ACM-ICPC-REFERENCE

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Contents

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 adds '\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

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

// ASIZE = alphabet size
// wpt = number of words passing through
// w = number of words ending in the node
// c = character
const int ASIZE = 30;

using namespace std;
struct Trie {
  struct Node {
    vector<Node *> ch;
    int w, wpt;
    Node() {
      w = wpt = 0;
      ch = vector<Node *>(ASIZE, nullptr);
    }
  };

  Node *root = new Node();

  void insert(string str) {
    Node *curr = root;
    for (auto &c : str) {
      curr->wpt++;
      int i = c - 'a';
      if (!curr->ch[i]) curr->ch[i] = new Node();
      curr = curr->ch[i];
      cout << i << endl;
    }
    curr->wpt++;
    curr->w++;
  }

  Node *find(string &str) {
    Node *curr = root;
    for (auto &c : str) {
      int i = c - 'a';
      if (!curr->ch[i]) return curr;
      curr = curr->ch[i];
    }
    return curr;
  }

  // returns number of repeated words removed.
  bool remove(Node *curr, string &str, int &i) {
    if (!curr) return 0;
    if (i == str.size()) return curr->w ?
    ↪  !(curr->w = 0 && curr->wpt--) : 0;
    int c = str[i] - 'a';
    if (remove(curr->ch[c], str, ++i)) {
```

```
      if (!curr->ch[c]->wpt) curr->wpt--,
      ↪ curr->ch[c] = nullptr;
      return true;
    }
    return false;
  }

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

  // number of words with given prefix
  int prefixCount(string prefix) { return
  ↪ find(prefix)->wpt; }
  // number of words matching str
  int strCount(string str) { return find(str)->w;
  ↪ }

  void getWords(Node *curr, vector<string> &words,
  ↪ string &word) {
    if (!curr) return;
    if (curr->w) words.push_back(word);
    for (int i = 0; i < ASIZE; i++) {
      getWords(curr->ch[i], words, word += (i +
      ↪ 'a'));
      word.pop_back();
    }
  }

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

void printv(vector<string> v) {
  if (v.size() == 0) {
    cout << "[]" << endl;
    return;
  }
  cout << "[" << v[0];
  for (int i = 1; i < v.size(); i++) {
    cout << ", " << v[i];
  }
  cout << "]" << endl;
}

int main() {
  Trie trie;
  trie.insert("hola");
  trie.insert("holo");
  trie.insert("que");
  trie.insert("hay");
  trie.insert("de");
  trie.insert("nuevo");
  trie.insert("nueva");
  cout << " haha " << trie.strCount("hola") <<
  ↪ endl;
  printv(trie.getWords());
  cout << " remove " << trie.remove("hola") <<
  ↪ endl;
  printv(trie.getWords());
  return 0;
}
```

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();) {
    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