#Reads all lines in stdin until EOF
lines = stdin.readlines()
#Writes a string to stdout, it doesn't add '\n'
stdout.write(line)
#Writes a list of strings to stdout
stdout.writelines(lines)
#Reads numbers separated by space in a line
numbers = list(map(int, stdin.readline().split()))
```

### 1.2.3 Permutations

```
import itertools
print(list(itertools.permutations([1, 2, 3])))
```

### 1.2.4 SortListOfClass

```
class MyObject :
    def __init__(self, first, second):
        self.first = first
        self.second = second

li = [MyObject('c', 3), MyObject('a', 1),
      ↪ MyObject('b', 2)]
li.sort(key = lambda x: x.first, reverse = False)
```

## 2 Data Structures

### 2.1 SegmentTree

### 2.2 Trie

```
// ASIZE = alphabet size
// wpt = number of words passing through
// w = number of words ending in the node
// c = character

struct Trie {
    struct Node {
        // for lexicographical order use 'map'
        // map<char, Node *> ch;
        unordered_map<char, Node *> ch;
        int w = 0, wpt = 0;
    };

    Node *root = new Node();

    void insert(string str) {
        Node *curr = root;
        for (auto &c : str) {
            curr->wpt++;
            if (!curr->ch.count(c))
                curr->ch[c] = new Node();
            curr = curr->ch[c];
        }
        curr->wpt++;
        curr->w++;
    }

    Node *find(string &str) {
        Node *curr = root;
        for (auto &c : str) {
            if (!curr->ch.count(c)) return nullptr;
            curr = curr->ch[c];
        }
        return curr;
    }

    // number of words with given prefix
    int prefixCount(string prefix) {
        Node *node = find(prefix);
        return node ? node->wpt : 0;
    }

    // number of words matching str
    int strCount(string str) {
        Node *node = find(str);
        return node ? node->w : 0;
    }

    void getWords(Node *curr, vector<string> &words,
                  string &word) {
        if (!curr) return;
        if (curr->w) words.push_back(word);
        for (auto &c : curr->ch) {
```

```

        getWords(c.second, words, word += c.first);
        word.pop_back();
    }
}

vector<string> getWords() {
    vector<string> words;
    string word = "";
    getWords(root, words, word);
    return words;
}

vector<string> getWordsByPrefix(string prefix) {
    vector<string> words;
    getWords(find(prefix), words, prefix);
}

bool remove(Node *curr, string &str, int &i) {
    if (i == str.size()) {
        curr->wpt--;
        return curr->w ? !(curr->w = 0) : 0;
    }
    int c = str[i];
    if (!curr->ch.count(c)) return false;
    if (remove(curr->ch[c], str, ++i)) {
        if (!curr->ch[c]->wpt)
            curr->wpt--, curr->ch.erase(c);
        return true;
    }
    return false;
}

int remove(string str) {
    int i = 0;
    return remove(root, str, i);
}
};

```

## 2.3 UnionFind

```

struct UnionFind {
    vector<int> dad, size;
    int n;
    UnionFind(int N) : n(N), dad(N), size(N, 1) {
        while (--N) dad[N] = N;
    }

    int root(int u) {
        if (dad[u] == u) return u;
        return dad[u] = root(dad[u]);
    }

    bool areConnected(int u, int v) {
        return root(u) == root(v);
    }

    void join(int u, int v) {
        int Ru = root(u), Rv = root(v);
        if (Ru == Rv) return;
        --n, dad[Ru] = Rv;
    }
};

```

```

        size[Rv] += size[Ru];
    }

    int getSize(int u) {
        return size[root(u)];
    }

    int numberOfSets() {
        return n;
    }
};

```

## 2.4 pointers

```

#include <bits/stdc++.h>

using namespace std;

struct Hola {
    int x = 0, y = 0;
};

// int &id = i; just keeps the first
// initialization

int main() {
    Hola *h = new Hola();
    Hola *h1 = new Hola();
    Hola *hh = h;
    h->x = 1;
    h->y = 2;
    hh = h1;
    hh->x = 5;

    cout << h1->x << endl;
    return 0;
}

```

## 3 Geometry

## 4 Graphs

### 4.1 ArticulationPointsAndBridges

```

// APB = articulation points and bridges
// ap = Articulation Point
// br = bridges
// p = parent
// disc = discovery time
// low = lowTime
// ch = children

typedef pair<int, int> Edge;
int MAXN = 101, N = 7, Time;
vector<vector<int>> ady;
vector<int> disc, low, ap;
vector<Edge> br;

```

```

void initVars() {
    ady = vector<vector<int>>(MAXN, vector<int>());
}

int dfsAPB(int u, int p) {
    int ch = 0;
    low[u] = disc[u] = ++Time;
    for (int &v : ady[u]) {
        if (v == p) continue;
        if (!disc[v]) {
            ch++;
            dfsAPB(v, u);
            if (disc[u] <= low[v]) ap[u]++;
            if (disc[u] < low[v]) br.push_back({u, v});
            low[u] = min(low[u], low[v]);
        } else
            low[u] = min(low[u], disc[v]);
    }
    return ch;
}

void APB() {
    br.clear();
    ap = low = disc = vector<int>(MAXN);
    Time = 0;
    for (int u = 0; u < N; u++)
        if (!disc[u]) ap[u] = dfsAPB(u, u) > 1;
}

void addEdge(int u, int v) {
    ady[u].push_back(v);
    ady[v].push_back(u);
}

```

## 4.2 ConnectedComponents

```

// comp = component
int MAXN = 26, N, compId = 1;
vector<vector<int>> ady;
vector<int> getComp;

void initVars() {
    ady = vector<vector<int>>(MAXN, vector<int>());
    getComp = vector<int>(MAXN);
}

void dfsCC(int u, vector<int> &comp) {
    if (getComp[u]) return;
    getComp[u] = compId;
    comp.push_back(u);
    for (auto &v : ady[u]) dfsCC(v, comp);
}

vector<vector<int>> connectedComponents() {
    vector<vector<int>> comps;
    for (int u = 0; u < N; u++) {
        vector<int> comp;
        dfsCC(u, comp);
        compId++;
        if (!comp.empty()) comps.push_back(comp);
    }
}

```

```

}
return comps;
}

```

```

void addEdge(int u, int v) {
    ady[u].push_back(v);
    ady[v].push_back(u);
}

```

## 4.3 CycleInDirectedGraph

```

int n; // max node id >= 0
vector<vector<int>> ady; // ady.resize(n)
vector<int> vis; // vis.resize(n)
vector<vector<int>> cycles;
vector<int> cycle;
bool flag = false;
int rootNode = -1;

bool hasDirectedCycle(int u) {
    vis[u] = 1;
    for (auto &v : ady[u]) {
        if (v == u || vis[v] == 2) continue;
        if (vis[v] == 1 || hasDirectedCycle(v)) {
            if (rootNode == -1)
                rootNode = v, flag = true;
            if (flag) {
                cycle.push_back(u);
                if (rootNode == u) flag = false;
            }
            return true;
        }
    }
    vis[u] = 2;
    return false;
}

bool hasDirectedCycle() {
    vis.clear();
    for (int u = 0; u < n; u++)
        if (!vis[u]) {
            cycle.clear();
            if (hasDirectedCycle(u))
                cycles.push_back(cycle);
        }
    return cycles.size() > 0;
}

```

## 4.4 CycleInUndirectedGraph

```

int n; // max node id >= 0
vector<vector<int>> ady; // ady.resize(n)
vector<bool> vis; // vis.resize(n)
vector<vector<int>> cycles;
vector<int> cycle;
bool flag = false;
int rootNode = -1;

bool hasUndirectedCycle(int u, int prev) {

```

```

vis[u] = true;
for (auto &v : ady[u]) {
    if (v == u || v == prev) continue;
    if (vis[v] || hasUndirectedCycle(v, u)) {
        if (rootNode == -1)
            rootNode = v, flag = true;
        if (flag) {
            cycle.push_back(u);
            if (rootNode == u) flag = false;
        }
        return true;
    }
}
return false;
}

bool hasUndirectedCycle() {
    vis.clear();
    for (int u = 0; u < n; u++)
        if (!vis[u]) {
            cycle.clear();
            if (hasUndirectedCycle(u, -1))
                cycles.push_back(cycle);
        }
    return cycles.size() > 0;
}

```

## 4.5 FloodFill

```

int n, m, oldColor = 0, color = 1;
vector<vector<int>>> mat;

vector<vector<int>>> movs = {
    {1, 0}, {0, 1}, {-1, 0}, {0, -1}};

void floodFill(int i, int j) {
    if (i >= mat.size() || i < 0 ||
        j >= mat[i].size() || j < 0 ||
        mat[i][j] != oldColor)
        return;
    mat[i][j] = color;
    for (auto move : movs)
        floodFill(i + move[1], j + move[0]);
}

void floodFill() {
    for (int i = 0; i < n; i++)
        for (int j = 0; j < m; j++)
            if (mat[i][j] == oldColor) floodFill(i, j);
}

```

## 4.6 Flow

### 4.6.1 MaxFlowDinic

```

// cap[a][b] = Capacity from a to b
// flow[a][b] = flow occupied from a to b
// level[a] = level in graph of node a
// Num = number
typedef int Num;

```

```

int N, MAXN = 101;
vector<int> level;
vector<vector<int>>> ady(MAXN, vector<int>()),
    cap(MAXN, vector<int>(MAXN)),
    flow(MAXN, vector<int>(MAXN));

bool levelGraph(int s, int t) {
    level = vector<int>(MAXN);
    level[s] = 1;
    queue<int> q;
    q.push(s);
    while (!q.empty()) {
        int u = q.front();
        q.pop();
        for (int &v : ady[u]) {
            if (!level[v] && flow[u][v] < cap[u][v]) {
                q.push(v);
                level[v] = level[u] + 1;
            }
        }
    }
    return level[t];
}

Num blockingFlow(int u, int t,
                  Num currPathMaxFlow) {
    if (u == t) return currPathMaxFlow;
    for (int v : ady[u]) {
        Num capleft = cap[u][v] - flow[u][v];
        if ((level[v] == (level[u] + 1)) &&
            (capleft > 0)) {
            Num pathMaxFlow = blockingFlow(
                v, t, min(currPathMaxFlow, capleft));
            if (pathMaxFlow > 0) {
                flow[u][v] += pathMaxFlow;
                flow[v][u] -= pathMaxFlow;
                return pathMaxFlow;
            }
        }
    }
    return 0;
}

Num dinicMaxFlow(int s, int t) {
    if (s == t) return -1;
    Num maxFlow = 0;
    while (levelGraph(s, t))
        while (Num flow = blockingFlow(s, t, 1 << 30))
            maxFlow += flow;
    return maxFlow;
}

void addEdge(int u, int v, Num capacity) {
    cap[u][v] = capacity;
    ady[u].push_back(v);
}

```

## 4.7 IsBipartite

```
int n; // max node id >= 0
vector<vector<int>> ady; // ady.resize(n)

bool isBipartite() {
    vector<int> color(n, -1);
    for (int s = 0; s < n; s++) {
        if (color[s] > -1) continue;
        color[s] = 0;
        queue<int> q;
        q.push(s);
        while (!q.empty()) {
            int u = q.front();
            q.pop();
            for (int &v : ady[u]) {
                if (color[v] < 0)
                    q.push(v), color[v] = !color[u];
                if (color[v] == color[u]) return false;
            }
        }
    }
    return true;
}
```

## 4.8 KruskalMST

```
typedef int Weight;
typedef pair<int, int> Edge;
typedef pair<Weight, Edge> Wedge;

vector<Wedge> Wedges; // gets filled from input;
vector<Wedge> mst;

int kruskal() {
    int cost = 0;
    sort(Wedges.begin(), Wedges.end());
    // reverse(Wedges.begin(), Wedges.end());
    UnionFind uf(N);
    for (Wedge &wedge : Wedges) {
        int u = wedge.second.first,
            v = wedge.second.second;
        if (!uf.areConnected(u, v))
            uf.join(u, v), mst.push_back(wedge),
            cost += wedge.first;
    }
    return cost;
}
```

## 4.9 ShortestPaths

### 4.9.1 BellmanFord

```
typedef int Weight;
int MAXN = 20001, N, INF = 1 << 30,
    isDirected = true;
vector<vector<int>> ady, weight;

void initVars() {
    ady = vector<vector<int>>(MAXN, vector<int>());
```

```
    weight = vector<vector<int>>(
        MAXN, vector<int>(MAXN, INF));
}

vector<Weight> bellmanFord(int s) {
    vector<Weight> dist(MAXN, INF);
    dist[s] = 0;
    for (int i = 0; i <= N; i++)
        for (int u = 0; u < N; u++)
            for (auto &v : ady[u]) {
                Weight w = weight[u][v];
                if (dist[u] != INF &&
                    dist[v] > dist[u] + w) {
                    if (i == N) return vector<Weight>();
                    dist[v] = dist[u] + w;
                }
            }
    return dist;
}

void addEdge(int u, int v, Weight w) {
    ady[u].push_back(v);
    weight[u][v] = w;
    if (isDirected) return;
    ady[v].push_back(u);
    weight[v][u] = w;
}
```

### 4.9.2 Dijkstra

```
typedef int Weight;
typedef pair<Weight, int> NodeDist;
int MAXN = 20001, INF = 1 << 30,
    isDirected = false;
vector<vector<int>> ady, weight;

void initVars() {
    ady = vector<vector<int>>(MAXN, vector<int>());
    weight = vector<vector<int>>(
        MAXN, vector<int>(MAXN, INF));
}

vector<Weight> dijkstra(int s) {
    vector<int> dist(MAXN, INF);
    set<NodeDist> q;
    q.insert({0, s});
    dist[s] = 0;
    while (!q.empty()) {
        NodeDist nd = *q.begin();
        q.erase(nd);
        int u = nd.second;
        for (int &v : ady[u]) {
            Weight w = weight[u][v];
            if (dist[v] > dist[u] + w) {
                if (dist[v] != INF) q.erase({dist[v], v});
                dist[v] = dist[u] + w;
                q.insert({dist[v], v});
            }
        }
    }
}
```



```

    return dist;
}

void addEdge(int u, int v, Weight w) {
    ady[u].push_back(v);
    weight[u][v] = w;
    if (isDirected) return;
    ady[v].push_back(u);
    weight[v][u] = w;
}

```

## 4.10 StronglyConnectedComponents

```

// tv = top value from stack
// sccs = strongly connected components
// scc = strongly connected component
// disc = discovery time
// low = low time
// s = stack
// top = top index of the stack

int MAXN = 101, N = 7, Time, top;
vector<vector<int>> ady, sccs;
vector<int> disc, low, s;

void initVars() {
    ady = vector<vector<int>>(MAXN, vector<int>());
}

void dfsSCCS(int u) {
    if (disc[u]) return;
    low[u] = disc[u] = ++Time;
    s[++top] = u;
    for (int &v : ady[u]) {
        dfsSCCS(v);
        low[u] = min(low[u], low[v]);
    }
    if (disc[u] == low[u]) {
        vector<int> scc;
        while (true) {
            int tv = s[top--];
            scc.push_back(tv);
            low[tv] = N;
            if (tv == u) break;
        }
        sccs.push_back(scc);
    }
}

void SCCS() {
    s = low = disc = vector<int>(MAXN);
    Time = 0, top = -1, sccs.clear();
    for (int u = 0; u < N; u++) dfsSCCS(u);
}

void addEdge(int u, int v) {
    ady[u].push_back(v);
}

```

## 4.11 TopologicalSort

```

int n; // max node id >= 0
vector<vector<int>> ady; // ady.resize(n)
vector<int> vis; // vis.resize(n)
vector<int> toposorted;

bool toposort(int u) {
    vis[u] = 1;
    for (auto &v : ady[u]) {
        if (v == u || vis[v] == 2) continue;
        if (vis[v] == 1 || !toposort(v)) return false;
    }
    vis[u] = 2;
    toposorted.push_back(u);
    return true;
}

bool toposort() {
    vis.clear();
    for (int u = 0; u < n; u++)
        if (!vis[u])
            if (!toposort(u)) return false;
    return true;
}

```

## 5 Maths

### 5.1 Game Theory

### 5.2 Number Theory

#### 5.2.1 DivisibilityCriterion

```

def divisorCriteria(n, lim):
    results = []
    tenElevated = 1
    for i in range(lim):
        # remainder = pow(10, i, n)
        remainder = tenElevated % n
        negremainder = remainder - n
        if (remainder <= abs(negremainder)):
            results.append(remainder)
        else:
            results.append(negremainder)
    tenElevated *= 10
    return results

def testDivisibility(dividend, divisor,
    ↪ divisor_criteria):
    dividend = str(dividend)
    addition = 0
    dividendSize = len(dividend)
    i = dividendSize - 1
    j = 0
    while j < dividendSize:
        addition += int(dividend[i]) *
        ↪ divisor_criteria[j]
        i -= 1

```

```

        j += 1
    return addition % divisor == 0

if __name__ == '__main__':
    dividend, divisor = map(int, input().split())
    divisor_criteria = divisorCriteria(divisor,
        → len(str(dividend)))
    print(divisor_criteria)
    print(testDivisibility(dividend, divisor,
        → divisor_criteria))

```

### 5.2.2 ExtendedEuclidean

```

// gcd(a, b) = ax + by
vector<long long int> extendedGCD(
    long long int a, long long int b) {
    if (a > 0LL && b == 0LL) {
        return {a, 1LL, 0LL};
    }
    long long int x = 1LL, y = 0LL, prevx = 0LL,
        prevy = 1LL, q, remainder;
    while (true) {
        q = a / b;
        remainder = a - b * q;
        if (remainder == 0LL) break;
        a = b;
        b = remainder;
        x = x - prevx * q;
        swap(x, prevx);
        y = y - prevy * q;
        swap(y, prevy);
    }
    // gcd = b, x = prevx, y = prevy
    return {b, prevx, prevy};
}

```

### 5.2.3 GCD

```

int gcd(int a, int b) {
    return b == 0 ? a : gcd(b, a % b);
}

int gcdI(int a, int b) {
    while (b) {
        a %= b;
        swap(a, b);
    }
    return a;
}

```

### 5.2.4 PrimeCheckMillerRabin

```

from random import randrange

def is_prime(p):
    k = 100
    if p == 2 or p == 3:
        return True

```

```

    if (p & 1) == 0 or p == 1:
        return False
    phi = p - 1
    d = phi
    r = 0
    while (d & 1) == 0:
        d = int(d >> 1)
        r += 1
    for i in range(k):
        a = randrange(2, p - 2)
        exp = pow(a, d, p)
        if exp == 1 or exp == p - 1:
            continue
        flag = False
        for j in range(r - 1):
            exp = pow(exp, 2, p)
            if exp == 1:
                return False
            if exp == p - 1:
                flag = True
                break
        if flag:
            continue
        else:
            return False
    return True

```

### 5.2.5 PrimeSieve

```

vector<int> primeSieve(int n) {
    vector<int> sieve(n + 1);
    for (int i = 4; i <= n; i += 2) sieve[i] = 2;
    for (int i = 3; i * i <= n; i += 2)
        if (!sieve[i])
            for (int j = i * i; j <= n; j += 2 * i)
                if (!sieve[j]) sieve[j] = i;
    return sieve;
}

```

## 5.3 Probability

### 5.3.1 Combinations

### 5.3.2 Permutations

## 6 Multiple Queries

### 6.1 Mo

```
#include <bits/stdc++.h>
```

### 6.2 SqrtDecomposition

```
#include <bits/stdc++.h>
```

## 7 Rare Topics

## 8 Strings

### 8.1 KMP

```
// f = error function
// cf = create error function
// p = pattern
// t = text
// pos = positions where pattern is found in text
```

```
int MAXN = 1000000;
vector<int> f(MAXN + 1);

vector<int> kmp(string &p, string &t, int cf) {
    vector<int> pos;
    if (cf) f[0] = -1;
    for (int i = cf, j = 0; j < t.size(); i++) {
        while (i > -1 && p[i] != t[j]) i = f[i];
        i++, j++;
        if (cf) f[j] = i;
        if (!cf && i == p.size())
            pos.push_back(j - i), i = f[i];
    }
    return pos;
}

vector<int> search(string &p, string &t) {
    kmp(p, p, -1); // create error function
    return kmp(p, t, 0); // search in text
}
```

### 8.2 RabinKarp

```
class RollingHash {
public:
    vector<unsigned long long int> pow;
    vector<unsigned long long int> hash;
    unsigned long long int B;
    RollingHash(const string &text) : B(257) {
        int N = text.size();
        pow.resize(N + 1);
        hash.resize(N + 1);
        pow[0] = 1;
        hash[0] = 0;
        for (int i = 1; i <= N; ++i) {
            // in c++ an unsigned long long int is
            // automatically modulated by 2^64
            pow[i] = pow[i - 1] * B;
            hash[i] = hash[i - 1] * B + text[i - 1];
        }
    }

    unsigned long long int getWordHash() {
        return hash[hash.size() - 1];
    }

    unsigned long long int getSubstrHash(int begin,
                                         int end) {
```

```
        return hash[end] -
            hash[begin - 1] * pow[end - begin + 1];
    }

    int size() {
        return hash.size();
    }
};

vector<int> rabinKarp(RollingHash &rhStr,
                    string &pattern) {
    vector<int> positions;
    RollingHash rhPattern(pattern);
    unsigned long long int patternHash =
        rhPattern.getWordHash();
    int windowSize = pattern.size(),
        end = windowSize;
    for (int i = 1; end < rhStr.size(); i++) {
        if (patternHash ==
            rhStr.getSubstrHash(i, end))
            positions.push_back(i);
        end = i + windowSize;
    }
    return positions;
}
```

## 9 Faster But Longer

### 9.1 BellmanFerrari

```
// will be with queue
```

### 9.2 KMP