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,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

```
__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/

```
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<int> euler(vector<vector<pair<int, int>>> g,
    int src) {  // g[cur][i] = pair{nxt, idx}
  int n = g.size();
  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); // or {cur, nxt}
    }
  };
  dfs(dfs, src);
  reverse(cycle.begin(), cycle.end());
  if (cycle.size() != m) return {}; // check that all
    edges are present in the cycle, fail otherwise
  return cycle;
}
```

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;
```

2.4 DCP offline

```
struct Dsu {
    int n;
    vector<pair<int &, int>> s;
    vector<int> p, sz;
    // other info

    Dsu(int n) : n(n), p(n), sz(n, 1){
        iota(all(p), 0);
    }

    int get(int u) {
        while (u != p[u]) u = p[u];
        return u;
    }

    bool merge(int u, int v) {
        u = get(u), v = get(v);
        if (u == v) return false;
        if (sz[v] < sz[u]) swap(u, v);
        s.app({p[u], p[u]});
        s.app({sz[v], sz[v]});
        // app other info like s.app({comp, comp});
        p[u] = v;
        sz[v] += sz[u];
        return true;
    }

    void rollback(int sz) {
        while (s.size() != sz) {
            s.back().first = s.back().second;
            s.pop_back();
        }
    }
};

struct DcpOffline {
    int n;
    vector<vector<pair<int, int>>> d;

    void addEdgeOnSegment(int l, int r, int a, int b)
    {
        for (l += n, r += n; l < r; l /= 2, r /= 2) {
            if (l & 1) d[l++].app({a, b});
            if (r & 1) d[--r].app({a, b});
        }
    }

    template<typename T>
    void dfs(Dsu &dsu, T act) {
        dfs(1, 0, n, dsu, act);
    }

    template<typename T>
    void dfs(int v, int l, int r, Dsu &dsu, T act) {
        int sz = dsu.s.size();
        for (auto [u, v]: d[v]) {
            dsu.merge(u, v);
        }
        if (l + 1 == r) {
            act(l, dsu);
        } else {
            int m = (l + r) / 2;
            dfs(v * 2, l, m, dsu, act);
            dfs(v * 2 + 1, m, r, dsu, act);
        }
        dsu.rollback(sz);
    }

    DcpOffline(int maxt) : n(2 << __lg(maxt + 1)), d(2
     * n) {}
};
```

2.5 Взвешенное паросочетание

```
// https://judge.yosupo.jp/submission/201334

namespace blossom {
#define d(x) (lab[x.u] + lab[x.v] - 2 * e[x.u][x.v].w)
    const int N = 403 * 2;
    const int inf = 1e18;
    struct Q{ int u, v, w; } e[N][N];
    vector<int> p[N];
    int n, m = 0, id, h, t, lk[N], sl[N], st[N], f[N],
     b[N][N], s[N], ed[N], q[N], lab[N];
    void upd(int u, int v) { if (!sl[v] || d(e[u][v])
    < d(e[sl[v]][v])) sl[v] = u; }
    void ss(int v) {
        sl[v] = 0;
        for (int u = 1; u <= n; ++u) if (e[u][v].w > 0
     && st[u] != v && !s[st[u]]) upd(u, v);
    }
    void ins(int u){ if (u <= n) q[++t] = u; else for
    (int v : p[u]) ins(v); }
    void ch(int u, int w) { st[u] = w; if (u > n) for
    (int v : p[u]) ch(v, w); }
    int gr(int u, int v) {
        if ((v = find(all(p[u]), v) - p[u].begin()) &
    1) {
            reverse(1 + all(p[u]));
            return (int)p[u].size() - v;
        }
        return v;
    }
    void stm(int u, int v) {
        lk[u] = e[u][v].v;
        if (u <= n) return; Q w = e[u][v];
        int x = b[u][w.u], y = gr(u,x);
        for (int i = 0; i < y; ++i) stm(p[u][i], p[u][
    i^1]);
        stm(x, v); rotate(p[u].begin(), y+all(p[u]));
    }
    void aug(int u, int v) {
        int w = st[lk[u]];stm(u, v);if (!w) return;
        stm(w, st[f[w]]);
        aug(st[f[w]], w);
    }
    int lca(int u, int v) {
        for (id++; u|v; swap(u, v)) {
            if (!u) continue;if(ed[u] == id) return u;
            ed[u] = id; if (u = st[lk[u]]) u = st[f[u
    ]]; // =, not ==
        }
        return 0;
    }
    void add(int u, int a, int v) {
        int x = n + 1; while (x <= m && st[x]) ++x;
        if (x > m) ++m;
        lab[x] = s[x] = st[x] = 0;
        lk[x] = lk[a];
        p[x].clear();
        p[x].push_back(a);
#define op(q) for (int i = q, j = 0; i != a; i=st[f[j
    ]]) p[x].push_back(i), p[x].push_back(j=st[lk[i]])
    , ins(j) // also not ==
        op(u); reverse(1+all(p[x]));op(v);
        ch(x, x); for (int i = 1; i <= m; ++i) e[x][i
    ].w = e[i][x].w = 0;
        fill(b[x]+1, b[x]+n+1, 0);
        for (int u : p[x]) {
            for (int v = 1; v <= m; ++v) if (!e[x][v].
    w || d(e[u][v]) < d(e[x][v])) e[x][v] = e[u][v], e
    [v][x] = e[v][u];
            for (int v = 1; v <= n; ++v) if (b[u][v])
    b[x][v] = u;
        }
        ss(x);
    }
    void ex(int u) {
        for (int x : p[u]) ch(x, x);
        int a = b[u][e[u][f[u]].u], r = gr(u, a);
        for (int i = 0; i < r; i += 2) {
            int x = p[u][i], y = p[u][i + 1];
            f[x] = e[y][x].u; s[x] = 1; s[y] = 0; sl[x
    ] = 0; ss(y); ins(y);
        }
        s[a] = 1; f[a] = f[u];
        for (int i = r + 1; i < p[u].size(); ++i) s[p[
```

```
    u][i]] = -1, ss(p[u][i]);
        st[u] = 0;
    }
    bool on(const Q &e) {
        int u = st[e.u], v = st[e.v], a;
        if (s[v] == -1) {
            f[v] = e.u, s[v] = 1, a = st[lk[v]], sl[v]
     = sl[a] = s[a] = 0, ins(a);
        } else if (!s[v]) {
            a = lca(u, v); if (!a) return aug(u, v),
    aug(v, u), 1; else add(u, a, v);
        }
        return 0;
    }
    bool bfs() {
        fill(s+1, s+m+1, -1);fill(sl+1, sl+m+1, 0); //
     s is filled with -1
        h = 1, t = 0; for (int i = 1; i <= m; ++i) if
    (st[i] == i && !lk[i]) f[i] = s[i] = 0, ins(i);
        if (h > t) return 0;
        while (1) {
            while (h <= t) {
                int u = q[h++];
                if (s[st[u]] != 1) {
                    for (int v = 1; v <= n; ++v) if (e
    [u][v].w > 0 && st[u] != st[v]) {
                        if (d(e[u][v])) upd(u, st[v]);
     else if (on(e[u][v])) return 1;
                    }
                }
            }
            int x = inf;
            for (int i = n+1; i <= m; ++i) if (st[i]
    == i && s[i] == 1) x = min(x, lab[i]/2);
            for (int i = 1; i <= m; ++i) if (st[i] ==
    i && sl[i] && s[i] != 1) x = min(x, d(e[sl[i]][i])
    >>s[i]+1);
            for (int i = 1; i <= n; ++i) if (~s[st[i
    ]]) if ((lab[i] += (s[st[i]] * 2 - 1) * x) <=0)
    return 0;
            for (int i = n + 1; i <= m; ++i) if (st[i]
     == i && ~s[st[i]]) lab[i] += (2 - 4 * s[st[i]]) *
     x;
            h = 1, t = 0;
            for (int i = 1; i <= m; ++i) if (st[i] ==
    i && sl[i] && st[sl[i]] != i && !d(e[sl[i]][i]) &&
     on(e[sl[i]][i])) return 1;
            for (int i = n+1; i <= m; ++i) if (st[i]
    == i && s[i] == 1 && !lab[i]) ex(i);
        }
    }

    pair<int, vector<array<int, 2>>> run(int N, vector
    <array<int, 3>> edges) {
        for (auto &[u, v, w] : edges) ++u, ++v;
        fill(ed+1, ed+m+1, 0);
        fill(lk+1, lk+m+1, 0);
        n = m = N;
        id = 0;
        iota(st + 1, st + n + 1, 1);
        int wm = 0, weight = 0;
        for (int i = 1; i <= n; ++i) for (int j = 1; j
     <= n; ++j) e[i][j] = {i,j,0};
        for (auto [u, v, w] : edges) wm = max(wm, e[v
    ][u].w = e[u][v].w = max(e[u][v].w, w));
        for (int i = 1; i <= n; ++i) p[i].clear();
        for (int i = 1; i <= n; ++i) for (int j = 1; j
     <= n; ++j) b[i][j] = i==j?i:0;
        fill_n(lab+1, n, wm); while (bfs());
        vector<array<int, 2>> matching;
        for (int i = 1; i <= n; ++i) if (i < lk[i])
    weight += e[i][lk[i]].w, matching.push_back({i -
    1, lk[i] - 1});
        return {weight, matching};
    }
}
```

3 Свёртки

3.1 AND, OR, XOR 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;
}
```

3.2 NTT & co

```
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*1
    LL*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(vector<int> a, vector<int> b
    ) const {
    if(a.empty() || b.empty()) return {};
    for(int& x:a) {x%=p;if(x>=p) x-=p; if(x<0) x+=p;}
    for(int& x:b) {x%=p;if(x>=p) x-=p; if(x<0) x+=p;}
    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);
}
```

3.3 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;
}
```

4 Структуры данных

4.1 Дерево Фенвика

```
int fe[maxn];
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);} ///
    sum of [l,r)
```

4.2 Дерево отрезков в точке

```
template<typename T, typename U>
struct SegmentTree {
    int n;
    T neutral;
    U unite;
    vector<T> data;

    template<typename I>
    SegmentTree(int n, T neutral, U unite, I init) : n
    (n), neutral(neutral), unite(unite), data(2 * n) {
        for (int i = 0; i < n; ++i) data[i + n] = init
    (i);
        for (int i = n - 1; i > 0; --i) data[i] =
    unite(data[2 * i], data[2 * i + 1]);
    }

    SegmentTree(int n, T neutral, U unite) : n(n),
    neutral(neutral), unite(unite), data(2 * n,
    neutral) {}

    void set(int i, T x) {
        data[i += n] = x;
        for (i /= 2; i > 0; i /= 2) data[i] = unite(
    data[2 * i], data[2 * i + 1]);
    }

    T get(int l, int r) {
        T leftRes = neutral, rightRes = neutral;
        for (l += n, r += n; l < r; l /= 2, r /= 2) {
            if (l & 1) leftRes = unite(leftRes, data[l
    ++]);
            if (r & 1) rightRes = unite(data[--r],
    rightRes);
        }
        return unite(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) {
        T cur = neutral;
        l += n;
        do {
            l >>= __builtin_ctz(l);
            T with1 = unite(cur, data[l]);
            if (ok(with1, right(l))) {
                cur = with1;
                ++l;
            } else {
                while (l < n) {
                    T with2 = unite(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) {
        T cur = neutral;
        r += n;
        while (r & (r - 1)) {
            r >>= __builtin_ctz(r);
            T with1 = unite(data[--r], cur);
            if (ok(with1, left(r))) {
                cur = with1;
            } else {
                while (r < n) {
                    T with2 = unite(data[2 * r + 1],
    cur);
                    if (ok(with2, left(2 * r + 1))) {
                        cur = with2;
                        r = 2 * r;
                    } else {
                        r = 2 * r + 1;
                    }
                }
                return r - n + 1;
            }
        }
        return 0;
    }
};

void example () {
  // max
  SegmentTree segtree(n, -(long long)1e18,  [](int x,
    int y) { return max(x, y); });

  // sum
  SegmentTree ones(n, 0LL,  [](int x, int y) { return
    x + y; });

  auto left_zero = [&](int r) { // nearest zero
    strictly to the left
    return ones.firstTrue(r, [r](int sum, int l){
    return r - l == sum; }) - 1;
  };
  auto right_zero = [&](int l) { // nearest zero
    strictly to the right
    return ones.lastTrue(l + 1, [l](int sum, int r){
    return r - (l + 1) == sum; });
  };
}
```

4.3 Массовое дерево отрезков

```
#ifdef LOCAL
int __lg(int x) { return 63 - __builtin_clzll(x); }
#endif

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;
  }
};
```

```
void example () {
  // max and +=
  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; });

  // sum and +=
  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; });

  // sum and assignment
  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; });
}
```

4.4 Битовый бор

```
template<unsigned int sz,typename T=int>
struct binarytrie{
  using Bit=typename conditional<sz<=32,unsigned int,
    unsigned long long>::type;
  struct node{
    T cnt;
    array<int,2>nxt;
    node():cnt(0),nxt({-1,-1}){}
  };
  vector<node>v;
  binarytrie(){v.emplace_back();}
  void insert(Bit x){add(x,1);}
  void erase(Bit x){add(x,-1);}
  void add(Bit x,T k)
  {
    assert(0<=x&&(x>>sz)==0);
    int p=0;
    v[p].cnt+=k;
    for(int i=sz;i--;)
    {
      int j=x>>i&1;
      if(v[p].nxt[j]==-1)
      {
        v[p].nxt[j]=v.size();
        v.emplace_back();
      }
      p=v[p].nxt[j];
      v[p].cnt+=k;
    }
  }
  T count(Bit x,Bit xor_val=0)const//[0,x)
  {
    assert(0<=xor_val&&(xor_val>>sz)==0);
    if(x<0)return 0;
    else if(x>>sz)return v[0].cnt;
    T ret=0;
    int p=0;
    for(int i=sz;i--;)
    {
      int j=x>>i&1,k=xor_val>>i&1;
      if(j==0)p=v[p].nxt[k];
      else
      {
        if(v[p].nxt[k]>=0)ret+=v[v[p].nxt[k]].cnt;
        p=v[p].nxt[!k];
      }
      if(p==-1)break;
    }
    return ret;
  }
  Bit max(Bit xor_val=0)const
  {
    assert(0<=xor_val&&(xor_val>>sz)==0);
    int p=0;
    Bit ret=0;
    if(v[p].cnt==0)return ret;
    for(int i=sz;i--;)
    {
      ret<<=1;
      int k=xor_val>>i&1;
      if(v[p].nxt[!k]>=0&&v[v[p].nxt[!k]].cnt>0)
      {
        p=v[p].nxt[!k];
        ret|=1;
      }
      else p=v[p].nxt[k];
    }
    return ret;
  }
  Bit min(Bit xor_val=0)const
  {
    assert(0<=xor_val&&(xor_val>>sz)==0);
    int p=0;
    Bit ret=0;
    for(int i=sz;i--;)
    {
      ret<<=1;
      int k=xor_val>>i&1;
      if(v[p].nxt[k]>=0&&v[v[p].nxt[k]].cnt>0)p=v[p].
    nxt[k];
      else
      {
        p=v[p].nxt[!k];
        ret|=1;
      }
    }
    return ret;
  }
  Bit find_by_order(T ord,Bit xor_val=0)const
  {
    assert(0<=xor_val&&(xor_val>>sz)==0);
    assert(0<=ord&&ord<v[0].cnt);
    int p=0;
    Bit ret=0;
    for(int i=sz;i--;)
    {
      ret<<=1;
      int k=xor_val>>i&1;
      if(v[p].nxt[k]>=0)
      {
        if(ord>=v[v[p].nxt[k]].cnt)
        {
          ord-=v[v[p].nxt[k]].cnt;
          p=v[p].nxt[!k];
          ret|=1;
        }
        else p=v[p].nxt[k];
      }
      else
      {
        p=v[p].nxt[!k];
        ret|=1;
      }
    }
    return ret;
  }
  T order_of_key(Bit x,Bit xor_val=0)const{return
    count(x,xor_val);}
};
binarytrie<32>bt;
```

4.5 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>;
```

4.6 Convex hull trick

```
int div_up(int a, int b) { return a/b+((a^b)>0&&a%b);
    } // divide a by b rounded up
const int LQ = ..., RQ = ...; //leftmost query,
    rightmost query
```

```
int in(ii L, int x) {
    return L.x * x + L.y;
}
struct Hull {
vector <pair <int, int> > lines;
vector <int> borders;
void push(ii L) {
    while (lines.size() && in(L,borders.back()) < in(
    lines.back(),borders.back())) {
        lines.pop_back();
        borders.pop_back();
    }
    if (lines.empty()) {
        lines = {L};
        borders = {LQ};
    }
    else if (lines.back().x > L.x) {
        int x = div_up(L.y - lines.back().y, lines.
    back().x - L.x);
        if (x <= RQ) {
            lines.app(L);
            borders.app(x);
        }
    }
}
Hull (){}
Hull (vector <ii> a) {
    auto comp = [&] (ii u, ii v) {
        return u.x > v.x || (u.x == v.x && u.y < v.y);
    };
    sort(all(a), comp);
    for (auto L : a) {
        push(L);
    }
}
int get(int x) {
    int pos = upper_bound(all(borders), x) - borders.
    begin();
    assert(pos>0);
    pos--;
    return in(lines[pos],x);
}
};
```

4.7 Центроиды

```
vector<int> sz(n), lvl(n, -1);
auto dfs = [&](auto dfs, int cur, int prev) -> int {
    if (lvl[cur] != -1) return 0;
    sz[cur] = 1;
    for (auto [nxt, w] : g[cur]) {
        if (nxt != prev) sz[cur] += dfs(dfs, nxt, cur)
    ;
    }
    return sz[cur];
};
auto find = [&](auto find, int cur, int prev, int tot)
     -> int {
    int bch = -1, bsz = 0;
    for (auto [nxt, w] : g[cur]) {
        if (nxt == prev || lvl[nxt] != -1) continue;
        if (sz[nxt] > bsz) {
            bch = nxt;
            bsz = sz[nxt];
        }
    }
    if (bsz + bsz <= tot) return cur;
    return find(find, bch, cur, tot);
};
dfs(dfs, 0, 0);
auto c = find(find, 0, 0, sz[0]);
vector<pair<int, int>> stack{{c, 0}};
int ans = INF;
while (!stack.empty()) {
    auto [centroid, l] = stack.back();
    stack.pop_back();
    lvl[centroid] = l;
    for (auto [nxt, w] : g[centroid]) {
        if (lvl[nxt] != -1) continue;
        dfs(dfs, nxt, centroid);
        int new_centroid = find(find, nxt, centroid,
    sz[nxt]);
        stack.push_back({new_centroid, lvl[centroid] +
     1});
    }
}
```

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)
```

```
  auto pal = [&] (int i, int from, int len) {
    if (len == 0) {
        return true;
    }
    int m = len/2;
    if (len & 1) {
        return o[i][from + m] >= m;
    }
    else {
        return e[i][from + m - 1] >= m;
    }
};
```

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>
vector <int> SA(const T &a) {
    int m = *max_element(all(a)) + 1, n = a.size();
    vector <int> sa(n), nsa(n), pre(max(n, m)), x(a.
    begin(), a.end()), y(n);
    for (int e : x) pre[e]++;
    for (int i = 1; i < m; ++i) pre[i] += pre[i - 1];
    for (int i = 0; i < n; ++i) sa[--pre[x[i]]]=i;
    int dif = 1;
    y[sa.front()]=0;
    for (int i = 1; i < n; ++i) {
        dif += x[sa[i]]!=x[sa[i-1]];
        y[sa[i]] = dif - 1;
    }
    x = y;
    for (int h = 1; dif < n; h *= 2) {
        fill(all(pre), 0);
        for (int e : x) pre[e]++;
        for (int i = 1; i < dif; ++i) pre[i] += pre[i
    - 1];
        for (int t = n; t--; ) {
            int i = sa[t];
            if (i>=h) {
                nsa[--pre[x[i-h]]]=i-h;
            }
            else if (i + 1 != h) {
                nsa[--pre[x[i-h+n+1]]]=i-h+n+1;
            }
        }
        nsa[--pre[x[n - h]]]=n-h;
        sa = nsa;
        auto getr = [&] (int i) {
            if (i + h < n) {
                return x[i + h];
            }
            else {
                return x[i + h - n - 1];
            }
        };
        dif = 1;
        y[sa.front()]=0;
        for (int i = 1; i < n; ++i) {
            if (x[sa[i]]!=x[sa[i-1]] || sa[i-1]+h==n)
    {
                dif++;
            }
            else {
                dif += getr(sa[i]) != getr(sa[i-1]);
            }
            y[sa[i]]=dif-1;
        }
        x = y;
    }
    return sa;
}

template <typename T>
struct suar {
    vector <int> sa, lcp, pos; rmq t;
    suar (const T &a) : t((int)a.size() - 1) {
        sa = SA(a);
        int n = (int)a.size(), k = 0;
        lcp.resize(n - 1);
        pos.resize(n);
        for (int i = 0; i < n; ++i) pos[sa[i]] = i;
        for (int i = 0; i < n; ++i) {
            if (pos[i]+1<n) {
                int j = sa[pos[i]+1];
                while (i+k<n&&j+k<n&&a[i+k]==a[j+k])k
    ++;
                lcp[pos[i]]=k;
            }
            if (k) {
                k--;
            }
        }
        t.build(lcp);
    }
    int getLcp(int i, int j) {
        i = pos[i]; j = pos[j];
        if (j < i) {
          swap(i, j);
        }
        if (i == j) {
          return inf;
        }
        else {
          return t.getMin(i, j);
        }
    }
};
```

5.5 Алгоритм Ахо — Корасик

5.6 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
}
```

5.7 Дерево палиндромов

5.8 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

```
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);
};
/* in case of undirected graph use this:
addEdge(u, v, capacity, cost);
addEdge(v, u, capacity, cost);
*/
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);
// now shortest path using dijkstra with potentials
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;
}
// now recover answer
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 Геома

7.1 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;
}
```

7.2 Выпуклая оболочка

```
using pt = pair<int, int>;
#define x first
#define y second

int cross(pt p, pt q) {
    return p.x * q.y - p.y * q.x;
}
int scalar(pt p, pt q) {
    return p.x * q.x + p.y * q.y;
}
pt operator-(pt a, pt b) { return {a.x - b.x, a.y - b.
    y}; }
vector<pt> convex(vector<pt> a) {
    sort(all(a));
    if (a.size() == 2 && a[0] == a[1]) return {a[0]};
    if (a.size() <= 1) return a;
    vector<pt> h;
    for (int t = 0; t < 2; ++t) {
        int sz = h.size() - t;
        for (auto p: a) {
            while (h.size() >= sz + 2 && cross(p - h.
    end()[-1], h.end()[-2] - h.end()[-1]) <= 0) h.
    pop_back();
            h.push_back(p);
        }
        reverse(all(a));
    }
    return h; // h is circular: h.front() == h.back()
}
```

7.3 Точка внутри многоугольника

```
    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);
    };
```

7.4 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 Разное

8.1 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
```

8.1.1 Сеточка в vim

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

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

8.2 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

8.3 Шаблон

```
#ifdef LOCAL
#define _GLIBCXX_DEBUG
#endif
#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__)
#define debugv(v) do { cout << #v << ": "; for (
    auto x : v) cout << x << ' '; cout << endl; }
    while(0)
#else
#define debug(...)
#define debugv(v)
#endif
```

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