Содержание

1 Теория чисел

1.1 KTO

```cpp
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,y,x);
  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

```cpp
__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;
}
```

1.3 Алгоритм Берлекэмпа — Месси

https://mzhang2021.github.io/cp-blog/berlekamp-massey/

```cpp
template<typename T>
vector<T> berlekampMassey(const vector<T> &s) {
  int n = s.size(), l = 0, m = 1;
  vector<T> b(n), c(n);
  T ld = b[0] = c[0] = 1;
  for (int i=0; i<n; i++, m++) {
    T d = s[i];
    for (int j=1; j<=l; j++)
      d += c[j] * s[i-j];
    if (d == 0) continue;
    vector<T> temp = c;
    T coef = d / ld;
    for (int j=m; j<n; j++) c[j] -= coef * b[j-m];
    if (2 * l <= i) {
      l = i + 1 - l;
      b = temp;
      ld = d;
      m = 0;
    }
  }
  c.resize(l + 1);
  c.erase(c.begin());
  for (T &x : c)
    x = -x;
  return c;
}
```

2 Графы

2.1 SCC и 2-SAT

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

В случае 2-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 {};
```

2.3 Компоненты рёберной двусвязности

```
int n, m;
cin >> n >> m;
vector <vector <int> > g(n + 1);
map <pair <int, int>, int> comp, col;
for (int i = 0; i < m; ++i) {
  int u, v, c; cin >> u >> v >> c;c--;
  col[{u,v}]=col[{v,u}]=c;
  g[u].push_back(v);
  g[v].push_back(u);
}
vector <int> used(n + 1);
vector <int> newCompWithoutParent(n + 1), h(n + 1),
     up(n + 1);
auto findCutPoints = [&] (auto self, int u, int p)
    -> void {
  used[u] = 1;
  up[u] = h[u];
  for (int v : g[u]) {
    if (!used[v]) {
      h[v] = h[u] + 1;
      self(self, v, u);
      up[u] = min(up[u], up[v]);
      if (up[v] >= h[u]) {
        newCompWithoutParent[v] = 1;
      }
    }
    else {
      up[u] = min(up[u], h[v]);
    }
  }
};
for (int u = 1; u <= n; ++u) {
  if (!used[u]) {
    findCutPoints(findCutPoints, u, u);
  }
}
int ptr = 0;
vector <map <int, int> > colors(m);
auto markComponents = [&] (auto self, int u, int
    cur) -> void {
  used[u] = 1;
  for (int v : g[u]) {
    if (!used[v]) {
      if (newCompWithoutParent[v]) {
        ptr++;
        self(self, v, ptr - 1);
      }
      else {
        self(self, v, cur);
      }
    }
    else if (h[v] < h[u]) {
      comp[{u,v}]=comp[{v,u}]=cur;
      int c = col[{u,v}];
      colors[cur][u] |= 1 << c;
      colors[cur][v] |= 1 << c;
    }
  }
};
used.assign(n + 1, 0);
for (int u = 1; u <= n; ++u) {
  if (!used[u]) {
    markComponents(markComponents, u, -1);
  }
}
for (int comp = 0; comp < m; ++comp) {
  vector <int> cnt(4);
```

```
  int tot = 0;
  for (auto [u, mask] : colors[comp]) {
    tot |= mask;
    cnt[bp(mask)]++;
  }
  if (bp(tot)<3) {
    continue;
  }
  if (cnt[2] || cnt[3]>2) {
    cout << "Yes" << endl;
    return;
  }
}
cout << "No" << endl;
```

3 xor, and, or-свёртки

```
const int p = 998244353;
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;
}
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;
}
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 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;
  }
};
```

4.2.1 Примеры использования

- 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; });
```

4.3 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
    >;
```

4.4 Convex hull trick

```
ll div_up(ll a, ll b) { return a/b+((a^b)>0&&a%b);
    } // divide a by b rounded up

struct Line {
    ll k, b;

    Line() : k(), b() {}
    Line (ll _k, ll _b) : k(_k), b(_b) {}

    ll getVal(ll x) {
        return k * x + b;
    }
};
struct Hull {
    vector<Line> lines;
    vector<ll> borders;

```

```
    Hull() : lines(), borders() {}

    void addLine(Line L) {
        while(!lines.empty()) {
            if (lines.back().getVal(borders.back())
     >= L.getVal(borders.back())) {
                lines.pop_back();
                borders.pop_back();
            } else break;
        }
        if (lines.empty()) {
            lines.push_back(L);
            borders.push_back(0LL); //leftmost
    query
            return;
        }
        if (lines.back().k <= L.k) return;
        ll x = div_up(L.b - lines.back().b, lines.
    back().k - L.k); //must work for negative!
        lines.push_back(L);
        borders.push_back(x);
    }
    ll getMinVal(ll x) {
        int pos = upper_bound(borders.begin(),
    borders.end(), x) - borders.begin();
        if (pos == 0) throw;
        pos--;
        return lines[pos].getVal(x);
    }
};
```

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

Переработанный китайский суффмассив

```
const int inf = 1e9;
struct rmq {
  int n;
  vector<int> a;
  void build(const vector<int> &x) {
    assert(x.size() == n);
    for (int i = 0; i < n; ++i) a[n + i] = x[i];
    for (int i = n - 1; i > 0; --i) a[i] = min(a[2
    * i], a[2 * i + 1]);
  }
  rmq(int n) : n(n), a(2 * n, inf) {}
  void put(int i, int x) {
    a[i + n] = min(a[i + n], x);
    for (i = (i + n) / 2; i > 0; i /= 2) {
      a[i] = min(a[i * 2], a[i * 2 + 1]);
    }
  }
  int getMin(int l, int r) { //[l;r)
    assert(l < r);
    int res = inf;
    for (l += n, r += n; l < r; l /= 2, r /= 2) {
      if (l & 1) res = min(res, a[l++]);
      if (r & 1) res = min(res, a[--r]);
    }
    return res;
  }
};
template <typename T>
struct suar {
    vector <int> sa, lcp, rank; rmq t;
    suar (T s, int lim=256) : t((int)s.size() - 1)
    { // s must be nonempty, 0 < s[i] < lim!
        int n = (int)s.size() + 1, k = 0, a, b; s.
    app(0);
        vector <int> x(s.begin(), s.end()), y(n),
    ws(max(n, lim));rank.resize(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++);
        sa.erase(sa.begin()); lcp.erase(lcp.begin()); lcp.erase(lcp.begin());
        t.build(lcp);
        for (auto &e : rank) {
            e--;
        }
    }
    int getLcp(int i, int j) {
        i = rank[i]; j = rank[j];
        if (j < i) {
          swap(i, j);
        }
        if (i == j) {
          return inf;
        }
        else {
          return t.getMin(i, j);
        }
    }
};
```

5.5 Алгоритм Ахо — Корасик

```
struct node{
  int next[alpha] = {}, link[alpha] = {};
  int suf = 0;
  ll visited = 0, ans = 0;
  vector<int> term;
  node() {}
};

vector<node> mem;

int get_next(int nd, char c) {
  if (!mem[nd].next[c - a]) { mem[nd].next[c - a] = mem.size(); mem.emplace_back(); }
  return mem[nd].next[c - a];
}

void find(string s, vector<string> t) {
  mem.reserve(1e6 + 100);mem.clear();
  mem.emplace_back();mem.emplace_back();
  // 0th element is nullptr, 1st is the root
  int q = t.size();
  for (int j = 0; j < q; ++j) {
    int cur = 1;
    for (char c : ts[j]) cur = get_next(cur, c);
    mem[cur].term.push_back(j);
  }
  vector<int> bfs_order;
  queue<int> bfs;
  {
      node &root = mem[1];
      root.suf = 1;
      for (char c = a; c < a + alpha; ++c) {
          root.link[c - a] = (root.next[c - a] ? root.next[c - a] : 1);
      }
      bfs.push(1);
  }
  while (!bfs.empty()) {
    int cur_idx = bfs.front();
    bfs.pop();
    node &cur = mem[cur_idx];
    bfs_order.push_back(cur_idx);
    for (char c = a; c < a + alpha; ++c) {
      int nxt_idx = cur.next[c - a];
      if (!nxt_idx) continue;
      node &nxt = mem[nxt_idx];
      nxt.suf = (cur_idx == 1 ? 1 : mem[cur.suf].link[c - a]);
      for (char c = a; c < a + alpha; ++c) {
        nxt.link[c - a] = (nxt.next[c - a] ? nxt.next[c - a] : mem[nxt.suf].link[c - a]);
      }
      bfs.push(nxt_idx);
    }
  }
  // do something
}
```

5.6 Дерево палиндромов

```
struct palindromic{
  int n;
  vector<int> p, suf{0, 0}, len{-1, 0};
  vector<array<int, alpha>> to{{}, {}};
  int sz = 2;

  palindromic(const string &s) : n(s.size()), p(n + 1, 1) {
    suf.reserve(n);
    len.reserve(n);
    for (int i = 0; i < n; ++i) {
      auto check = [&](int l) { return i > l && s[i] == s[i - l - 1]; };
      int par = p[i];
      while (!check(len[par])) par = suf[par];
      if (to[par][s[i] - a]) {
        p[i + 1] = to[par][s[i] - a];
        continue;
      }
      p[i + 1] = sz++;
      to[par][s[i] - a] = p[i + 1];
      to.emplace_back();
      len.emplace_back(len[par] + 2);
      do {
        par = suf[par];
      } while (!check(len[par]));
      int link = to[par][s[i] - a];
      if (link == p[i + 1]) link = 1;
      suf.emplace_back(link);
    }
  }
};
```

6 Потоки

6.1 Алгоритм Диница

```
#define pb push_back
struct Dinic{
struct edge{
  int to, flow, cap;
};

const static int N = 555; //count of vertices

vector<edge> e;
vector<int> g[N + 7];
int dp[N + 7];
int ptr[N + 7];

void clear(){
  for (int i = 0; i < N + 7; i++) g[i].clear();
  e.clear();
}

void addEdge(int a, int b, int cap){
  g[a].pb(e.size());
  e.pb({b, 0, cap});
  g[b].pb(e.size());
  e.pb({a, 0, 0});
}

int minFlow, start, finish;

bool bfs(){
```

```
  for (int i = 0; i < N; i++) dp[i] = -1;
  dp[start] = 0;
  vector<int> st;
  int uk = 0;
  st.pb(start);
  while(uk < st.size()){
    int v = st[uk++];
    for (int to : g[v]){
      auto ed = e[to];
      if (ed.cap - ed.flow >= minFlow && dp[ed.to] == -1){
        dp[ed.to] = dp[v] + 1;
        st.pb(ed.to);
      }
    }
  }
  return dp[finish] != -1;
}

int dfs(int v, int flow){
  if (v == finish) return flow;
  for (; ptr[v] < g[v].size(); ptr[v]++){
    int to = g[v][ptr[v]];
    edge ed = e[to];
    if (ed.cap - ed.flow >= minFlow && dp[ed.to] == dp[v] + 1){
      int add = dfs(ed.to, min(flow, ed.cap - ed.flow));
      if (add){
        e[to].flow += add;
        e[to ^ 1].flow -= add;
        return add;
      }
    }
  }
  return 0;
}

int dinic(int start, int finish){
  Dinic::start = start;
  Dinic::finish = finish;
  int flow = 0;
  for (minFlow = (1 << 30); minFlow; minFlow >>= 1){
    while(bfs()){
      for (int i = 0; i < N; i++) ptr[i] = 0;
      while(int now = dfs(start, (int)2e9 + 7))
    flow += now;
    }
  }
  return flow;
}
} dinic;
```

6.2 Mincost k-flow

6.2.1 Строим граф

```
struct edge {
  int next, capacity, cost, flow = 0;

  edge() = default;

  edge(int next, int capacity, int cost) : next(next), capacity(capacity), cost(cost) {}

  int rem() const { return capacity - flow; }

  int operator+=(int f) { return flow += f; }

  int operator-=(int f) { return flow -= f; }
};
auto addEdge = [&](auto from, auto next, auto capacity, int cost) {
  g[from].push_back(e.size());
  e.emplace_back(next, capacity, cost);
  g[next].push_back(e.size());
  e.emplace_back(from, 0, -cost);
};
```

Если граф ориентированный, то addEdge вызываем один раз. Если неориентированный, то два, вот так:

```
addEdge(u, v, capacity, cost);
addEdge(v, u, capacity, cost);
```

6.2.2 Запускаем Форда — Беллмана

```
vector<ll> phi(n, 0);
auto fordBellman = [&](int s, int t) {
  phi.assign(n, 0);
  for (int iter = 0; iter < n; ++iter) {
    bool changed = false;
    for (int u = 0; u < n; ++u) {
      for (auto index : g[u]) {
        auto edge = e[index];
        if (edge.rem() > 0 && phi[edge.next] > phi[u] + edge.cost) {
          phi[edge.next] = phi[u] + edge.cost;
          changed = true;
        }
      }
    }
    if (!changed) break;
  }
};
fordBellman(s, t);
```

6.2.3 Ищем кратчайший путь Дейкстрой с потенциалами

```
vector<ll> dist;
vector<int> from;
vector<bool> cnt;
auto dijkstra = [&](int s, int t) {
  dist.assign(n, 1e18);
  from.assign(n, -1);
  cnt.assign(n, false);
  dist[s] = 0;
  set <pair <int, int> > se;
  se.insert({0, s});
  while ((int)(se.size())) {
    int cur = se.begin()->y;
    se.erase(se.begin());
    cnt[cur] = true;
    for (int index : g[cur]) {
      auto &edge = e[index];
      if (edge.rem() == 0) continue;
      ll weight = edge.cost + phi[cur] - phi[edge.next];
      if (dist[edge.next] > dist[cur] + weight) {
        se.erase({dist[edge.next], edge.next});
        dist[edge.next] = dist[cur] + weight;
        se.insert({dist[edge.next], edge.next});
        from[edge.next] = cur;
      }
    }
  }
  if (dist[t] == (ll) 1e18) return -1LL;
  ll cost = 0;
  for (int p = t; p != s; p = from[p]) {
    for (auto index : g[from[p]]) {
      auto &edge = e[index];
      ll weight = edge.cost + phi[from[p]] - phi[edge.next];
      if (edge.rem() > 0 && edge.next == p && dist[edge.next] == dist[from[p]] + weight) {
        edge += 1;
        e[index ^ 1] -= 1;
        cost += edge.cost;
        break;
      }
    }
  }
  for (int i = 0; i < n; ++i) {
    phi[i] += dist[i];
  }
  return cost;
};
ll cost = 0;
```

```
for (int flow = 0; flow < k; ++flow) {
  ll a = dijkstra(s, t);
  if (a == -1) {
    cout << "-1\n";
    return;
  }
  cost += a;
}
```

6.2.4 Восстанавливаем ответ

```
auto findPath = [&](int s, int t) {
  vector<int> ans;
  int cur = s;
  while (cur != t) {
    for (auto index : g[cur]) {
      auto &edge = e[index];
      if (edge.flow <= 0) continue;
      edge -= 1;
      e[index ^ 1] += 1;
      ans.push_back(index / 4);
// index / 4 because each edge has 4 copies
      cur = edge.next;
      break;
    }
  }
  return ans;
};
for (int flow = 0; flow < k; ++flow) {
  auto p = findPath(s, t);
  cout << p.size() << ' ';
  for (int x : p) cout << x + 1 << ' ';
  cout << '\n';
}
```

7 FFT & co

7.1 NTT & co

```
#define int long long
using namespace std;
typedef long long ll;
const int p=998244353;
int po(int a,int b) {if(b==0) return 1; if(b==1) return a; if(b%2==0) {int u=po(a,b/2);return (u*1LL*u)%p;} else {int u=po(a,b-1);return (a*1LL*u)%p;}}
int inv(int x) {return po(x,p-2);}
template<int M, int K, int G> struct Fft {
  // 1, 1/4, 1/8, 3/8, 1/16, 5/16, 3/16, 7/16, ...
  int g[1 << (K - 1)];
  Fft() : g() { //if tl constexpr...
    static_assert(K >= 2, "Fft: K >= 2 must hold");
    g[0] = 1;
    g[1 << (K - 2)] = G;
    for (int l = 1 << (K - 2); l >= 2; l >>= 1) {
      g[l >> 1] = (g[l] * 1LL* g[l]) % M;
    }
    assert((g[1]*1LL * g[1]) % M == M - 1);
    for (int l = 2; l <= 1 << (K - 2); l <<= 1) {
      for (int i = 1; i < l; ++i) {
        g[l + i] = (g[l] * 1LL * g[i]) % M;
      }
    }
  }
  void fft(vector<int> &x) const {
    const int n = x.size();
    assert(n <= 1 << K);
    for (int h = __builtin_ctz(n); h--; ) {
      const int l = (1 << h);
      for (int i = 0; i < n >> (h+1); ++i) {
        for (int j = i << (h+1); j < (((i << 1) + 1) << h); ++j) {
          const int t = (g[i] * 1LL* x[j | l]) % M;
          x[j | l] = x[j] - t;
          if (x[j|l] < 0) x[j | l] += M;
          x[j]+=t;
          if (x[j] >= M) x[j] -= M;
        }
      }
    }
    for (int i = 0, j = 0; i < n; ++i) {
      if (i < j) std::swap(x[i], x[j]);
      for (int l = n; (l >>= 1) && !((j ^= l) & l); ) {}
    }
  }
  vector<int> convolution(const vector<int> &a, const vector<int> &b) const {
    if(a.empty() || b.empty()) return {};
    const int na = a.size(), nb = b.size();
    int n, invN = 1;
    for (n = 1; n < na + nb - 1; n <<= 1) invN = ((invN & 1) ? (invN + M) : invN) >> 1;
    vector<int> x(n, 0), y(n, 0);
    std::copy(a.begin(), a.end(), x.begin());
    std::copy(b.begin(), b.end(), y.begin());
    fft(x);
    fft(y);
    for (int i = 0; i < n; ++i) x[i] = (((static_cast<long long>(x[i]) * y[i]) % M) * invN) % M;
    std::reverse(x.begin() + 1, x.end());
    fft(x);
    x.resize(na + nb - 1);
    return x;
  }
};
Fft<998244353,23,31> muls;
vector<int> form(vector<int> v,int n)
{
  while(v.size()<n) v.push_back(0);
  while(v.size()>n) v.pop_back();
  return v;
}
vector<int> operator *(vector<int> v1,vector<int> v2)
{
  return muls.convolution(v1,v2);
}
vector<int> operator +(vector<int> v1,vector<int> v2)
{
  while(v2.size()<v1.size()) v2.push_back(0); while(v1.size()<v2.size()) v1.push_back(0);
  for(int i=0;i<v1.size();++i) {v1[i]+=v2[i];if(v1[i]>=p) v1[i]-=p; else if(v1[i]<0) v1[i]+=p;}
  return v1;
}
vector<int> operator -(vector<int> v1,vector<int> v2)
{
  int sz=max(v1.size(),v2.size());while(v1.size()<sz) v1.push_back(0); while(v2.size()<sz) v2.push_back(0);
  for(int i=0;i<sz;++i) {v1[i]-=v2[i];if(v1[i]<0) v1[i]+=p; else if(v1[i]>=p) v1[i]-=p;} return v1;
}
vector<int> trmi(vector<int> v)
{
  for(int i=1;i<v.size();i+=2) {if(v[i]>0) v[i]=p-v[i]; else v[i]=(-v[i]);}
  return v;
}
vector<int> deriv(vector<int> v)
{
  if(v.empty()) return{};
  vector<int> ans(v.size()-1);
  for(int i=1;i<v.size();++i) ans[i-1]=(v[i]*1LL*i)%p;
  return ans;
}
vector<int> integ(vector<int> v)
{
  vector<int> ans(v.size()+1);ans[0]=0;
  for(int i=1;i<v.size();++i) ans[i-1]=(v[i]*1LL*i)%p;
```

```
  return ans;
}
vector<int> mul(vector<vector<int> > v)
{
  if(v.size()==1) return v[0];
  vector<vector<int> > v1,v2;for(int i=0;i<v.size()/2;++i) v1.push_back(v[i]); for(int i=v.size()/2;i<v.size();++i) v2.push_back(v[i]);
  return muls.convolution(mul(v1),mul(v2));
}
vector<int> inv1(vector<int> v,int n)
{
  assert(v[0]!=0);
  int sz=1;v=form(v,n);vector<int> a={inv(v[0])};
  while(sz<n)
  {
    vector<int> vsz;for(int i=0;i<min(n,2*sz);++i) vsz.push_back(v[i]);
    vector<int> b=((vector<int>) {1})-muls.convolution(a,vsz);
    for(int i=0;i<sz;++i) assert(b[i]==0);
    b.erase(b.begin(),b.begin()+sz);
    vector<int> c=muls.convolution(b,a);
    for(int i=0;i<sz;++i) a.push_back(c[i]);
    sz*=2;
  }
  return form(a,n);
}
```

7.2 старое доброе FFT

```
using cd = complex<double>;
const double PI = acos(-1);

void fft(vector<cd> & a, bool invert) {
  int n = a.size();

  for (int i = 1, j = 0; i < n; i++) {
    int bit = n >> 1;
    for (; j & bit; bit >>= 1)
      j ^= bit;
    j ^= bit;

    if (i < j)
      swap(a[i], a[j]);
  }

  for (int len = 2; len <= n; len <<= 1) {
    double ang = 2 * PI / len * (invert ? -1 : 1);
    cd wlen(cos(ang), sin(ang));
    for (int i = 0; i < n; i += len) {
      cd w(1);
      for (int j = 0; j < len / 2; j++) {
        cd u = a[i+j], v = a[i+j+len/2] * w;
        a[i+j] = u + v;
        a[i+j+len/2] = u - v;
        w *= wlen;
      }
    }
  }

  if (invert) {
    for (cd & x : a)
      x /= n;
  }
}
vector<int> multiply(vector<int> const& a, vector<int> const& b) {
  vector<cd> fa(a.begin(), a.end()), fb(b.begin(), b.end());
  int n = 1;
  while (n < a.size() + b.size())
    n <<= 1;
  fa.resize(n);
  fb.resize(n);

  fft(fa, false);
  fft(fb, false);
  for (int i = 0; i < n; i++)
    fa[i] *= fb[i];
  fft(fa, true);

  vector<int> result(n);
  for (int i = 0; i < n; i++)
    result[i] = round(fa[i].real());
  while(!result.empty() && !result.back()) result.pop_back();
  return result;
}
```

8 Геома

8.1 Касательные

```
    auto max = [&] (auto cmp) {
        int k = 0;
        for (int lg = 18; lg >= 0; --lg) {
            int i = k + (1 << lg), j = k - (1 << lg);
            i = (i % n + n) % n;
            j = (j % n + n) % n;
            array<int, 3> ind{i, j, k};
            sort(all(ind), cmp);
            k = ind[2];
        }
        return k;
    };
    auto uppert = [&](Point p) { //last vertex in counterclockwise order about p
        auto cmp = [&] (int i, int j) {return (a[i] - p) < (a[j] - p); };
        return max(cmp);
    };
    auto lowert = [&](Point p) { //first vertex in counterclockwise order about p
        auto cmp = [&] (int i, int j) {return (a[i] - p) > (a[j] - p); };
        return max(cmp);
    };
    auto uppertinf = [&](Point p) { //upper tangent line parallel to vector p
        swap(p.x, p.y);
        p.x = -p.x;
        auto cmp = [&] (int i, int j) { return a[i] % p < a[j] % p; };
        return max(cmp);
    };
    auto lowertinf = [&](Point p) { //lower tangent line parallel to vector p
        swap(p.x, p.y);
        p.x = -p.x;
        auto cmp = [&] (int i, int j) { return a[i] % p > a[j] % p; };
        return max(cmp);
    };
```

8.2 Примитивы

```
struct Point {
    int x, y;
    Point(){}
    Point (int x_, int y_) {
        x = x_; y = y_;
    }
    Point operator + (Point p) {
        return Point(x+p.x,y+p.y);
    }
    Point operator - (Point p) {
        return Point(x - p.x, y - p.y);
    }
    int operator * (Point p) {
        return x * p.y - y * p.x;
    }
    int operator % (Point p) {
        return x * p.x + y * p.y;
    }
    bool operator < (Point v) {
        return (*this) * v > 0;
```

```
    }
    bool operator > (Point v) {
        return v < (*this);
    };
    bool operator <= (Point v) {
        return (*this) * v >= 0;
    }
};
bool line(Point a, Point b, Point c) {
    return (b-a)*(c-b)==0;
}
bool ord(Point a, Point p, Point b) {
    return (p - a)%(p - b)<0;
}
```

8.3 Точка нестрого внутри выпуклости

```
    auto inT = [&] (Point a, Point b, Point c,
    Point p) {
        a = a-p; b = b-p; c = c-p;
        return abs(a*b)+abs(b*c)+abs(c*a) == abs(a*
    b+b*c+c*a);
    };
    auto inP = [&] (Point p) { //a must be in
    counterclockwise order!
        int l = 1, r = n - 1;
        while (l < r - 1) {
            int m = (l + r) / 2;
            if ((a[m] - a[0]) < (p - a[0])) {
                l = m;
            }
            else {
                r = m;
            }
        }
        return inT(a[l], a[0], a[r], p);
    };
```

9 Разное

9.1 Флаги компияции

```
-DLOCAL -Wall -Wextra -pedantic -Wshadow -Wformat=2
-Wfloat-equal -Wconversion -Wlogical-op -Wshift-overflow=2
-Wduplicated-cond -Wcast-qual -Wcast-align -D_GLIBCXX_DEBUG
-D_GLIBCXX_DEBUG_PEDANTIC -D_FORTIFY_SOURCE=2
-fsanitize=address -fsanitize=undefined -fno-sanitize-recover
-fstack-protector -std=c++2a
```

9.1.1 Сеточка в vim

https://codeforces.com/blog/entry/122540

```
i|<esc>25A   |<esc>
o+<esc>25A---+<esc>
Vky35Pdd
```

9.2 Что сделать на пробном туре

- Убедиться, что работаеют все IDE. Разобраться, как настраивать в них LOCAL.
- В системе ML — это ML или RE?
- Максимальный размер файла
- Можно посмотреть на время работы серверов позапускав Флойда — Варшалла

9.3 Шаблон

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

using namespace std;

#define int long long
#define app push_back
#define all(x) x.begin(), x.end()
#ifdef LOCAL
#define debug(...) [](auto...a){ ((cout << a <<
    ' '), ...) << endl; }(#__VA_ARGS__, ":",
    __VA_ARGS__)
#else
#define debug(...)
#endif

int32_t main() {
    cin.tie(0);ios_base::sync_with_stdio(0);
}
```