Содержание

1 Теория чисел

1.1 КТО

```
int gcd(int a, int b, int &x, int &y) {
    if (b==0) { x = 1; y = 0; return a; }
    int d = gcd(b,a%b,x,y);
    swap(x,y);
    y-=a/b*x;
    return d;
}
int inv(int r, int m) {
    int x, y;
    gcd(r,m,x,y);
    return (x+m)%m;
}
int crt(int r, int n, int c, int m) { return r + ((
    c - r) % m + m) * inv(n, m) % m * n; }
```

1.2 Алгоритм Миллера — Рабина

```
__int128 one=1;
int po(int a,int b,int p)
{
    int res=1;
    while(b) {if(b & 1) {res=(res*one*a)%p;--b;}
    else {a=(a*one*a)%p;b>>=1;}} return res;
}
bool chprime(int n) ///miller-rabin
{
    if(n==2) return true;
    if(n<=1 || n%2==0) return false;
    int h=n-1;int d=0;while(h%2==0) {h/=2;++d;}
    for(int a:{2, 3, 5, 7, 11, 13, 17, 19, 23, 29,
    31, 37})
        {
        if(a==n) return true;
        int u=po(a,h,n);bool ok=0;
        if(u%n==1) continue;
        for(int c=0;c<d;++c)
            {
            if((u+1)%n==0) {ok=1;break;}
            u=(u*one*u)%n;
        }
        if(!ok) return false;
    }
    return true;
}
```

2 Графы

2.1 $\mathcal{SCC}$ и 2-$\mathcal{SAT}$

Алгоритм ищет сильносвязные компоненты в графе g, если есть путь $i \to j$, то $scc[i] \le scc[j]$

В случае 2-$\mathcal{SAT}$ рёбра $i \Rightarrow j$ и $(j \oplus 1) \Rightarrow (i \oplus 1)$ должны быть добавлены одновременно.

```
vector<vector<int>> g(2 * n);
vector<vector<int>> r(g.size());
for (int i = 0; i < g.size(); ++i) {
    for (int j : g[i]) r[j].push_back(i);
}
vector<int> used(g.size()), tout(g.size());
int time = 0;
auto dfs = [&](auto dfs, int cur) -> void {
    if (used[cur]) return;
    used[cur] = 1;
    for (int nxt : g[cur]) {
        dfs(dfs, nxt);
    }
    // used[cur] = 2;
    tout[cur] = time++;
};
for (int i = 0; i < g.size(); ++i) if (!used[i])
    dfs(dfs, i);
vector<int> ind(g.size());
iota(ind.begin(), ind.end(), 0);
```

```
sort(all(ind), [&](int i, int j){return tout[i] > tout[j];});
vector<int> scc(g.size(), -1);
auto go = [&](auto go, int cur, int color) -> void {
    if (scc[cur] != -1) return;
    scc[cur] = color;
    for (int nxt : r[cur]) {
        go(go, nxt, color);
    }
};
int color = 0;
for (int i : ind) {
    if (scc[i] == -1) go(go, i, color++);
}
for (int i = 0; i < g.size() / 2; ++i) {
    if (scc[2 * i] == scc[2 * i + 1]) "IMPOSSIBLE"
    if (scc[2 * i] < scc[2 * i + 1]) {
        // !i => i, assign i = true
    } else {
        // i => !i, assign i = false
    }
}
```

2.2 Эйлеров цикл

```
vector<vector<pair<int, int>>> g(n); // pair{nxt, idx}
vector<pair<int, int>> e(p.size());
// build graph
vector<int> in(n), out(n);
for (auto [u, v] : e) in[v]++, out[u]++;
vector<int> used(m), it(n), cycle;
auto dfs = [&](auto dfs, int cur) -> void {
    while (true) {
        while (it[cur] < g[cur].size() && used[g[cur][it[cur]].second]) it[cur]++;
        if (it[cur] == g[cur].size()) return;
        auto [nxt, idx] = g[cur][it[cur]];
        used[idx] = true;
        dfs(dfs, nxt);
        cycle.push_back(idx);
    }
};
int cnt = 0, odd = -1;
for (int i = 0; i < n; ++i){
    if (out[i] && odd == -1) odd = i;
    if (in[i] != out[i]) {
        if (in[i] + 1 == out[i]) odd = i;
        if (abs(in[i] - out[i]) > 1) return {}; // must hold
        cnt++;
    }
}
if (cnt != 0 && cnt != 2) return {}; // must hold
// for undirected find odd vertex (and count that # of odd is 0 or 2)
dfs(dfs, odd);
reverse(cycle.begin(), cycle.end());
if (cycle.size() != m) return {};
```

3 xor, and, or-свёртки

3.1 and-свёртка

```
vector<int> band(vector<int> a,vector<int> b)
{
    int n=0;while((1<<n)<a.size()) ++n;
    a.resize(1<<n);b.resize(1<<n);
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(mask & (1<<i)) {a[mask-(1<<i)]+=a[mask];a[mask-(1<<i)]%=p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(mask & (1<<i)) {b[mask-(1<<i)]+=b[mask];b[mask-(1<<i)]%=p;}
    vector<int> c(1<<n,0);
    for(int mask=0;mask<(1<<n);++mask) {c[mask]=a[mask]*b[mask];c[mask]%=p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {c[mask]-=c[mask+(1<<i)];c[mask]%=p;}
    return c;
}
```

3.2 or-свёртка

```
vector<int> bor(vector<int> a,vector<int> b)
{
    int n=0;while((1<<n)<a.size()) ++n;
    a.resize(1<<n);b.resize(1<<n);
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {a[mask+(1<<i)]+=a[mask];a[mask+(1<<i)]%=p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {b[mask+(1<<i)]+=b[mask];b[mask+(1<<i)]%=p;}
    vector<int> c(1<<n,0);
    for(int mask=0;mask<(1<<n);++mask) {c[mask]=a[mask]*b[mask];c[mask]%=p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(mask & (1<<i)) {c[mask]-=c[mask-(1<<i)];c[mask]%=p;}
    return c;
}
```

3.3 xor-свёртка

```
vector<int> bxor(vector<int> a,vector<int> b)
{
    assert(p%2==1);int inv2=(p+1)/2;
    int n=0;while((1<<n)<a.size()) ++n;
    a.resize(1<<n);b.resize(1<<n);
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {int u=a[mask],v=a[mask+(1<<i)];a[mask+(1<<i)]=(u+v)%p;a[mask]=(u-v)%p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {int u=b[mask],v=b[mask+(1<<i)];b[mask+(1<<i)]=(u+v)%p;b[mask]=(u-v)%p;}
    vector<int> c(1<<n,0);
    for(int mask=0;mask<(1<<n);++mask) {c[mask]=a[mask]*b[mask];c[mask]%=p;}
    for(int i=0;i<n;++i) for(int mask=0;mask<(1<<n);++mask) if(!(mask & (1<<i))) {int u=c[mask],v=c[mask+(1<<i)];c[mask+(1<<i)]=((v-u)*inv2)%p;c[mask]=((u+v)*inv2)%p;}
    return c;
}
```

4 Структуры данных

4.1 Дерево Фенвика

```
int fe[maxn]; /// fenwick tree
void pl(int pos,int val) {while(pos<maxn) {fe[pos]+=val;pos|=(pos+1);}}
int get(int pos) {int ans=0;while(pos>=0) {ans+=fe[pos];pos&=(pos+1);--pos;} return ans;} /// [0, pos] - vkluchitelno!!!
int get(int l,int r) {return get(r-1)-get(l-1);} /// summa na [l,r)
```

4.2 Ordered set

```
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>

using namespace __gnu_pbds;
using namespace std;

using ordered_set = tree<int, null_type, less<>, rb_tree_tag, tree_order_statistics_node_update>;
```

4.3 Дерево отрезков

```
template<typename Data, typename Mod, typename UniteData, typename UniteMod, typename Apply>
struct MassSegmentTree {
    int h, n;
    Data zd;
    Mod zm;
    vector<Data> data;
    vector<Mod> mod;

    UniteData ud; // Data (Data, Data)
    UniteMod um; // Mod (Mod, Mod);
    Apply a; // Data (Data, Mod, int); last argument is the length of current segment (could be used for range += and sum counting, for instance)

    template<typename I>
    MassSegmentTree(int sz, Data zd, Mod zm, UniteData ud, UniteMod um, Apply a, I init) : h(__lg(sz > 1 ? sz - 1 : 1) + 1), n(1 << h), zm(zm), zd(zd), data(2 * n, zd), mod(n, zm), ud(ud), um(um), a(a) {
        for (int i = 0; i < sz; ++i) data[i + n] = init(i);
        for (int i = n - 1; i > 0; --i) data[i] = ud(data[2 * i], data[2 * i + 1]);
    }

    MassSegmentTree(int sz, Data zd, Mod zm, UniteData ud, UniteMod um, Apply a) : h(__lg(sz > 1 ? sz - 1 : 1) + 1), n(1 << h), zm(zm), zd(zd), data(2 * n, zd), mod(n, zm), ud(ud), um(um), a(a) {}

    void push(int i) {
        if (mod[i] == zm) return;
        apply(2 * i, mod[i]);
        apply(2 * i + 1, mod[i]);
        mod[i] = zm;
    }

    // is used only for apply
    int length(int i) { return 1 << (h - __lg(i)); }

    // is used only for descent
    int left(int i) {
        int lvl = __lg(i);
        return (i & ((1 << lvl) - 1)) * (1 << (h - lvl));
    }

    // is used only for descent
    int right(int i) {
        int lvl = __lg(i);
        return ((i & ((1 << lvl) - 1)) + 1) * (1 << (h - lvl));
    }

    template<typename S>
    void apply(int i, S x) {
        data[i] = a(data[i], x, length(i));
        if (i < n) mod[i] = um(mod[i], x);
    }

    void update(int i) {
        if (mod[i] != zm) return;
        data[i] = ud(data[2 * i], data[2 * i + 1]);
    }

    template<typename S>
    void update(int l, int r, S x) { // [l; r)
        l += n, r += n;
        for (int shift = h; shift > 0; --shift) {
            push(l >> shift);
            push((r - 1) >> shift);
        }
        for (int lf = l, rg = r; lf < rg; lf /= 2, rg /= 2) {
            if (lf & 1) apply(lf++, x);
            if (rg & 1) apply(--rg, x);
        }
        for (int shift = 1; shift <= h; ++shift) {
            update(l >> shift);
            update((r - 1) >> shift);
        }
    }

    Data get(int l, int r) { // [l; r)
        l += n, r += n;
        for (int shift = h; shift > 0; --shift) {
            push(l >> shift);
            push((r - 1) >> shift);
        }
        Data leftRes = zd, rightRes = zd;
        for (; l < r; l /= 2, r /= 2) {
            if (l & 1) leftRes = ud(leftRes, data[l++]);
            if (r & 1) rightRes = ud(data[--r], rightRes);
        }
        return ud(leftRes, rightRes);
    }

    // l \in [0; n) && ok(get(l, l), l);
    // returns last r: ok(get(l, r), r)
    template<typename C>
    int lastTrue(int l, C ok) {
        l += n;
        for (int shift = h; shift > 0; --shift) push(l >> shift);
        Data cur = zd;
        do {
            l >>= __builtin_ctz(l);
            Data with1;
            with1 = ud(cur, data[l]);
            if (ok(with1, right(l))) {
                cur = with1;
                ++l;
            } else {
                while (l < n) {
                    push(l);
                    Data with2;
                    with2 = ud(cur, data[2 * l]);
                    if (ok(with2, right(2 * l))) {
                        cur = with2;
                        l = 2 * l + 1;
                    } else {
                        l = 2 * l;
                    }
                }
                return l - n;
            }
        } while (l & (l - 1));
        return n;
    }

    // r \in [0; n) && ok(get(r, r), r);
    // returns first l: ok(get(l, r), l)
    template<typename C>
    int firstTrue(int r, C ok) {
        r += n;
        for (int shift = h; shift > 0; --shift) push((r - 1) >> shift);
        Data cur = zd;
        while (r & (r - 1)) {
            r >>= __builtin_ctz(r);
            Data with1;
            with1 = ud(data[--r], cur);
            if (ok(with1, left(r))) {
                cur = with1;
            } else {
                while (r < n) {
                    push(r);
                    Data with2;
                    with2 = ud(data[2 * r + 1], cur);
                    if (ok(with2, right(2 * r))) {
```

```
                        cur = with2;
                        r = 2 * r;
                    } else {
                        r = 2 * r + 1;
                    }
                }
                return r - n + 1;
            }
        }
        return 0;
    }
};
```

4.3.1 Примеры:

- Взятие максимума и прибавление константы

```
MassSegmentTree segtree(n, 0LL, 0LL,
[](int x, int y) { return max(x, y); },
[](int x, int y) { return x + y; },
[](int x, int y, int len) { return x + y; });
```

- Взятие суммы и прибавление константы

```
MassSegmentTree segtree(n, 0LL, 0LL,
[](int x, int y) { return x + y; },
[](int x, int y) { return x + y; },
[](int x, int y, int len) { return x + y * len;
    });
```

- Взятие суммы и присовение

```
MassSegmentTree segtree(n, 0LL, -1LL,
[](int x, int y) { return x + y; },
[](int x, int y) { return y; },
[](int x, int y, int len) { return y * len; });
```

5 Строковые алгоритмы

5.1 Префикс-функция

```
vector<int> prefix_function(string s) {
    vector<int> p(s.size());
    for (int i = 1; i < s.size(); ++i) {
        p[i] = p[i - 1];
        while (p[i] && s[p[i]] != s[i]) p[i] = p[p[
    i] - 1];
        p[i] += s[i] == s[p[i]];
    }
    return p;
}
```

5.2 Z-функция

```
vector<int> z_function (string s) { // z[i] - lcp
    of s and s[i:]
 int n = (int) s.length();
 vector<int> z (n);
 for (int i=1, l=0, r=0; i<n; ++i) {
  if (i <= r)
   z[i] = min (r-i+1, z[i-l]);
  while (i+z[i] < n && s[z[i]] == s[i+z[i]])
   ++z[i];
  if (i+z[i]-1 > r)
   l = i,  r = i+z[i]-1;
 }
 return z;
}
```

5.3 Алгоритм Манакера

```
vector<int> manacher_odd(const string &s) {
    vector<int> man(s.size(), 0);
    int l = 0, r = 0;
    int n = s.size();
    for (int i = 1; i < n; i++) {
        if (i <= r) {
            man[i] = min(r - i, man[l + r - i]);
        }
        while (i + man[i] + 1 < n && i - man[i] - 1
     >= 0 && s[i + man[i] + 1] == s[i - man[i] -
    1]) {
            man[i]++;
        }
        if (i + man[i] > r) {
            l = i - man[i];
            r = i + man[i];
        }
    }
    return man;
}
// abacaba : (0 1 0 3 0 1 0)
// abbaa : (0 0 0 0 0)

vector <int> manacher_even(const string &s) {
    assert(s.size());
    string t;
    for (int i = 0; i + 1 < s.size(); ++i) {
        t += s[i];
        t += '#';
    }
    t += s.back();
    auto odd = manacher_odd(t);
    vector <int> ans;
    for (int i = 1; i < odd.size(); i += 2) {
        ans.push_back((odd[i]+1)/2);
    }
    return ans;
}
// abacaba : (0 0 0 0 0 0)
// abbaa : (0 2 0 1)
```

5.4 Суфмассив

```
struct SuffixArray {
    vector <int> sa, lcp;
    SuffixArray (string &s, int lim=256) {
        int n = (int)s.size() + 1, k = 0, a, b;
        vector <int> x(s.begin(), s.end() + 1), y(n
    ), ws(max(n, lim)), rank(n);
        sa = lcp = y, iota(sa.begin(), sa.end(), 0)
    ;
        for (int j = 0, p = 0; p < n; j = max(1ll,
    j * 2), lim = p) {
            p = j, iota(y.begin(), y.end(), n - j);
            for (int i = 0; i < n; i++) if (sa[i]
    >= j) y[p++] = sa[i] - j;
            fill(ws.begin(), ws.end(), 0);
            for (int i = 0; i < n; i++) ws[x[i]]++;
            for (int i = 1; i < lim; i++) ws[i] +=
    ws[i - 1];
            for (int i = n; i--; ) sa[--ws[x[y[i
    ]]]] = y[i];
            swap(x, y), p = 1, x[sa[0]] = 0;
            for (int i = 1; i < n; i++) a = sa[i -
    1], b = sa[i], x[b] = (y[a] == y[b] && y[a + j]
     == y[b + j]) ? p - 1 : p++;
        }
        for (int i = 1; i < n; i++) rank[sa[i]] = i
    ;
        for (int i = 0, j; i < n - 1; lcp[rank[i
    ++]]=k)
        for (k && k--, j = sa[rank[i] - 1];
        s[i + k] == s[j + k]; k++);
    }
};
struct Rmq {
    const int INF = 1e9;
    vi rmq;
    int sz;
    Rmq(){}
    void build(int n) {
        sz = 1;
        while (sz < n) sz *= 2;
        rmq.assign(sz * 2, INF);
    }
```

```
33      Rmq(int n) {
34          sz = 1;
35          while (sz < n) sz *= 2;
36          rmq.assign(sz * 2, INF);
37      }
38      void put(int i, int x) {
39          i += sz;
40          ckmin(rmq[i], x);
41          for (i/= 2; i; i/= 2) {
42              rmq[i] = min(rmq[i * 2], rmq[i * 2 +
    1]);
43          }
44      }
45      int getMin(int l, int r) { //[l;r)
46      assert(l < r);
47      r--;
48      l += sz;
49      r += sz;
50      int res = INF;
51      while(l < r) {
52          if (l%2 == 1) res = min(res, rmq[l]);
53          if (r%2 == 0) res = min(res, rmq[r]);
54          l = (l + 1)/2;
55          r = (r - 1) /2;
56      }
57      if (l == r) res = min(res, rmq[l]);
58      return res;
59      }
60  };
61
62  struct Lc {
63      vi pos;
64      Rmq rmq;
65      void build(string s) {
66          SuffixArray sa(s);
67          auto ss = sa.sa;
68          ss.erase(ss.begin());
69
70          auto lcp = sa.lcp;
71          lcp.erase(lcp.begin());
72          lcp.erase(lcp.begin());
73
74          pos.resize(s.size());
75          assert(s.size() == ss.size());
76          FOR (i, ss.size()) {
77              pos[ss[i]] = i;
78          }
79          int n = s.size();
80          assert(lcp.size() == n - 1);
81          rmq.build(n - 1);
82          FOR (i, n - 1) {
83              rmq.put(i, lcp[i]);
84          }
85      }
86      int getLcp(int i, int j) {
87          i = pos[i]; j = pos[j];
88          if (j < i) {
89              swap(i, j);
90          }
91          if (i == j) {
92              return 1e18;
93          }
94          else {
95              return rmq.getMin(i, j);
96          }
97      }
98  };
```