Contents

1 Setups

1.1 vimrc [6c9876]

```
se nu ai rnu cin ts=4 sw=4 | sy on
inoremap {<CR> {<CR>}<Esc>O
inoremap jk <Esc>
```

1.2 pbds [9f7c3e]

```
#include <bits/stdc++.h>
#include <bits/extc++.h>
using namespace __gnu_pbds;
using namespace std;

template <typename T>
using ordered_set = tree<T,null_type,less
    <T>,rb_tree_tag,tree_order_statistics_node_update>;

int main(){
    ordered_set<int> st;
    st.insert(1);
    st.find_by_order(0);//iterator to 1
    st.order_of_key(1);//returns 0
}
```

1.3 terminal [46fc34]

```
-- terminal --
$ setxkbmap -option caps:swapescape
```

1.4 debug [33c0d3]

```
#ifdef MIKU
string
     dbmc = "\033[1;38;2;57;197;187m", dbrs = \033[0m;
#define debug
    (x...) cout << dbmc << "[" << #x << "] : ", dout(x)
void dout() { cout << dbrs << endl; }
template <typename T, typename ...U>
void dout(T t, U ...u) { cout
     << t << sizeof...(u) ? ", " : ""; dout(u...); }
#else
#define debug(...) 39
#endif

int main(){
    int a = 49;
    char c = '8';
    debug(a);// outputs "[a] : 49"
    debug(a, c); // outputs "[a, c] : 49, 8"
    debug("PCCORZ"); // outputs "["PCCORZ"] : PCCORZ"
    debug(); // outputs "[] : "
}
```

1.5 template [5116af]

```
#include <bits/stdc++.h>
using namespace std;
#define fs first
#define sc second
#define F first
#define S second
#define FOR(i, j, k) for (int i = j, Z = k; i < Z; i++)
using ll = long long;
using lll = __int128_t;
typedef pair<int, int> pii;
typedef tuple<int,int,int> tiii;
typedef pair<ll,ll> pll


int main(){
}
```

2 Graph

2.1 Dominator Tree [3b89c3]

```
struct DominatorTree{
  //1-indexed
  //not reachable from s -> not on tree
  int n;
  vector<vector<int>> G,rG;
  vector<int> pa,dfn,id;
  int dfnCnt;
  vector<int> semi,idom,best;
  vector<vector<int>> ret;
  void init(int _n){
    n=_n;
    G = rG = ret = vector<vector<int>>(n+1);
    pa = dfn = id = vector<int>(n+1,-1);
    dfnCnt = 0;
    semi = idom = best = vector<int>(n+1,-1);
  }
  void add_edge(int u,int v){
    G[u].push_back(v);
    rG[v].push_back(u);
  }
  void dfs(int u){
    id[dfn[u]=++dfnCnt]=u;
    for(auto v:G[u]) if(!dfn[v]){
      dfs(v),pa[dfn[v]]=dfn[u];
    }
  }
  int find(int y,int x){
    if(y<=x)return y;
    int tmp=find(pa[y],x);
    if(semi[best[y]]>semi[best[pa[y]]])
      best[y]=best[pa[y]];
    return pa[y]=tmp;
  }
  void tarjan(int root){
    dfnCnt=0;
    for(int i=1;i<=n;++i){
      dfn[i]=idom[i]=0;
      ret[i].clear();
      best[i]=semi[i]=i;
    }
    dfs(root);
    for(int i=dfnCnt;i>1;--i){
      int u=id[i];
      for(auto v:rG[u]) if(v=dfn[v]){
        find(v,i);
        semi[i]=min(semi[i],semi[best[v]]);
      }
      ret[semi[i]].push_back(i);
      for(auto v:ret[pa[i]]){
        find(v,pa[i]);
        idom[v
            ] = semi[best[v]]==pa[i] ? pa[i] : best[v];
      }
      ret[pa[i]].clear();
    }
    for(int i=2; i<=dfnCnt; ++i){
      if(idom[i]!=semi[i]) idom[i]=idom[idom[i]];
      ret[id[idom[i]]].push_back(id[i]);
    }
  }
  vector<vector<int>> solve(int s){
    tarjan(s);
    return ret;
  }
};
```

2.2 Incremental SCC [d8b556]

```
struct IncrementalSCC{
#define pii pair<int,int>
#define fs first
#define sc second
#define tiii tuple<int,int,int>
```

```
//if u == v : ans[i] = -1
//if not connected : ans[i] = m
//all 0-indexed
int n;
vector<int> ans;
int m;
vector<tiii> all;
vector<int> SCC(int n,vector<vector<int>>& paths){
  vector<int> scc_id(n,-1),idx(n,-1),low(n,-1),st;
  int cnt = 0,gcnt = 0;
  function<void(int)> dfs = [&](int now)->void{
    low[now] = idx[now] = cnt++;
    st.push_back(now);
    for(auto nxt:paths[now]){
      if(scc_id[nxt] != -1)continue;
      if(idx[nxt] == -1){
        dfs(nxt);
        low[now] = min(low[now],low[nxt]);
      }
      else{
        low[now] = min(low[now],idx[nxt]);
      }
    }
    if(low[now] == idx[now]){
      int id = -1;
      while(id != now){
        id = st.back();
        st.pop_back();
        scc_id[id] = gcnt;
      }
      gcnt++;
    }
  };
  for(int i = 0;i<n;i++){
    if(scc_id[i] == -1)dfs(i);
  }
  return scc_id;
}
vector<int> mapping;
void dc(int l,int r,vector<tiii> &edges){
  if(l == r){
    for(auto
        &[id,_,__]:edges)ans[id] = min(ans[id],l);
    return;
  }
  int mid = (l+r)>>1;
  int cnt = 0;
  for(auto &[t,u,v]:edges){
    if(mapping[u] == -1)mapping[u] = cnt++;
    if(mapping[v] == -1)mapping[v] = cnt++;
  }
  n = cnt;
  vector<vector<int>> paths(n);
  vector<int> vv;
  for(auto &[t,u,v]:edges){
    vv.push_back(u);
    vv.push_back(v);
    u = mapping[u],v = mapping[v];
    if(t<=mid)paths[u].push_back(v);
  }
  for(auto &i:vv)mapping[i] = -1;

  auto scc_id = SCC(n,paths);
  vector<tiii> vl,vr;
  for(auto &[t,u,v]:edges){
    if(scc_id[u] == scc_id[v]){
      ans[t] = min(ans[t],mid);
      vl.push_back(tiii(t,u,v));
    }
    else{
      u = scc_id[u],v = scc_id[v];
      vr.push_back(tiii(t,u,v));
    }
  }
  vector<tiii>().swap(edges);
  dc(l,mid,vl);
  dc(mid+1,r,vr);
  return;
}
void add_edge(int u,int v){
  all.push_back(tiii(all.size(),u,v));
}
vector<tiii> solve(){//[time,u,v]
  m = all.size();
  vector<tiii> ret(m);
  for(auto [t,u,v]:all)ret[t] = tiii(m,u,v);
  for(auto [t,u,v]:all)n = max({n,u,v});
  n++;
  ans = vector<int>(m,m);
  for(auto [t,u,v]:all){
    if(u == v)ans[t] = -1;
  }
  mapping = vector<int>(n,-1);
  dc(0,m,all);
  for(int i = 0;i<m;i++)get<0>(ret[i]) = ans[i];
  return ret;
}
IncrementalSCC(){
  ans.clear();
  n = m = 0;
}
#undef tiii
#undef pii
#undef fs
#undef sc
};
```

2.3 Block-Cut Tree [f44682]

```
struct BlockCutTree{
  //0-indexed
  //returns a forest if the graph is not connected
  vector<vector<int>> g;
  vector<vector<int>> groups;
  vector<vector<int>> tr;
  vector<int> idx,low,st;
  int cnt,gcnt;
  int n;
  RoundSquareTree(int _n = 0){
    cnt = gcnt = 0;
    n = _n;
    g = vector<vector<int>>(n);
  }
  void add_edge(int a,int b){//adds bidirectional edges
    g[a].push_back(b);
    g[b].push_back(a);
  }
  void dfs(int now){
    idx[now] = low[now] = cnt++;
    st.push_back(now);
    for(auto nxt:g[now]){
      if(idx[nxt] == -1){
        dfs(nxt);
        low[now] = min(low[now],low[nxt]);
        if(low[nxt] == idx[now]){
          int id = -1;
          tr.push_back(vector<int>());
          while(id != nxt){
            id = st.back();st.pop_back();
            groups[id].push_back(gcnt);
            tr[id].push_back(gcnt+n);
            tr[gcnt+n].push_back(id);
          }
          groups[now].push_back(gcnt);
          tr[now].push_back(gcnt+n);
          tr[gcnt+n].push_back(now);
          gcnt++;
        }
      }
      else idx[now] = min(idx[now],idx[nxt]);
    }
    return;
  }
  vector<vector<int>> solve(){//
      returns the tree (round vertices numbered [0,n))
    idx = low = vector<int>(n,-1);
    tr = vector<vector<int>>(n);
    for(int i = 0;i<n;i++){
      if(idx[i] == -1)dfs(i);
    }
    return tr;
  }
};
```

2.4 Euler Tour [22e960]

```
#include <bits/stdc++.h>
using namespace std;

struct EulerTour{
  //undirected graph,0-indexed,fails if doesn't exist
  //returns the order of edges
  vector<vector<pii>> g;
```

```
  vector<int> ptr;
  vector<bool> vis;
  vector<int> re;
  int n,ecnt;
  void init(int _n){
    n = _n;
    ecnt = 0;
    g = vector<vector<pii>>(n);
    ptr = vector<int>(n);
  }
  void add_edge(int a,int b,int id = -1){
    if(id == -1)id = ecnt;
    g[a].push_back(pii(b,id));
    g[b].push_back(pii(a,id));
    ecnt++;
  }
  void dfs(int now){
    for(int &i = ptr[now];i<g[now].size();i++){
      auto [to,eid] = g[now][i];
      if(vis[eid])continue;
      vis[eid] = true;
      dfs(to);
      re.push_back(eid);
    }
    return;
  }
  vector<int> solve(int s){
    re.clear();
    vis = vector<bool>(ecnt,0);
    dfs(s);
    reverse(re.begin(),re.end());
    return re;
  }
};
```

2.5 Dinic [360712]

```
struct Dinic{//0-indexed
  struct E{
    int t,f,c;
    E(int tt
        = 0,int cc = 0,int ff = 0):t(tt),c(cc),f(ff){}
  };
  vector<vector<int>> paths;
  vector<int> ptr,lvl;
  vector<E> e;
  queue<int> q;
  Dinic(int _n = 0){
    paths = vector<vector<int>>(_n);
    ptr = lvl = vector<int>(_n);
  }
  void add_edge(int a,int b,int c,int d = 0){
    paths[a].push_back(e.size());
    e.push_back(E(b,c));
    paths[b].push_back(e.size());
    e.push_back(E(a,d));
  }
  bool bfs(int s,int t){
    fill(lvl.begin(),lvl.end(),-1);
    q.push(s);
    lvl[s] = 0;
    while(!q.empty()){
      auto now = q.front();q.pop();
      for(auto &eid:paths[now]){
        if(e[eid].f == e[eid].c)continue;
        if(lvl[e[eid].t] == -1){
          lvl[e[eid].t] = lvl[now]+1;
          q.push(e[eid].t);
        }
      }
    }
    return lvl[t] != -1;
  }
  int dfs(int now,int t,int flow){
    if(now == t)return flow;
    for(int &i = ptr[now];i<paths[now].size();i++){
      int eid = paths[now][i];
      if(e[eid].f == e[
          eid].c||lvl[e[eid].t] != lvl[now]+1)continue;
      if(int re =
          dfs(e[eid].t,t,min(flow,e[eid].c-e[eid].f))){
        e[eid].f += re;
        e[eid^1].f -=re;
        return re;
      }
    }
    return 0;
  }
  int flow(int s,int t){
    int ans = 0;
    while(bfs(s,t)){
      fill(ptr.begin(),ptr.end(),0);
      while(auto re = dfs(s,t,INT_MAX)){
        ans += re;
      }
    }
    return ans;
  }
  bool inScut(int k){
    return lvl[k] != -1;
  }
};
```

2.6 Gomory-Hu Tree [3ab29a]

```
struct GomoryHuTree{//0-indexed
#define pii pair<int,int>
#define tiii tuple<int,int,int>
  vector<tiii> edges;
  vector<vector<pii>> tr;
  vector<int> p;
  int n;
  GomoryHuTree(int _n = 0){
    n = _n;
    p = vector<int>(_n,0);
    tr = vector<vector<pii>>(_n);
  }
  void add_edge(int a,int b,int c){
    edges.push_back(tiii(a,b,c));
  }
  vector<vector<pii>> make_tree(){
    fill(p.begin(),p.end(),0);
    tr = vector<vector<pii>>(n);
    for(int i = 1;i<p.size();i++){
      Dinic din(n);
      for(auto &[a,b,w]:edges){
        din.add_edge(a,b,w,w);
      }
      int w = din.flow(i,p[i]);
      tr[i].push_back(pii(p[i],w));
      tr[p[i]].push_back(pii(i,w));
      for(int j = i+1;j<n;j++){
        if(p[j] == p[i]&&din.inScut(j))p[j] = i;
      }
    }
    return tr;
  }
#undef pii
#undef tiii
};
```

2.7 Min-Cost-Max-Flow [80eed6]

```
#define T ll
const T inf = 1e12;
struct MCMF{//TC:O(VEF)
  struct E{
    int t,f;
    T c,w;
    E(int tt,T cap,T wei):t(tt),c(cap),w(wei),f(0){}
  };
  vector<E> e;
  vector<vector<int>> paths;
  vector<T> dis;
  vector<int> pre;
  vector<bool> inq;
  queue<int> q;
  int n;
  MCMF(int _n = 0){
    n = _n;
    paths = vector<vector<int>>(n);
    e.clear();
    pre = vector<int>(n);
    dis = vector<T>(n);
    inq = vector<bool>(n);
  }
  void add_edge
      (int a,int b,int c,int d){//from,to,cap,wei
    paths[a].push_back(e.size());
    e.push_back(E(b,c,d));
    paths[b].push_back(e.size());
    e.push_back(E(a,0,-d));
  }
  bool SPFA(int s,int t){
```

```
    fill(dis.begin(),dis.end(),inf);
    fill(pre.begin(),pre.end(),-1);
    dis[s] = 0;
    q.push(s);inq[s] = true;
    while(!q.empty()){
      auto now = q.front();q.pop();
      inq[now] = false;
      //assert(dis[now]>=0);
      for(auto &eid:paths[now]){
        if(e[eid].f == e[eid].c)continue;
        int nxt = e[eid].t;
        if(dis[nxt]>dis[now]+e[eid].w){
          pre[nxt] = eid;
          dis[nxt] = dis[now]+e[eid].w;
          if(!inq[nxt]){
            inq[nxt] = true;
            q.push(nxt);
          }
        }
      }
    }
    return dis[t] != inf;
  }
  T flow(int s,int
      t,int cnt = INT_MAX){//cnt is the number of flows
    T ans = 0;
    while(cnt--&&SPFA(s,t)){
      ans += dis[t];
      int now = t;
      while(pre[now] != -1){
        int eid = pre[now];
        e[eid].f++;
        e[eid^1].f--;
        now = e[eid^1].t;
      }
    }
    return ans;
  }
};
#undef T
```

2.8 KM [2bf044]

```
// Kuhn-Munkres :
     Bipartite matching with "maximum" weight in O(n^3)
struct KM{
    const static int
         M = 500; // modify maximum number of vertices
    int n;
    ll ans = 0;
    // 0-base
    vector
        <vector<ll>> w; // input weighted edges w[x][y]
    vector<int> match; // match[y] = x
    vector<ll> lx, ly, slack;
    bitset<M> visx, visy; // initialize with all zero

    // abbr
# define forx for(int x=0; x<n; x++)
# define fory for(int y=0; y<n; y++)
# define z match[y]

    bool dfs(int x){
        visx[x] = 1;
        fory{
            if(visy[y]) continue;
            ll d = lx[x]+ly[y]-w[x][y];
            if(!d){
                visy[y] = 1;
                if(z==-1 || (!visx[z] && dfs(z))){
                    z = x;
                    return 1;
                }
            }
            else if(d<slack[y]) slack[y] = d;
        }
        return 0;
    }

    bool augment(){
        fory if(!visy[y] && !slack[y]){
            visy[y] = 1;
            if(z==-1) return 1;
            else if(!visx[z] && dfs(z)){
                z = -1;
                return 1;
            }
        }
        return 0;
    }

    void relabel(){
        ll d = INT64_MAX;
        fory if(!visy[y]) d = min(d, slack[y]);
        forx if(visx[x]) lx[x] -= d;
        fory{
            if(visy[y]) ly[y] += d;
            else slack[y] -= d;
        }
    }

    KM(vector<vector<ll>>
        &W): n(W.size()), w(W) { // input edges' weight
        //initialize
        slack.resize(n);
        match.assign(n, -1);
        lx.assign(n, INT64_MIN);
        ly.assign(n, 0);
        forx fory lx[x] = max(lx[x], w[x][y]);
        //matching
        forx{
            visx.reset();
            visy.reset();
            visx[x] = 1;
            fory slack[y] = lx[x]+ly[y]-w[x][y];
            while(!augment()) relabel();
            visx.reset();
            visy.reset();
            dfs(x);
        }
        //summing
        forx ans += lx[x];
        fory ans += ly[y];
    }

# undef forx
# undef fory
# undef z
};
```

2.9 Max Clique [0de041]

```
constexpr size_t kN = 150; using bits = bitset<kN>;
#define _all(T) T.begin(),T.end()
struct MaxClique {
  bits G[kN], cs[kN];
  int ans, sol[kN], q, cur[kN], d[kN], n;
  void init(int _n) {
    n = _n;
    for (int i = 0; i < n; ++i) G[i].reset();
  }
  void
      add_edge(int u, int v) { G[u][v] = G[v][u] = 1; }
  void pre_dfs(vector<int> &v, int i, bits mask) {
    if (i < 4) {
      for (
          int x : v) d[x] = (int)(G[x] & mask).count();
      sort(_all(v), [&](int x, int y) {
        return d[x] > d[y]; });
    }
    vector<int> c(v.size());
    cs[1].reset(), cs[2].reset();
    int l = max(ans - q + 1, 1), r = 2, tp = 0, k;
    for (int p : v) {
      for (k = 1; (cs[k] & G[p]).any(); ++k);
      if (k >= r) cs[++r].reset();
      cs[k][p] = 1;
      if (k < l) v[tp++] = p;
    }
    for (k = l; k < r; ++k)
      for (auto p = cs[k]._Find_first();
          p < kN; p = cs[k]._Find_next(p))
        v[tp] = (int)p, c[tp] = k, ++tp;
    dfs(v, c, i + 1, mask);
  }
  void dfs(vector<int> &v, vector<int> &c,
      int i, bits mask) {
    while (!v.empty()) {
      int p = v.back(); v.pop_back(); mask[p] = 0;
      if (q + c.back() <= ans) return;
      cur[q++] = p;
      vector<int> nr;
      for (int x : v) if (G[p][x]) nr.push_back(x);
      if (!nr.empty()) pre_dfs(nr, i, mask & G[p]);
```

```
      else if (q > ans) ans = q, copy_n(cur, q, sol);
      c.pop_back(); --q;
    }
  }
  int solve() {
    vector<int> v(n); iota(_all(v), 0);
    ans = q = 0; pre_dfs(v, 0, bits(string(n, '1')));
    return ans; // sol[0 ~ ans-1]
  }
};
```

3 Data Structure

3.1 Li Chao Tree [565209]

```
//range add line get min
//can even be used if modifies aren't range modify
#define ll long long
const ll SZ = 8e6+10;
const ll inf = 3e18;
vector<ll> all;
struct Line{
  ll m,b;
  Line(ll mm = 0,ll bb = 0):m(mm),b(bb){}
  ll operator()(ll k){
    return m*k+b;
  }
};
struct LiChao{
#define ls now*2+1
#define rs now*2+2
#define mid ((l+r)>>1)
  Line seg[SZ];
  LiChao(){
    fill(seg,seg+SZ,Line(0,inf));
  }
  void modify(int now,int l,int r,int s,int e,Line v){
    if(l == r){
      if(seg[now](all[l])>v(all[l]))swap(seg[now],v);
      return;
    }
    if(l>=s&&e>=r){
      if(seg
          [now](all[mid])>v(all[mid]))swap(seg[now],v);
      if(seg[now].m<v.m)modify(ls,l,mid,s,e,v);
      else modify(rs,mid+1,r,s,e,v);
    }
    else{
      if(mid>=s)modify(ls,l,mid,s,e,v);
      if(mid<e)modify(rs,mid+1,r,s,e,v);
    }
    return;
  }
  ll getval(int now,int l,int r,int p){
    if(l == r)return seg[now](all[p]);
    if(mid>=p)return
          min(seg[now](all[p]),getval(ls,l,mid,p));
    else return
          min(seg[now](all[p]),getval(rs,mid+1,r,p));
  }
  void add_line(int s,int e,Line v){
    modify(0,0,all.size()-1,s,e,v);
    return;
  }
  ll getmin(int p){
    return getval(0,0,all.size()-1,p);
  }
#undef ls
#undef rs
#undef mid
};
#undef ll long long
```

3.2 Dynamic Convex Hull [98f67f]

```
//reference : 8BCube
#define ll long long
// only works for integer coordinates!! maintain max

struct Line {
  mutable ll a, b, p;
  bool operator
      <(const Line &rhs) const { return a < rhs.a; }
  bool operator<(ll x) const { return p < x; }
};
struct CHT : multiset<Line, less<>> {
  static const ll kInf = 1e18;
  ll Div(ll a,
       ll b) { return a / b - ((a ^ b) < 0 && a % b); }
  bool isect(iterator x, iterator y) {
    if (y == end()) { x->p = kInf; return 0; }
    if (x
        ->a == y->a) x->p = x->b > y->b ? kInf : -kInf;
    else x->p = Div(y->b - x->b, x->a - y->a);
    return x->p >= y->p;
  }
  void addline(ll a, ll b) {
    auto z = insert({a, b, 0}), y = z++, x = y;
    while (isect(y, z)) z = erase(z);
    if (x != begin
        () && isect(--x, y)) isect(x, y = erase(y));
    while ((y = x) != begin
        () && (--x)->p >= y->p) isect(x, erase(y));
  }
  ll query(ll x) {
    auto l = *lower_bound(x);
    return l.a * x + l.b;
  }
};
```

3.3 Treap [ff4001]

```
#define ll long long
//range reverse range add range sum
//need to push before using the info on node
struct node{
  int pri;
  int pl,pr;
  ll sum,tag,val;
  int sz;
  int rev;
  node(){
    pl = pr = sum = tag = 0;
    sz = 0;
    rev = 0;
    pri = rand();
  }
};

const int SZ = 2e5+10;
struct Treap{
  node nd[SZ];
  int cnt = 0;
  Treap(){
    cnt = 0;
  }
  int newnode(){
    cnt++;
    nd[cnt].sz = 1;
    return cnt;
  }
  void pull(int now){
    if(!now)return;
    nd[now].sz = nd[nd[now].pr].sz+nd[nd[now].pl].sz+1;
    ll ls = nd[nd[now
        ].pl].sum+nd[nd[now].pl].tag*nd[nd[now].pl].sz;
    ll rs = nd[nd[now
        ].pr].sum+nd[nd[now].pr].tag*nd[nd[now].pr].sz;
    nd[now].sum = nd[now].val+ls+rs;
    return;
  }
  void push(int now){
    if(!now)return;
    if(nd[now].rev){
      swap(nd[now].pl,nd[now].pr);
      if(nd[now].pl)nd[nd[now].pl].rev ^= 1;
      if(nd[now].pr)nd[nd[now].pr].rev ^= 1;
      nd[now].rev = 0;
    }
    int tl = nd[now].pl,tr = nd[now].pr;
    nd[now].val += nd[now].tag;
    if(tl)nd[tl].tag += nd[now].tag;
    if(tr)nd[tr].tag += nd[now].tag;
    nd[now].tag = 0;
    pull(now);
  }
  int merge(int a,int b){
    if(!a)return b;
    if(!b)return a;
    if(nd[a].pri>nd[b].pri){
      push(a);
      nd[a].pr = merge(nd[a].pr,b);
      pull(a);
      return a;
```

```
    }
    else{
      push(b);
      nd[b].pl = merge(a,nd[b].pl);
      pull(b);
      return b;
    }
  }
  void split(int now,int &a,int &b,int tar){
    if(!now){
      a = b = 0;
      return;
    }
    push(now);
    if(nd[nd[now].pl].sz+1<=tar){
      a = now;
      split(nd[now
          ].pr,nd[a].pr,b,tar-(nd[nd[now].pl].sz+1));
    }
    else{
      b = now;
      split(nd[now].pl,a,nd[b].pl,tar);
    }
    pull(a);
    pull(b);
    return;
  }
};
Treap T;
```

3.4 quadrangle [1d61e6]

```
struct QUADRANGLE {
    struct TUPLE {
        int l, r, id;
        TUPLE() {}
        TUPLE(int _l,
            int _r, int _id) : l(_l), r(_r), id(_id) {}
    };
    int n, now;
    deque<TUPLE> dq;

    int calc_dp(int id, int i) {
        // ...
    }
    bool cmp(int cid, int pid, int i) {
        // ...
    }
    void init(int _n) {
        n = _n;
        now = 1;
        dq.clear();
    }
    void kill_head() {
        now++;
        if (dq
            .front().l == dq.front().r) dq.pop_front();
        else dq.front().l++;
    }
    void push(int id) {
        while (dq.size()) {
            TUPLE tl = dq.back();
            dq.pop_back();
            if (cmp(id, tl.id, tl.l)) {
                continue;
            }
            int l = tl.l, r = tl.r + 1;
            while (l + 1 < r) {
                int mid = (l + r) >> 1;
                (cmp(id, tl.id, mid) ? r : l) = mid;
            }
            dq.push_back(TUPLE(tl.l, l, tl.id));
            if (r <= n) dq.push_back(TUPLE(r, n, id));
            return;
        }
        dq.push_back(TUPLE(now, n, id));
    }
    int determine(int id) {
        return calc_dp(dq.front().id, id);
    }
};
```

3.5 Splay [977ab6]

```
#include <bits/stdc++.h>
using namespace std;
#define ll long long
const int SZ = 2e5+10;
//1-indexed,0 used for nullptr
//range reverse range sum
struct Splay{
#define ls ch[now][0]
#define rs ch[now][1]
  ll val[SZ];
  ll sum[SZ];
  int ch[SZ][2],fa[SZ],cnt,rev[SZ],sz[SZ];
  void pull(int now){
    if(!now)return;
    sum[now] = sum[ls]+sum[rs]+val[now];
    sz[now] = sz[ls]+sz[rs]+1;
    return;
  }
  void push(int now){
    if(!now)return;
    if(rev[now]){
      swap(ls,rs);
      rev[ls] ^= 1;
      rev[rs] ^= 1;
      rev[now] = 0;
    }
    pull(now);
    return;
  }
  Splay(){
    fill(sz+1,sz+SZ,1);
    return;
  }
  int newnode(){
    return ++cnt;
  }
  int dir(int now){//is ls or rs
    return ch[fa[now]][1] == now;
  }
  bool isroot(int k){//for LCT
    return !fa[k]||ch[fa[k]][dir(k)] != k;
  }
  void rot(int now){
    assert(now);
    assert(fa[now]);
    int p = fa[now];
    int g = fa[p];
    push(g);
    push(p);
    push(now);
    int d = dir(now);
    if(!isroot(p))ch[g][dir(p)] = now;
    fa[ch[now][d^1]] = p;
    ch[p][d] = ch[now][d^1];
    fa[now] = g;
    fa[p] = now;
    ch[now][d^1] = p;
    pull(p);
    pull(now);
    return;
  }
  void splay(int now){
    if(!now)return;
    while(!isroot(now)){
      push(fa[fa[now]]);
      push(fa[now]);
      push(now);
      if(!isroot(fa[now])){
        if(dir(fa[now]) == dir(now))rot(fa[now]);
        else rot(now);
      }
      rot(now);
    }
    push(now);
    return;
  }
  int get_sz(int now,int tar){
    push(now);
    while(now&&sz[ls]+1 != tar){
      if(sz[ls]>=tar)now = ls;
      else{
        tar -= sz[ls]+1;
        now = rs;
      }
      push(now);
    }
    return now;
  }
```

```
  void merge(int a,int b){
    if(!a||!b)return;
    splay(a);splay(b);
    a = get_sz(a,sz[a]);
    b = get_sz(b,1);
    splay(a);splay(b);
    ch[a][1] = b;
    fa[b] = a;
    pull(a);
    return;
  }
  pair<int,int> split(int a,int tar){
    splay(a);
    if(!tar)return make_pair(0,a);
    int b = get_sz(a,tar);
    splay(b);
    pair<int,int> re;
    re.first = b;
    re.second = ch[b][1];
    fa[ch[b][1]] = 0;
    ch[b][1] = 0;
    pull(b);
    return re;
  }
#undef ls
#undef rs
};
```

3.6 Link-Cut Tree [085466]

```
#define ll long long
//needs splay
//vertex add paths sum link-cut
struct LCT{
  Splay sp;
  void access(int x){
    sp.splay(x);
    sp.ch[x][1] =  0;
    sp.pull(x);
    while(sp.fa[x]){
      int u = sp.fa[x];
      sp.splay(u);
      sp.push(u);
      sp.ch[u][1] = x;
      sp.pull(u);
      sp.splay(x);
    }
  }
  void makeroot(int x){
    access(x);sp.splay(x);
    sp.rev[x] ^= 1;
  }
  void link(int u,int v){
    makeroot(u);
    sp.splay(u);
    sp.fa[u] = v;
  }
  void cut(int u,int v){
    makeroot(u);
    access(v);
    sp.splay(v);
    int lc = sp.ch[v][0];
    sp.fa[lc] = 0;
    sp.ch[v][0] = 0;
    sp.pull(v);
  }
  ll path_sum(int u,int v){
    makeroot(u);
    access(v);
    sp.splay(v);
    return sp.sum[v];
  }
  void addval(int u,int val){
    sp.splay(u);
    sp.val[u] += val;
    sp.pull(u);
    return;
  }
  int find(int p){
    access(p);
    return sp.get_sz(p,1);
  }
};
```

4 Geometry

4.1 Point [47044e]

```
template<typename T = int>
struct Pt{
  T x,y;
  Pt (T xx = (T)(0),T yy = (T)(0)):x(xx),y(yy){}
  Pt operator+(Pt b)const{return Pt(x+b.x,y+b.y);}
  Pt operator-(Pt b)const{return Pt(x-b.x,y-b.y);}
  T operator*(Pt b)const{return x*b.x+y*b.y;}
  T operator^(Pt b)const{return x*b.y-y*b.x;}
  T operator/(Pt b)const{return x*b.y-y*b.x;}
  bool operator
      <(Pt b)const{return x == b.x?y<b.y:x<b.x;}

  friend int dir(Pt a,Pt b){//returns sign(a ^ b)
    auto re = a ^ b;
    return re<0?-1:re>0?1:0;
  }
  friend bool onseg(Pt x,Pt s,Pt e){
    if(((e-x)^(s-x)) != 0)return false;
    else if((s-x)*(e-x)>0)return false;
    return true;
  }
  friend int
       intersect(Pt s1,Pt e1,Pt s2,Pt e2){//returns 0
       if doesn't intersect,1 if intersect,2 if on line
    if(onseg(s1,s2,e2)||onseg(e1,s2,
        e2)||onseg(s2,s1,e1)||onseg(e2,s1,e1))return 2;
    if(dir(s1-s2,e2-s2)*dir(e1-s2,e2-s2)<0&&
        dir(s2-s1,e1-s1)*dir(e2-s1,e1-s1)<0)return 1;
    return 0;
  }

};
```

4.2 Convex Hull [2a54da]

```
//needs Point.cpp
template<typename T = int>
struct ConvexHull{//returns in clockwise direction
  vector<Pt<T>> solve(vector<Pt<T>> v){
    sort(v.begin(),v.end());
    vector<Pt<T>> u,d;
    for(auto &i:v){
      while(u.size()>1&&((i-u.end()[-1])
          ^(u.end()[-2]-u.end()[-1]))>=0)u.pop_back();
      while(d.size()>1&&((i-d.end()[-1])
          ^(d.end()[-2]-d.end()[-1]))<=0)d.pop_back();
      u.push_back(i);
      d.push_back(i);
    }
    for(int i =
        1;i+1<d.size();i++)u.push_back(d.end()[-1-i]);
    return u;
  }
};
```

4.3 Minkowski sum [9db95e]

```
//needs Point template
template <typename T>
vector<Pt
    <T>> minkowski(vector<Pt<T>> va,vector<Pt<T>> vb){
  deque<Pt<T>> a,b;
  for(auto &i:va)a.push_back(i);
  for(auto &i:vb)b.push_back(i);
  Pt head = *min_element(a.begin(),a.end());
  while(a[0].x != head.x||a[0].y != head.y){
    a.push_back(a[0]);
    a.pop_front();
  }
  head = *min_element(b.begin(),b.end());
  while(b[0].x != head.x||b[0].y != head.y){
    b.push_back(b[0]);
    b.pop_front();
  }
  a.push_back(a[0]);
  b.push_back(b[0]);
  int p1 = 0,p2 = 0;
  vector<Pt<T>> re;
  while(p1 < a.size()&&p2 < b.size()){
    //cerr<<a
        .size()<<','<<b.size()<<":"<<p1<<' '<<p2<<endl;
    int dir = 0;
    re.push_back(a[p1]+b[p2]);
    if(p1+1 == a.size())dir = 1;
    else if(p2+1 == b.size())dir = 0;
    else
        if(((a[p1+1]-a[p1])^(b[p2+1]-b[p2]))>0)dir = 0;
```

```
    else dir = 1;
    if(dir == 0)p1++;
    else p2++;
  }
  return re;
}
```

4.4 Half Plane Intersection [591603]

```
#include <bits/stdc++.h>
using namespace std;


using i128 = __int128_t;
#define IM imag
#define RE real
using lld = int64_t;
using llf = long double;
using PT = complex<lld>;
using PF = complex<llf>;
using P = PT;

int sgn(lld x) { return (x > 0) - (x < 0); }
lld cross(P a, P b) { return IM(conj(a) * b); }
int ori(P a, P b, P c) {
  return sgn(cross(b - a, c - a));
}
int quad(P p) {
  return (IM(p) == 0) // use sgn for PF
    ? (RE(p) < 0 ? 3 : 1) : (IM(p) < 0 ? 0 : 2);
}
PF toPF(PT p) { return PF{RE(p), IM(p)}; }
template <typename V> llf area(const V & pt) {
  lld ret = 0; // BE CAREFUL OF TYPE!
  for (int i = 1; i + 1 < (int)pt.size(); i++)
    ret += cross(pt[i] - pt[0], pt[i+1] - pt[0]);
  return ret / 2.0;
}
int argCmp(P a, P b) {
  // returns 0/+-1, starts from theta = -PI
  int qa = quad(a), qb = quad(b);
  if (qa != qb) return sgn(qa - qb);
  return sgn(cross(b, a));
}
struct Line {
  P st, ed, dir;
  Line (P s, P e) : st(s), ed(e), dir(e - s) {}
}; using LN = const Line &;
PF intersect(LN A, LN B) {
  llf t = cross(B.st - A.st, B.dir) /
    llf(cross(A.dir, B.dir));
  return toPF(A.st) + toPF(A.dir) * t; // C^3 / C^2
}
bool cov(LN l, LN A, LN B) {
  i128 u = cross(B.st-A.st, B.dir);
  i128 v = cross(A.dir, B.dir);
  // ori(l.st, l.ed, A.st + A.dir*(u/v)) <= 0?
  i128 x = RE(A.dir) * u + RE(A.st - l.st) * v;
  i128 y = IM(A.dir) * u + IM(A.st - l.st) * v;
  return sgn(x*IM(l.dir) - y*RE(l.dir)) * sgn(v) >= 0;
} // x, y are C^3, also sgn<i128> is needed
bool operator<(LN a, LN b) {
  if (int c = argCmp(a.dir, b.dir)) return c == -1;
  return ori(a.st, a.ed, b.st) < 0;
}
// cross(pt-line.st, line.dir)<=0 <-> pt in half plane
// the half plane is the LHS when going from st to ed
llf HPI(vector<Line> &q) {
  sort(q.begin(), q.end());
  int n = (int)q.size(), l = 0, r = -1;
  for (int i = 0; i < n; i++) {
    if (i && !argCmp(q[i].dir, q[i-1].dir)) continue;
    while (l < r && cov(q[i], q[r-1], q[r])) --r;
    while (l < r && cov(q[i], q[l], q[l+1])) ++l;
    q[++r] = q[i];
  }
  while (l < r && cov(q[l], q[r-1], q[r])) --r;
  while (l < r && cov(q[r], q[l], q[l+1])) ++l;
  n = r - l + 1; // q[l .. r] are the lines
  if (n <= 2 || !argCmp(q[l].dir, q[r].dir)) return 0;
  vector<PF> pt(n);
  for (int i = 0; i < n; i++)
    pt[i] = intersect(q[i+l], q[(i+1)%n+l]);
  return area(pt);
} // test @ 2020 Nordic NCPC : BigBrother
```

5 String

5.1 KMP [bb2a1b]

```
template <typename T>
struct KMP {
    void operator()(T a, int n, int *pi) {
        pi[0] = -1, pi[1] = 0;
        for (int i = 1; i < n; i++) {
            int j = pi[i];
            while (j >= 0 && a[i] != a[j]) j = pi[j];
            pi[i + 1] = j + 1;
        }
    }
};
```

5.2 Z algorithm [58b140]

```
template <typename T>
struct Z_alg {
    void operator()(T a, int n, int *z) {
        fill(z, z + n + 1, 0);
        int l = 0;
        for (int i = 1; i <= n; i++) {
            if (i >= l + z[l]) {
                while (i + z[i] < n
                      && a[i + z[i]] == a[z[i]]) z[i]++;
                l = i;
                continue;
            }
            int i_ = i - l;
            if (i_ + z[i_] == z[l]) {
                z[i] = z[i_];
                while (i + z[i] < n
                      && a[i + z[i]] == a[z[i]]) z[i]++;
                l = i;
                continue;
            }
            z[i] = (
                i_ + z[i_] < z[l] ? z[i_] : z[l] - i_);
        }
    }
};
```

5.3 manacher [c7bcd5]

```
template <typename T>
struct MANACHER {
    void operator()(T a, int n, int *mn) {
        fill(mn, mn + n, 0);
        int l = 0;
        for (int i = 1; i < n; i++) {
            if (i > l + mn[l]) {
                while (i - mn[i] - 1 >= 0
                    && i + mn[i] + 1 < n && a[i - mn[i]
                     - 1] == a[i + mn[i] + 1]) mn[i]++;
                l = i;
                continue;
            }
            int i_ = 2 * l - i;
            if (i_ - mn[i_] == l - mn[l]) {
                mn[i] = mn[i_];
                while (i - mn[i] - 1 >= 0
                    && i + mn[i] + 1 < n && a[i - mn[i]
                     - 1] == a[i + mn[i] + 1]) mn[i]++;
                l = i;
                continue;
            }
            mn[i] = (i_ - mn[i_]
                > l - mn[l] ? mn[i_] : i_ - l + mn[l]);
        }
    }
};
```

5.4 Suffix Array (SAIS) [a683f1]

```
int SA[MXN * 2], H[MXN], RA[MXN];
namespace SAIS {
    bool _t[MXN * 2];
    int _s[MXN *
         2], _c[MXN * 2], x[MXN], _p[MXN], _q[MXN * 2];
    void pre(int *sa, int *c, int n, int z) {
        fill_n(sa, n, 0);
        copy_n(c, z, x);
    }
    void induce(int
         *sa, int *c, int *s, bool *t, int n, int z) {
        copy_n(c, z - 1, x + 1);
```

```
        FOR(i, 0, n) {
            if (sa[i] && !t[sa[i] - 1]) {
                sa[x[s[sa[i] - 1]]++] = sa[i] - 1;
            }
        }
        copy_n(c, z, x);
        for (int i = n - 1; i >= 0; i--) {
            if (sa[i] && t[sa[i] - 1]) {
                sa[--x[s[sa[i] - 1]]] = sa[i] - 1;
            }
        }
    }
    void sais(int *s, int *sa, int
         *p, int *q, bool *t, int *c, int n, int z) {
        bool uniq = t[n - 1] = true;
        int nn = 0, nmxz =
             -1, *nsa = sa + n, *ns = s + n, last = -1;
        fill_n(c, z, 0);
        FOR(i, 0, n) uniq &= ++c[s[i]] < 2;
        partial_sum(c, c + z, c);
        if (uniq) {
            FOR(i, 0, n) sa[--c[s[i]]] = i;
            return;
        }
        for (int i = n - 2; i >= 0; i--) {
            t[i] = (s[i] ==
                s[i + 1] ? t[i + 1] : s[i] < s[i + 1]);
        }
        pre(sa, c, n, z);
        FOR(i, 1, n) {
            if (t[i] && !t[i - 1]) {
                sa[--x[s[i]]] = p[q[i] = nn++] = i;
            }
        }
        induce(sa, c, s, t, n, z);
        FOR(i, 0, n) {
            if (sa[i] && t[sa[i]] && !t[sa[i] - 1]) {
                bool neq = last < 0 || !equal(s + sa[
                    i], s + p[q[sa[i]] + 1], s + last);
                ns[q[last = sa[i]]] = nmxz += neq;
            }
        }
        sais(ns, nsa,
            p + nn, q + n, t + n, c + z, nn, nmxz + 1);
        pre(sa, c, n, z);
        for (int i = nn - 1; i >= 0; i--) {
            sa[--x[s[p[nsa[i]]]]] = p[nsa[i]];
        }
        induce(sa, c, s, t, n, z);
    }
    void mkhei(int n) {
        for (int i = 0, j = 0; i < n; i++) {
            if (RA[i]) {
                for (; i + j < n
                     && SA[RA[i] - 1] + j < n && _s[i +
                     j] == _s[SA[RA[i] - 1] + j]; ++j);
                H[RA[i]] = j, j = max(0, j - 1);
            }
        }
    }
    void build(int *s, int n, int mxc) {
        copy_n(s, n, _s), _s[n] = 0;
        sais(_s, SA, _p, _q, _t, _c, n + 1, mxc);
        copy_n(SA + 1, n, SA);
        FOR(i, 0, n) RA[SA[i]] = i;
        mkhei(n);
        copy(H + 1, H + n, H);
    }
}
```

5.5 AC automaton [c073c7]

```
#define FOR(i, j, k) for (int i = j, Z = k; i < Z; i++)

struct AC {
    int nc;
    char c[MXN];
    int pi[MXN], p[MXN], nxt[MXN][MXC];
    void init() {
        nc = 2;
        fill(nxt[0], nxt[0] + MXC, 1);
        fill(nxt[1], nxt[1] + MXC, -1);
    }
    int add_node(int par, char _c) {
        c[nc] = _c;
        p[nc] = par;
        fill(nxt[nc], nxt[nc] + MXC, -1);
        return nc++;
    }
    int push(string &s) {
        int now = 1;
        for (auto &i : s) {
            if (nxt[now][i - 'a'] == -1)
                nxt[now][i - 'a'] = add_node(now, i);
            now = nxt[now][i - 'a'];
        }
        return now;
    }
    void build() {
        queue<int> q;
        pi[1] = 0;
        FOR(i, 0, MXC) {
            if (nxt[1][
                i] == -1) nxt[1][i] = nxt[pi[1]][i];
            else q.push(nxt[1][i]);
        }
        while (q.size()) {
            int id = q.front();
            q.pop();
            pi[id] = nxt[pi[p[id]]][c[id] - 'a'];
            FOR(i, 0, MXC) {
                if (nxt[id][i]
                    == -1) nxt[id][i] = nxt[pi[id]][i];
                else q.push(nxt[id][i]);
            }
        }
    }
};
```

6 Math

6.1 FFT [9ff2a9]

```
#define TYPE double
typedef complex<TYPE> cd;
#undef TYPE

struct FFT {
    const double pi = acos(-1);
    cd cis(double theta) {
        return cd(cos(theta), sin(theta));
    }
    cd OMEGA(int n, int k) {
        return cis(pi * 2 * k / n);
    }
    void operator()(cd *a, int N, bool inv) {
        auto REV = [&](int x) -> int {
            int ans = 0;
            for (int i = 1; i < N; i <<= 1) {
                ans <<= 1;
                if (i & x) ans |= 1;
            }
            return ans;
        };
        FOR(i, 0, N) {
            int r = REV(i);
            if (i < r) swap(a[i], a[r]);
        }
        for (int w = 1; w < N; w <<= 1) {
            int on = w << 1;
            for (int ok = 0; ok < w; ok++) {
                cd omega
                    = OMEGA(on, (inv ? -1 : 1) * ok);
                for (int s = 0; s < N; s += on) {
                    cd &L =
                        a[s + ok], &R = a[s + ok + w];
                    cd l = L, r = omega * R;
                    L = l + r;
                    R = l - r;
                }
            }
        }
        if (inv) {
            for (int i = 0; i < N; i++) a[i] /= N;
        }
    }
} fft;
```

6.2 FWT [b10773]

```
//      AND        OR         XOR
//  | 1  1 |   | 1  0 |   | 1  1 |
//  | 0  1 |   | 1  1 |   | 1 -1 |
```

```
struct FWT {
    // mod operations ADD, SUB, MUL, POW (if needed)
    void btf(int &L, int &R, bool inv) { // sample: XOR
        int l = L, r = R;
        L = ADD(l, r);
        R = SUB(l, r);
    }
    void operator()(int *a, int n, bool inv) {
        // sample: XOR
        for (int w = 1; w < n; w <<= 1) {
            FOR(i, 0, n) if (i & w) {
                btf(a[i - w], a[i], inv);
            }
        }
        if (inv) {
            int x = POW(n, mod - 2);
            FOR(i, 0, n) a[i] = MUL(a[i], x);
        }
    }
};
```

6.3 NTT [08e3ea]

```
#define FOR(i, j, k) for (int i = j, Z = k; i < Z; i++)

struct NTT {
    const static int LG = 20;
    int mod;
    int o[(1 << LG) + 1];
    int ADD(int a, int b) {
        // help yourself
    }
    int SUB(int a, int b) {
        // help yourself
    }
    int MUL(int a, int b) {
        // help yourself
    }
    int POW(int a, int b) {
        // help yourself
    }
    NTT(int g, int gap, int _mod) {
        mod = _mod;
        o[0] = 1;
        int pp = POW(g, gap);
        FOR(i,
            1, (1 << LG) + 1) o[i] = MUL(o[i - 1], pp);
    }
    void operator()(int *a, int n, bool inv) {
        auto REV = [&](int x) -> int {
            int ans = 0;
            for (int w = 1; w < n; w <<= 1) {
                ans = (ans << 1) | (x & 1);
                x >>= 1;
            }
            return ans;
        };
        FOR(i, 0, n) {
            int j = REV(i);
            if (i < j) swap(a[i], a[j]);
        }
        for (int w = 1; w < n; w <<= 1) {
            int owo = 1 << (LG - __lg(w) - 1), oid = 0;
            FOR(i, 0, w) {
                int omega
                    = o[inv ? (1 << LG) - oid : oid];
                for (int s = 0; s < n; s += (w << 1)) {
                    int &L
                        = a[s + i], &R = a[s + w + i];
                    int l = L, r = MUL(omega, R);
                    L = ADD(l, r);
                    R = SUB(l, r);
                }
                oid += owo;
            }
        }
        if (inv) {
            int x = POW(n, mod - 2);
            FOR(i, 0, n) a[i] = MUL(a[i], x);
        }
    }
};

NTT ntt1(3, 952, 998244353);
NTT ntt2(3, 100, 104857601);
NTT ntt3(3, 160, 167772161);
```

```
namespace POLY {
    const int MXM = 4 * MXN;
    int a[MXN], b[MXN];
    vector<int
        > VMUL(vector<int> v, vector<int> w, int m) {
        int N = 4 << __lg(m);
        fill(a, a + N, 0);
        fill(b, b + N, 0);
        int na = min((int)
             v.size(), m), nb = min((int) w.size(), m);
        FOR(i, 0, na) a[i] = v[i];
        FOR(i, 0, nb) b[i] = w[i];
        ntt(a, N, false);
        ntt(b, N, false);
        FOR(i, 0, N) a[i] = MUL(a[i], b[i]);
        ntt(a, N, true);
        vector<int> ans;
        FOR(i, 0, m) ans.push_back(a[i]);
        return ans;
    }
}
```

6.4 Chinese Remainder Theorem [6fdd6f]

```
using lll = __int128_t;

struct ICRT {
    lll p1, p2, p3;
    lll c1, c2, c3;
    ICRT() {}
    ICRT(lll _p1,
        lll _p2, lll _p3) : p1(_p1), p2(_p2), p3(_p3) {
        auto POW = [&](lll a, lll b, lll mod) -> lll {
            lll ans = 1;
            while (b) {
                if (b & 1) ans = ans * a % mod;
                b >>= 1;
                a = a * a % mod;
            }
            return ans;
        };
        c1 = POW(p2 * p3 % p1, p1 - 2, p1) * p2 * p3;
        c2 = POW(p3 * p1 % p2, p2 - 2, p2) * p3 * p1;
        c3 = POW(p1 * p2 % p3, p3 - 2, p3) * p1 * p2;
    }
    lll operator()(int r1, int r2, int r3) {
        return (c1
            * r1 + c2 * r2 + c3 * r3) % (p1 * p2 * p3);
    }
};

ICRT icrt(998244353, 104857601, 167772161);
```

6.5 Pollard Rho [b24d9c]

```
//needs mad,mub,mul,pw with changable mod
//!!!use int128 for pw and mul

bool isprime(ll x) {
  if (x <= 2 || ~x & 1) return x == 2;
  auto witn = [&](ll a, int t) {
    for (ll a2; t-- && (a2 = mul(a, a, x)); a = a2)
      if (a2 == 1 && a != 1 && a != x - 1) return true;
    return a > 1;
  };
  int t = __builtin_ctzll(x-1); ll odd = (x-1) >> t;
  for (ll m:
      {2, 325,
          9375, 28178, 450775, 9780504, 1795265022})
  if (witn(pw(m % x, odd, x), t)) return false;
  return true;
}

ll pollard_rho(ll n) {
  static mt19937_64 rnd(120821011);
  if (!(n & 1)) return 2;
  ll y = 2, z = y, c = rnd() % n, p = 1, i = 0, t;
  auto f = [&](ll x) {
    return mad(mul(x, x, n), c, n); };
  do {
    p = mul(mub(z = f(f(z)), y = f(y), n), p, n);
    if (++i &= 63) if (i == (i & -i)) t = gcd(p, n);
  } while (t == 1);
  return t == n ? pollard_rho(n) : t;
}

vector<ll> factorize(ll k){
```

```
  if(k == 1)return {};
  else if(isprime(k))return {k};
  else{
    vector<ll> re;
    function<void(ll)> dc = [&](ll k){
      if(isprime(k)){
        re.push_back(k);
        return;
      }
      ll x = pollard_rho(k);
      dc(x);dc(k/x);
    };
    dc(k);
    sort(re.begin(),re.end());
    return re;
  }
}
```