

算法模板

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目录

1	计算几何	3	3	数据结构	25
1.1	自适应辛普森	3	3.1	线段树套伸展树	25
1.2	立体几何	3	3.2	线段树	28
1.3	皮克定理	4	3.2.1	线段树合并	28
1.4	平面几何	4	3.2.2	线段树	28
1.5	动态凸包	7	3.2.3	矩形面积异或并	29
2	数论	8	3.2.4	矩形面积并	30
2.1	高斯消元	8	3.3	树链剖分	31
2.2	逆元	8	3.4	树状数组	32
2.3	线性基	9	3.4.1	树状数组	32
2.4	约瑟夫环	10	3.4.2	二维树状数组	32
2.5	欧拉函数	10	3.5	最近公共祖先	32
2.6	杜教筛	10	3.5.1	欧拉序 + RMQ	32
2.7	数论函数打表	11	3.5.2	倍增	33
2.8	扩展卢卡斯	11	3.5.3	tarjan	33
2.9	扩展中国剩余定理	12	3.6	伸展树	34
2.10	快速幂	12	3.7	主席树	35
2.11	快速傅里叶变换	13	3.8	dfs 序	36
2.12	快速乘	13	3.9	ST 表	36
2.13	卢卡斯定理	13	3.10	Link Cut Tree	36
2.14	十进制快速幂	14	4	字符串	38
2.15	二次剩余	14	4.1	最小表示法	38
2.16	三分	15	4.2	扩展 kmp	38
2.17	min25 筛	15	4.3	字典树	38
2.18	SG 函数	16	4.4	回文树	39
2.19	Pollard Rho	16	4.5	哈希	39
2.20	NTT	17	4.6	后缀自动机	39
2.21	Miller Rabin	19	4.7	后缀数组	40
2.22	BigInteger	20	4.8	kmp	41
2.23	BSGS	21	4.9	AC 自动机	41
2.24	BM	22	5	图论	43
			5.1	次小生成树	43

5.2	最小树形图	44
5.3	拓扑排序	44
5.4	Tarjan	45
5.5	Dinic	45
6	其它	46
6.1	闰年	46
6.2	蔡勒公式	46
6.3	莫队算法	46
6.3.1	静态莫队	46
6.3.2	带修莫队	47
6.4	快读	47
6.5	对拍	48
6.6	vimrc	48
6.7	int128	48

1 计算几何

1.1 自适应辛普森

```
typedef double db;
struct Simpson {
    /* 系数 */
    db F(db x) { return /* 表达式 */; }
    db Simpson(db l, db r) {
        db m = (l + r) / 2.0;
        return (F(l) + 4 * F(m) + F(r)) * (r - l) / 6.0;
    }
    db Asr(db l, db r, db ans, db eps) {
        db m = (l + r) / 2.0;
        db l_ans = Simpson(l, m), r_ans = Simpson(m, r);
        if (fabs(l_ans + r_ans - ans) <= 15.0 * eps) return
            l_ans + r_ans + (l_ans + r_ans - ans) / 15.0;
        return Asr(l, m, l_ans, eps / 2.0) + Asr(m, r, r_ans,
            eps / 2.0);
    }
};
```

1.2 立体几何

```
typedef double db;
const db inf = 1e100;
const db eps = 1e-9;
const db pi = acos(-1.);
const db delta = 0.98;
int Sgn(db k) { return std::fabs(k) < eps ? 0 : (k < 0 ?
    -1 : 1); }
int Cmp(db k1, db k2) { return Sgn(k1 - k2); }
db Min(db k1, db k2) { return Cmp(k1, k2) < 0 ? k1 : k2; }
db Max(db k1, db k2) { return Cmp(k1, k2) > 0 ? k1 : k2; }
struct point { db x, y, z; }
bool operator == (point k1, point k2) { return !Sgn(k1.x
    - k2.x) && !Sgn(k1.y, k2.y) && !Sgn(k1.z, k2.z); }
point operator + (point k1, point k2) { return (point){k1
    .x + k2.x, k1.y + k2.y, k1.z + k2.z}; }
point operator - (point k1, point k2) { return (point){k1
    .x - k2.x, k1.y - k2.y, k1.z - k2.z}; }
point operator * (point k1, db k2) { return (point){k1.x
    * k2, k1.y * k2, k1.z * k2}; }
point operator / (point k1, db k2) { return (point){k1.x
    / k2, k1.y / k2, k1.z / k2}; }
db operator * (point k1, point k2) { k1.x * k2.x + k1.y *
    k2.y + k1.z * k2.z; }
```

```
point operator ^ (point k1, point k2) { return (point){k1
    .y * k2.z - k1.z * k2.y, k1.z * k2.x - k1.x * k2.z,
    k1.x * k2.y - k1.y * k2.x}; }
db GetLen(point k) { return std::sqrt(k * k); }
db GetLen2(point k) { return k * k; }
point GetUnit(point k) { return k / GetLen(k); }
db GetDis(point k1, point k2) { return GetLen(k2 - k1); }
db GetDis2(point k1, point k2) { return GetLen2(k2 - k1);
    }
db GetMinSphereR(std::vector<point> p) {
    point cur = p[0];
    db pro = 10000, ret = inf;
    while (pro > eps) {
        int idx = 0;
        for (int i = 0; i < p.size(); ++i)
            if (Cmp(GetDis(cur, p[i]), GetDis(cur, p[idx])) >
                0)
                idx = i;
        db r = GetDis(cur, p[idx]);
        ret = Min(ret, r);
        cur = cur + (p[idx] - cur) / r * pro;
        pro *= delta;
    }
    return ret;
}
struct line { point s, t; };
struct seg: public line {};
db GetLen(seg k) { return GetDis(k.s, k.t); }
db GetLen2(seg k) { return GetDis2(k.s, k.t); }
db GetDis(point k1, line k2) { return std::fabs((k1 - k2.
    s) ^ (k2.t - k2.s)) / GetLen(k2); }
db GetDis(point k1, seg k2) {
    if (Sgn((k1 - k2.s) * (k2.t - k2.s)) < 0 || Sgn((k1 -
        k2.t) * (k2.s - k2.t)) < 0)
        return Min(GetDis(k1, k2.s), GetDis(k1, k2.t));
    return GetDis(k1, seg); // point to line dis
}
struct sphere { point o; db r; };
db GetV(sphere k) { return 4. / 3. * pi * k.r * k.r * k.r
    ; }
db GetInterV(sphere k1, sphere k2) {
    db dis = GetDisP2P(k1.o, k2.o);
    if (Sgn(dis - k1.r - k2.r) >= 0) return ret;
    if (Sgn(k2.r - (dis + k1.r)) >= 0) return GetV(k1);
    else if (Sgn(k1.r - (dis + k2.r)) >= 0) return GetV(k2)
        ;
    db len1 = ((k1.r * k1.r - k2.r * k2.r) / dis + dis) /
        2;
    db len2 = dis - len1;
    db x1 = k1.r - len1, x2 = k2.r - len2;
    db v1 = pi * x1 * x1 * (k1.r - x1 / 3.0);
    db v2 = pi * x2 * x2 * (k2.r - x2 / 3.0);
    return v1 + v2;
}
```

1.3 皮克定理

polygon: $S = in + (on / 2) - 1$

1.4 平面几何

```
typedef double db; // typedef long double db;
const db inf = 1e100;
const db eps = 1e-9;
const db delta = 0.98;
int Sgn(db k) { return std::fabs(k) < eps ? 0 : (k < 0 ? -1 : 1); }
int Cmp(db k1, db k2) { return Sgn(k1 - k2); }
bool IsInMid(db k1, db k2, db k3) { return Sgn(k1 - k3) * Sgn(k2 - k3) <= 0; }
db Max(db k1, db k2) { return Cmp(k1, k2) > 0 ? k1 : k2; }
db Min(db k1, db k2) { return Cmp(k1, k2) < 0 ? k1 : k2; }
struct point { db x, y; };
bool operator == (point k1, point k2) { return !Cmp(k1.x, k2.x) && !Cmp(k1.y, k2.y); }
point operator + (point k1, point k2) { return (point){k1.x + k2.x, k1.y + k2.y}; }
point operator - (point k1, point k2) { return (point){k1.x - k2.x, k1.y - k2.y}; }
point operator * (point k1, db k2) { return (point){k1.x * k2, k1.y * k2}; }
point operator / (point k1, db k2) { return (point){k1.x / k2, k1.y / k2}; }
db operator * (point k1, point k2) { return k1.x * k2.x + k1.y * k2.y; }
db operator ^ (point k1, point k2) { return k1.x * k2.y - k1.y * k2.x; }
bool IsInMid(point k1, point k2, point k3) { return IsInMid(k1.x, k2.x, k3.x) && IsInMid(k1.y, k2.y, k3.y); }
db GetLen(point k) { return std::sqrt(k * k); }
db GetLen2(point k) { return k * k; }
point GetUnit(point k) { return k / GetLen(k); }
db GetDis(point k1, point k2) { return GetLen(k2 - k1); }
db GetDis2(point k1, point k2) { return GetLen2(k2 - k1); }
db GetAng(point k1, point k2) { return std::atan2((k1 ^ k2), (k1 * k2)); }
point Rotate(point k, db ang) { return (point){k.x * std::cos(ang) - k.y * std::sin(ang), k.x * std::sin(ang) + k.y * std::cos(ang)}; }
```

```
point Rotate90(point k) { return (point){-k.y, k.x}; }
struct line { point s, t; };
struct seg: public line {}; // typedef line seg
db GetLen(seg k) { return GetDis(k.s, k.t); }
bool IsOn(point k1, seg k2) { return !Sgn((k1 - k2.s) ^ (k2.t - k2.s)) && Sgn((k1 - k2.s) * (k1 - k2.t)) <= 0; }
point Proj(point k1, line k2) { point k = k2.t - k2.s; return k2.s + k * ((k1 - k2.s) * k) / GetLen(k); }
point Reflect(point k1, line k2) { return Proj(k1, k2) * 2 - k1; }
bool IsParallel(line k1, line k2) { return !Sgn((k1.s - k1.t) ^ (k2.s - k2.t)); }
bool IsInter(seg k1, seg k2) { return Max(k1.s.x, k1.t.x) >= Min(k2.s.x, k2.t.x) && Max(k2.s.x, k2.t.x) >= Min(k1.s.x, k1.t.x) && Max(k1.s.y, k1.t.y) >= Min(k2.s.y, k2.t.y) && Max(k2.s.y, k2.t.y) >= Min(k1.s.y, k1.t.y) && Sgn((k2.s - k1.t) ^ (k1.s - k1.t)) * Sgn((k2.t - k1.t) ^ (k1.s - k1.t)) <= 0 && Sgn((k1.s - k2.t) ^ (k2.s - k2.t)) * Sgn((k1.t - k2.t) ^ (k2.s - k2.t)) <= 0; }
bool IsInter(line k1, seg k2) { return Sgn((k2.s - k1.t) ^ (k1.s - k1.t)) * Sgn((k2.t - k1.t) ^ (k1.s - k1.t)) <= 0; }
bool IsInter(line k1, line k2) { if (!IsParallel(k1, k2)) return true; return !Sgn((k1.s - k2.s) ^ (k2.t - k2.s)); }
db GetDis(point k1, line k2) { point k = Proj(k1, k2); return GetDis(k1, k); }
db GetDis(point k1, seg k2) { point k = Proj(k1, k2); if (IsInMid(k2.s, k2.t, k)) return GetDis(k1, k); return Min(GetDis(k1, k2.s), GetDis(k1, k2.t)); }
point Cross(line k1, line k2) { db w1 = (k1.s - k2.s) ^ (k2.t - k2.s), w2 = (k2.t - k2.s) ^ (k1.t - k2.s); return (k1.s * w2 + k1.t * w1) / (w1 + w2); }
// 平面直线图(PSLG)
struct edge { int u, v; db ang; };
struct PSLG { int n, m, face_cnt; // 多边形数 point p[maxn]; std::vector<edge> e; std::vector<int> g[maxn]; bool vis[maxn * 2]; }
```

```

int left[maxn * 2], prev[maxn * 2];
std::vector<polygon> faces; // 多边形
db area[maxn]; // 多边形面积
void Init() {
    n = m = 0;
    for (int i = 0; i < n; ++i) g[i].clear();
    e.clear();
    faces.clear();
}
// 有向线段pt.x→pt.y的极角
db GetAng(point pt) {
    return std::atan2(pt.y, pt.x);
}
void AddEdge(int u, int v) {
    e.push_back((edge){u, v, GetAng(p[v] - p[u])});
    e.push_back((edge){v, u, GetAng(p[u] - p[v])});
    m = e.size();
    g[u].push_back(m - 2);
    g[v].push_back(m - 1);
}
// 找出faces并计算面积
void Build() {
    for (int u = 0; u < n; ++u) {
        int sz = g[u].size();
        for (int i = 0; i < sz; ++i)
            for (int j = i + 1; j < sz; ++j)
                if (e[g[u][i]].ang > e[g[u][j]].ang) std::swap(
                    g[u][i], g[u][j]);
        for (int i = 0; i < sz; ++i) prev[g[u][(i + 1) % sz]] = g[u][i];
    }
    face_cnt = 0;
    memset(vis, false, sizeof(vis));
    for (int u = 0; u < n; ++u) {
        int sz = g[u].size();
        for (int i = 0; i < sz; ++i) {
            int v = g[u][i];
            // 卷包裏逆时针找圈
            if (!vis[v]) {
                ++face_cnt;
                polygon poly;
                while (true) {
                    vis[v] = 1;
                    left[v] = face_cnt;
                    int f = e[v].u;
                    poly.push_back(p[f]);
                    v = prev[v ^ 1];
                    if (v == g[u][i]) break;
                    assert(vis[v] == 0);
                }
                faces.push_back(poly);
            }
        }
    }
}

```

```

    for (int i = 0; i < face_cnt; ++i) area[i] = GetArea(
        faces[i]);
}
};
struct circle { point o; db r; };
// 切点
std::vector<point> TagentCP(circle k1, point k2) {
    db a = GetLen(k2 - k1.o), b = k1.r * k1.r / a, c = std::
        ::sqrt(Max(0., k1.r * k1.r - b * b));
    point k = GetUnit(k2 - k1.o), m = k1.o + k * b, del =
        Rotate90(k) * c;
    return {m - del, m + del};
}
// 公切线数量
int CheckPosCC(circle k1, circle k2) {
    if (Cmp(k1.r, k2.r) == -1) std::swap(k1, k2);
    double dis = k1.o.Dis(k2.o);
    int w1 = Cmp(dis, k1.r + k2.r), w2 = Cmp(dis, k1.r - k2
        .r);
    if (w1 > 0) return 4;
    if (w1 == 0) return 3;
    else if (w2 > 0) return 2;
    else if (w2 == 0) return 1;
    return 0;
}
// 交点
std::vector<point> GetCC(circle k1, circle k2) {
    int pd = CheckPosCC(k1, k2);
    if (pd == 0 || pd == 4) return {};
    double a = (k2.o - k1.o).Abs2();
    double cosA = (k1.r * k1.r + a - k2.r * k2.r) / (2 * k1
        .r * sqrt(std::max(a, 0.0)));
    double b = k1.r * cosA, c = sqrt(std::max(0.0, k1.r *
        k1.r - b * b));
    point k = (k2.o - k1.o).Unit(), m = k1.o + k * b, del =
        k.Turn90(c) * c;
    return {m - del, m + del};
}
circle GetCircle(point k1, point k2, point k3) {
    db a1 = k2.x - k1.x, b1 = k2.y - k1.y, c1 = (a1 * a1 +
        b1 * b1) * 0.5;
    db a2 = k3.x - k1.x, b2 = k3.y - k1.y, c2 = (a2 * a2 +
        b2 * b2) * 0.5;
    db d = a1 * b2 - a2 * b1;
    point o = (point){k1.x + (c1 * b2 - c2 * b1) / d, k1.y
        + (a1 * c2 - a2 * c1) / d};
    return (circle){o, GetDis(k1, o)};
}
db GetMinCircleR(std::vector<point> p) {
    point cur = p[0];
    db pro = 10000, ret = inf;
    while (Sgn(pro) > 0) {
        int idx = 0;
        for (int i = 0; i < p.size(); ++i)

```

```

        if (GetDis(cur, p[i]) > GetDis(cur, p[idx]))
            idx = i;
        db r = GetDis(cur, p[idx]);
        ret = Min(ret, r);
        cur = cur + (p[idx] - cur) / r * pro;
        pro *= delta;
    }
    return ret;
}

circle GetMinCircle(std::vector<point> p) {
    std::random_shuffle(p.begin(), p.end());
    circle ret = (circle){p[0], 0.};
    for (int i = 1; i < p.size(); ++i) {
        if (Cmp(GetDis(ret.o, p[i]), ret.r) <= 0) continue;
        ret = (circle){p[i], 0.};
        for (int j = 0; j < i; ++j) {
            if (Cmp(GetDis(ret.o, p[j]), ret.r) <= 0) continue;
            ret.o = (p[i] + p[j]) * 0.5;
            ret.r = GetDis(ret.o, p[i]);
            for (int k = 0; k < j; ++j) {
                if (Cmp(GetDis(ret.o, p[k]), ret.r) <= 0)
                    continue;
                ret = GetCircle(p[i], p[j], p[k]);
            }
        }
    }
    return ret;
}

typedef std::vector<point> polygon;
db GetArea(polygon &poly) {
    db ret = 0.;
    for (int i = 0; i < poly.size(); ++i) ret += poly[i] ^
        poly[(i + 1) % poly.size()];
    return ret * 0.5;
}

polygon GrahamScan(std::vector<point> p) {
    polygon ret;
    if (p.size() < 3) {
        for (point &v : p) ret.push_back(v);
        return ret;
    }
    int idx = 0;
    for (int i = 0; i < p.size(); ++i)
        if (Cmp(p[i].x, p[idx].x) < 0 || (!Cmp(p[i].x, p[idx].x) && Cmp(p[i].y, p[idx].y) < 0))
            idx = i;
    std::swap(p[0], p[idx]);
    std::sort(p.begin() + 1, p.end(),
        [&](const point &k1, const point &k2) {
            db tmp = (k1 - p[0]) ^ (k2 - p[0]);
            if (Sgn(tmp) > 0) return true;
            else if (!Sgn(tmp) && Cmp(GetDis(k1, p[0]), GetDis(k2, p[0])) <= 0) return true;
            return false;
        });

```

```

    }
};
ret.push_back(p[0]);
for (int i = 1; i < p.size(); ++i) {
    while (ret.size() > 1 && Sgn((ret.back() - ret[ret.size() - 2]) ^ (p[i] - ret[ret.size() - 2])) <= 0) ret.pop_back();
    ret.push_back(p[i]);
}
return ret;
}

bool IsIn(point p, const polygon &ch) {
    point base = ch[0];
    if (Sgn((p - base) ^ (ch[1] - p)) > 0 || Sgn((p - base) ^ (ch.back() - base)) < 0) return false;
    if (!Sgn((p - base) ^ (ch[1] - p)) && Cmp(GetLen(p - base), GetLen(ch[1] - base)) <= 0) return true;
    int idx = std::lower_bound(ch.begin(), ch.end(), p, [&](const point &k1, const point &k2) {
        return Sgn((k1 - base) ^ (k2 - base)) > 0;
    }) - ch.begin() - 1;
    return Sgn((ch[idx + 1] - ch[idx]) ^ (p - ch[idx])) >= 0;
}

polygon Minkowski(const polygon &k1, const polygon &k2) {
    int sz1 = k1.size(), sz2 = k2.size();
    std::queue<point> buf1, buf2;
    for (int i = 0; i < sz1; ++i) buf1.push(k1[(i + 1) % sz1] - k1[i]);
    for (int i = 0; i < sz2; ++i) buf2.push(k2[(i + 1) % sz2] - k2[i]);
    polygon ret;
    ret.push_back(k1[0] + k2[0]);
    while (!buf1.empty() && !buf2.empty()) {
        point tmp1 = buf1.front(), tmp2 = buf2.front();
        if (Sgn(tmp1 ^ tmp2) > 0) {
            ret.push_back(ret.back() + tmp1);
            buf1.pop();
        }
        else {
            ret.push_back(ret.back() + tmp2);
            buf2.pop();
        }
    }
    while (!buf1.empty()) {
        ret.push_back(ret.back() + buf1.front());
        buf1.pop();
    }
    while (!buf2.empty()) {
        ret.push_back(ret.back() + buf2.front());
        buf2.pop();
    }
    return GrahamScan(ret);
}

```

```

}
db RotateCaliper(polygon p) {
    db ret = -inf;
    if (p.size() == 3) {
        ret = Max(ret, GetDis(p[0], p[1]));
        ret = Max(ret, GetDis(p[0], p[2]));
        ret = Max(ret, GetDis(p[1], p[2]));
        return ret;
    }
    int cur = 2, sz = p.size();
    for (int i = 0; i < sz; ++i) {
        while (Cmp(std::fabs((p[i] - p[(i + 1) % sz]) ^ (p[
            cur] - p[(i + 1) % sz])), std::fabs((p[i] - p[(i
            + 1) % sz]) ^ (p[(cur + 1) % sz] - p[(i + 1) %
            sz])) < 0) cur = (cur + 1) % sz;
        ret = Max(ret, GetDis(p[i], p[cur]));
    }
    return ret;
}

```

1.5 动态凸包

```

// CodeForces 70D 动态凸包
#include <bits/stdc++.h>
typedef double db;
const int maxn = 1e5 + 5;
const db eps = 1e-9;
int Sgn(db k) { return fabs(k) < eps ? 0 : (k < 0 ? -1 : 1); }
int Cmp(db k1, db k2) { return Sgn(k1 - k2); }
struct point { db x, y; };
point operator - (point k1, point k2) { return (point){k1
    .x - k2.x, k1.y - k2.y}; }
point operator + (point k1, point k2) { return (point){k1
    .x + k2.x, k1.y + k2.y}; }
db operator * (point k1, point k2) { return k1.x * k2.x +
    k1.y * k2.y; }
db operator ^ (point k1, point k2) { return k1.x * k2.y -
    k1.y * k2.x; }
db GetLen(point k) { return sqrt(k * k); }
int n;
point basic;
point p[maxn];
std::set<point> set;
bool operator < (point k1, point k2) {
    k1 = k1 - basic; k2 = k2 - basic;
    db ang1 = atan2(k1.y, k1.x), ang2 = atan2(k2.y, k2.x);
    db len1 = GetLen(k1), len2 = GetLen(k2);
    if (Cmp(ang1, ang2) != 0) return Cmp(ang1, ang2) < 0;
    return Cmp(len1, len2) < 0;
}

```

```

std::set<point>::iterator Prev(std::set<point>::iterator
    k) {
    if (k == set.begin()) k = set.end();
    return --k;
}
std::set<point>::iterator Next(std::set<point>::iterator
    k) {
    ++k;
    return k == set.end() ? set.begin() : k;
}
bool Query(point k) {
    std::set<point>::iterator it = set.lower_bound(k);
    if (it == set.end()) it = set.begin();
    return Sgn((k - *(Prev(it))) ^ (*(it) - *(Prev(it))))
        <= 0;
}
void Insert(point k) {
    if (Query(k)) return;
    set.insert(k);
    std::set<point>::iterator cur = Next(set.find(k));
    while (set.size() > 3 && Sgn((k - *(Next(cur))) ^ (*(
        cur) - *(Next(cur)))) <= 0) {
        set.erase(cur);
        cur = Next(set.find(k));
    }
    cur = Prev(set.find(k));
    while (set.size() > 3 && Sgn((k - *(cur)) ^ (*(cur) -
        *(Prev(cur)))) >= 0) {
        set.erase(cur);
        cur = Prev(set.find(k));
    }
}
int main() {
    scanf("%d", &n);
    basic.x = basic.y = 0.0;
    for (int i = 1, T; i <= 3; ++i) {
        scanf("%d%d", &T, &p[i].x, &p[i].y);
        basic.x += p[i].x; basic.y += p[i].y;
    }
    basic.x /= 3.0; basic.y /= 3.0;
    for (int i = 1; i <= 3; ++i) set.insert(p[i]);
    for (int i = 4, T; i <= n; ++i) {
        scanf("%d%d", &T, &p[i].x, &p[i].y);
        if (T == 1) Insert(p[i]);
        else {
            if (Query(p[i])) printf("YES\n");
            else printf("NO\n");
        }
    }
    return 0;
}

```


2 数论

2.1 高斯消元

```
const int Mod = 1e9 + 7;
const int maxn = 1e3 + 5;
const double eps = 0.0000001;
const int INF = 0x3f3f3f3f;
int n, m;
double a[maxn][maxn], x[maxn];
bool manySolutionFlag = false, noSolution = false;
void Swap(int i, int j) {
    for (int k = 1; k <= n + 1; k++)
        swap(a[i][k], a[j][k]);
}
bool Check(int i) {
    bool vis = false;
    for (int j = 1; j <= n; j++) {
        if (fabs(a[i][j]) >= eps) vis = true;
    }
    if (!vis && fabs(a[i][n + 1]) >= eps) return false;
    return true;
}
void GS() {
    for (int i = 1; i <= n; i++) {
        bool flag = false;
        for (int j = i; j <= m; j++) {
            if (a[j][i] != 0) {
                Swap(j, i);
                flag = true;
                break;
            }
        }
        if (!flag) {
            manySolutionFlag = true;
        }
        for (int j = i + 1; j <= m; j++)
            for (int k = n + 1; k >= i; k--)
                a[j][k] = a[j][k] * 1. - a[i][k] * (a[j][i]
                    * 1./a[i][i] * 1.) * 1.;
    }
    for (int i = 1; i <= m; i++) {
        if (!Check(i)) {
            noSolution = true;
            return;
        }
    }
    for (int i = n; i >= 1; i--) {
        for (int j = i + 1; j <= n; j++) {
            a[i][n + 1] = a[i][n + 1] - a[i][j] * x[j];
            a[i][j] = 0;
        }
        x[i] = a[i][n + 1] * 1./a[i][i] * 1.;
    }
}
```

```

    }
    x[i] = a[i][n + 1] * 1./a[i][i] * 1.;
}
}
int main()
{
    cin >> n >> m;
    for (int i = 1; i <= m; i++)
        for (int j = 1; j <= n + 1; j++)
            cin >> a[i][j];
    GS();
    if (noSolution) cout << "No solutions" << endl;
    else if (manySolutionFlag) cout << "Many solutions" <<
        endl;
    else {
        for (int i = 1; i <= n; i++)
            cout << (int)(x[i] + 0.5) << endl;
    }
    return 0;
}
```

2.2 逆元

```
int inv[maxn]; // 逆推打表
void getInv(int n, int m) {
    inv[1] = 1;
    for (int i = 2; i <= n; i++)
        inv[i] = (long long) (m - m/i) * inv[m%i] % m;
}
long long ex_gcd(long long a, long long b, long long &x,
    long long &y) { // 扩展欧几里德求逆元
    if (!b) {
        x = 1; y = 0;
        return a;
    }
    long long d = ex_gcd(b, a % b, x, y);
    long long t = x;
    x = y; y = t - (a/b) * y;
    return d;
}
long long getInv(long long a, long long p) {
    long long x, y;
    ex_gcd(a, p, x, y);
    return (x % p + p) % p;
}
long long Ksm(long long a, long long b, long long mod) {
    // 逆推打阶乘逆元表
    long long res = 1;
    while (b) {
        if (b & 1) res = res * a % mod;
        a = a % a % mod;
    }
}
```

```

        b >>= 1;
    }
    return res;
}
long long Fac[maxn], inv[maxn];
void init() {
    Fac[0] = 1;
    for (int i = 1; i <= maxn; i++)
        Fac[i] = (Fac[i-1] * i) % mod;
    inv[maxn] = Ksm(Fac[maxn], mod-2);
    for (int i = maxn - 1; i >= 0; i--)
        inv[i] = inv[i+1] * (i+1) % mod;
}

```

2.3 线性基

```

struct LB{
    long long b[35], nb[35], tot;
    bool flag;
    LB () { // 初始化
        memset(b, 0, sizeof(b));
        flag = false;
    }
    LB(const LB& a) {
        for (int i = 0; i < 35; i++)
            b[i] = a.b[i];
        flag = a.flag;
    }
    void Ins(long long x) { // 插入
        for (int i = 34; i >= 0; i--)
            if(x & (1ll << i)) {
                if(!b[i]) { b[i] = x; return; }
                x ^= b[i];
            }
        flag = true; // 能xor出0
    }
    bool Fin(long long x) {
        if(x == 0 && flag) return true;
        for (int i = 34; i >= 0; i--)
            if(x >> i) x ^= b[i];
        return x == 0;
    }
    long long getMax(long long x) { // 得到最大值
        long long res = x;
        for (int i = 34; i >= 0; i--)
            res = max(res, res ^ b[i]);
        return res;
    }
    long long getMin(long long x) { // 得到最小值
        long long res = x;
        for (int i = 0; i <= 34; i++)

```

```

        if(b[i]) res ^= b[i];
        return res;
    }
    long long ReBuild() { // 重新Build 为下面的Kth
        for (int i = 34; i >= 0; i--) {
            if(b[i] == 0) continue;
            for (int j = i - 1; j >= 0; j--) {
                if(b[j] == 0) continue;
                if(b[i] & (1ll << j)) b[i] ^= b[j];
            }
        }
        for (int i = 0; i <= 34; i++)
            if(b[i]) nb[tot++] = b[i];
    }
    long long Kth_Max(long long k) { // 得到第k小的数, k > 1,
        if(flag) k--;
        if(k == 0) return 0;
        long long res = 0;
        if(k >= (1ll << tot)) return -1;
        for (int i = 34; i >= 0; i--)
            if(k & (1ll << i)) res ^= nb[i];
        return res;
    }
    LB Corss(LB k) { // 求交集
        LB res, tmp = k;
        for (int i = 0; i < 35; i++) {
            long long x = b[i], y = 0;
            bool vis = false;
            for (int j = 34; j >= 0; j--) {
                if(x >> j) {
                    if(k.b[j]) x ^= k.b[j], y ^= tmp.b[j];
                }
                else {
                    k.b[j] = x;
                    tmp.b[j] = y;
                    vis = true;
                    break;
                }
            }
        }
        if(!vis) res.b[i] = y;
    }
    return res;
}
    LB Merge(LB u) { // 合并两个线性集
        LB w = *this;
        for (int i = 34; i >= 0; i--) {
            if(u.b[i] == 0) continue;
            w.Ins(u.b[i]);
        }
        return w;
    }
};

```

2.4 约瑟夫环

```
long long Josephus(long long N, long long K) { // N 个人,
    第K 淘汰
    if(N == 1) return 0;
    if(N < K) {
        long long ret = 0;
        for (long long i = 2; i <= N; i++)
            ret = (ret + K) % i;
        return ret;
    }
    long long ret = Josephus(N - N/K, K);
    if(ret < N % K) ret = ret - N % K + N;
    else ret = ret - N % K + (ret - N % K) / (K - 1);
    return ret;
}
```

2.5 欧拉函数

```
int getPhi(int n) {
    int rea = n;
    for (int i = 2; i * i <= n; i++) {
        if (n % i == 0) {
            rea = rea - rea / i;
            while(n % i == 0) n /= i;
        }
    }
    if(n > 1) rea = rea - rea / n;
    return rea;
}

int phi[maxn]; // 递推
void getPhi() {
    for (int i = 1; i < maxn; i++)
        phi[i] = i;
    for (int i = 2; i < maxn; i++)
        if(phi[i] == i)
            for (int j = i; j < maxn; j += i)
                phi[j] = (phi[j] / i) * (i - 1);
}
```

2.6 杜教筛

```
const int M = 5e6;
const int Mod = 1e9 + 7;
```

```
const double eps = 0.000000001;
long long phi[M + 30], prim[M + 30], tot;
bool mark[M + 30];
map<long long, long long> m;
#define inv_2 (Mod+1)/2
long long Add(long long a, long long b) {
    long long c = (a + b) % Mod;
    if(c >= Mod) return c - Mod;
    if(c < 0) return c + Mod;
    return c;
}

void init() {
    phi[1] = 1;
    for(long long i = 2; i <= M; i++) {
        if(!mark[i]) {
            prim[++tot] = i;
            phi[i] = i - 1;
        }
        for (long long j = 1; j <= tot; j++) {
            if(i * prim[j] > M) break;
            mark[i * prim[j]] = 1;
            if(i % prim[j] == 0) {
                phi[i * prim[j]] = phi[i] * prim[j];
                break;
            }
            phi[i * prim[j]] = phi[i] * phi[prim[j]];
        }
    }
    for (int i = 1; i <= M; i++) phi[i] = Add(phi[i-1], phi[i]);
}

long long getPhi(long long n) {
    if(n <= M) return phi[n];
    if(m[n]) return m[n];
    long long ans;
    ans = 1LL * n % Mod * (n % Mod + 1) % Mod * inv_2 % Mod;
    for (long long l = 2, r; l <= n; l = r + 1) {
        r = n / (n / l);
        ans = (ans - (r - l + 1) % Mod * getPhi(n / l) % Mod + Mod) % Mod;
    }
    return m[n] = ans;
}

long long solve(long long n) {
    long long ans = 0;
    for (long long l = 1, r; l <= n; l = r + 1) {
        r = n / (n / l);
        ans = Add(ans, 1ULL * (n / l) % Mod * (n / l) % Mod *
            (Add(getPhi(r) % Mod, -getPhi(l-1) % Mod)
            ) % Mod);
    }
    return ans;
}
```

```
int main()
{
    init();
    long long n;
    cin >> n;
    m.clear();
    cout << solve(n) << endl;
    return 0;
}
/*
gcd之和
gcd(i,j)(1<=i<=n)(1<=j<=m)
*/
```

2.7 数论函数打表

```
int phi[maxn], prime[maxn], tot; //线性打欧拉函数
bool vis[maxn];
void init() {
    phi[1] = 1;
    for (int i = 2; i < maxn; i++) {
        if (!vis[i]) {
            prime[++tot] = i;
            phi[i] = i - 1;
        }
        for (int j = 1; j <= tot; j++) {
            if (i * prime[j] >= maxn) break;
            vis[i * prime[j]] = 1;
            if (i % prime[j] == 0) {
                phi[i * prime[j]] = phi[i] * prime[j];
                break;
            }
            phi[i * prime[j]] = phi[i] * phi[prime[j]];
        }
    }
}
bool vis[maxn];
int mu[maxn], prime[maxn];
void Mobius() { //线性打莫比乌斯函数
    mu[1] = 1;
    int tot = 0;
    for (int i = 2; i < maxn; i++) {
        if (!vis[i]) {
            prime[++tot] = i;
            mu[i] = -1;
        }
        for (int j = 0; j < tot; j++) {
            if (i * prime[j] >= maxn) break;
            vis[i * prime[j]] = true;
            if (i % prime[j] == 0) {
                mu[i * prime[j]] = 0;
            }
        }
    }
}
```

```
        break;
    }
    mu[i * prime[j]] = -mu[j];
}
}
```

2.8 扩展卢卡斯

```
long long Pre[maxn];
long long extend_gcd(long long a, long long b, long long
    &x, long long &y) {
    if (!b) {
        x = 1; y = 0;
        return a;
    }
    long long d = extend_gcd(b, a % b, x, y);
    long long t = x;
    x = y; y = t - (a / b) * y;
    return d;
}
long long mul(long long a, long long b, long long P) {
    long long L = a * (b >> 25LL) % P * (1LL << 25) % P;
    long long R = a * (b & ((1LL << 25) - 1)) % P;
    return (L + R) % P;
}
long long Pow(long long a, long long b, long long P) {
    long long ans = 1; a %= P;
    while (b) {
        if (b & 1) ans = mul(ans, a, P);
        a = mul(a, a, P);
        b >>= 1;
    }
    return ans;
}
long long getInv(long long a, long long p) {
    long long x, y;
    extend_gcd(a, p, x, y);
    x = (x % p + p) % p;
    return x;
}
long long CRT(long long m, long long p, long long P) {
    return mul(mul(m, (P / p), P), getInv(P / p, p), P);
}
void init(long long pi, long long pk) {
    Pre[0] = 1;
    for (int i = 1; i <= pk; i++) {
        Pre[i] = Pre[i - 1];
        if (i % pi) Pre[i] = mul(Pre[i], i, pk);
    }
}
```

```

long long Mul(long long n, long long pi, long long pk) {
    if(n <= 1) return 1;
    long long ans = Pow(Pre[pk], n / pk, pk);
    if(n % pk) ans = mul(ans, Pre[n % pk], pk);
    return mul(ans, Mul(n / pi, pi, pk), pk);
}

long long C(long long n, long long m, long long pi, long
    long pk) {
    if(n < m) return 0;
    init(pi, pk);
    long long r = 0;
    for(long long i = n; i; i /= pi) r += i / pi;
    for(long long i = m; i; i /= pi) r -= i / pi;
    for(long long i = n - m; i; i /= pi) r -= i / pi;
    long long a = Mul(n, pi, pk);
    long long b = getInv(Mul(m, pi, pk), pk);
    long long c = getInv(Mul(n - m, pi, pk), pk);
    long long ans = mul(mul(a, b, pk), c, pk);
    return mul(ans, Pow(pi, r, pk), pk);
}

long long ex_lucas(long long n, long long m, long long P)
{
    //C_n^m %p
    long long ans = 0;
    long long p = P;
    for (int i = 2; i <= P; i++) {
        if(p % i == 0) {
            long long pi = i, pk = 1;
            while(p % i == 0) {
                p /= i;
                pk *= i;
            }
            ans = (ans + CRT(C(n, m, pi, pk), pk, P)) % P;
        }
    }
    return ans;
}

```

```

}

long long gcd(long long a, long long b) {
    return !b ? a : gcd(b, a % b);
}

long long exgcd(long long a, long long b, long long &x,
    long long &y) {
    if(!b) {
        x = 1;
        y = 0;
        return a;
    }
    long long d = exgcd(b, a % b, x, y);
    long long t = x;
    x = y;
    y = t - (a / b) * y;
    return d;
}

long long getInv(long long a, long long p) {
    long long x, y;
    exgcd(a, p, x, y);
    x = (x % p + p) % p;
    return x;
}

long long exCrt() {
    for (long long i = 2; i <= n; i++) {
        long long M1 = M[i - 1], M2 = M[i];
        long long C1 = C[i - 1], C2 = C[i];
        long long T = gcd(M1, M2);
        long long t = (C2 - C1 % M2 + M2) % M2;
        if(t % T) return -1;
        M[i] = M1 / T * M2;
        C[i] = mul(getInv(M1 / T, M2 / T), t / T, (M2 / T
            ));
        C[i] = C[i] * M1 + C1;
        C[i] = (C[i] % M[i] + M[i]) % M[i];
    }
    return C[n];
}

```

2.9 扩展中国剩余定理

```

long long M[maxn], C[maxn]; //模数, 余数
long long mul(long long a, long long b, long long p) {
    if(b < 0) b = -b;
    long long ans = 0;
    while(b) {
        if(b & 1) ans = (ans + a) % p;
        a = (a + a) % p;
        b >>= 1;
    }
    return ans;
}

```

2.10 快速幂

```

long long Ksm(long long a, long long b, long long mod) {
    long long res = 1;
    while(b) {
        if(b & 1) res = Ksc(res, a, mod);
        a = Ksc(a, a, mod);
        b >>= 1;
    }
    return res;
}

```

2.11 快速傅里叶变换

```
const int maxn = 5e5 + 5;
const int inf = 0x3f3f3f3f;
const int mod = 1e9 + 7;
typedef complex<double> cp;
const double PI = acos(-1);
char sa[maxn], sb[maxn];
int n = 1, lena, lenb, res[maxn];
cp a[maxn], b[maxn], omg[maxn], inv[maxn];
void init() {
    for (int i = 0; i < n; i++) {
        omg[i] = cp(cos(2*PI*i/n), sin(2*PI*i/n));
        inv[i] = conj(omg[i]);
    }
}
void fft(cp *a, cp *omg) {
    int lim = 0;
    while((1<<lim) < n) lim++;
    for (int i = 0; i < n; i++) {
        int t = 0;
        for (int j = 0; j < lim; j++)
            if((i>>j) & 1) t |= (1<<(lim-j-1));
        if(i < t) swap(a[i], a[t]);
    }
    for (int l = 2; l <= n; l *= 2) {
        int m = l / 2;
        for (cp *p = a; p != a + n; p += l)
            for (int i = 0; i < m; i++) {
                cp t = omg[n/l*i] * p[i+m];
                p[i+m] = p[i] - t;
                p[i] += t;
            }
    }
}
int main() {
    scanf("%d", &n);
    scanf("%s%s", sa, sb);
    lena = lenb = n;
    n = 1;
    while(n < lena + lenb) n <<= 1;
    for (int i = 0; i < lena; i++)
        a[i].real(sa[lena-1-i] - '0');
    for (int i = 0; i < lenb; i++)
        b[i].real(sb[lenb-1-i] - '0');
    init();
    fft(a, omg); fft(b, omg);
    for (int i = 0; i < n; i++)
        a[i] *= b[i];
    fft(a, inv);
    for (int i = 0; i < n; i++) {
        res[i] += floor(a[i].real()/n + 0.5);
        res[i+1] += res[i] / 10;
    }
}
```

```
res[i] %= 10;
}
int pos = n - 1;
while(!res[pos]) pos--;
for (int i = pos; i >= 0; i--) printf("%d", res[i]);
puts("");
return 0;
}
```

2.12 快速乘

```
long long Ksc(long long a, long long b, long long mod) {
    // 普通版
    long long ans = 0;
    while(b) {
        if(b & 1) ans = (ans + a) % mod;
        b >>= 1;
        a = (a + a) % mod;
    }
    return ans;
}
long long Ksc(long long a, long long b, long long mod){//
    快速版
    long long L = a * (b >> 25ll) % mod * (1ll << 25) %
        mod;
    long long R = a * (b & ((1ll << 25) - 1)) % mod;
    return (L + R) % mod;
}
long long Ksc(long long a, long long b, long long mod) {
    // 精确版
    a %= mod, b %= mod;
    return ((a * b - (long long)((long long)((long double)
        )a / mod * b + 1e-3) * mod)) % mod + mod) % mod;
}
```

2.13 卢卡斯定理

```
long long exgcd(long long a, long long b, long long &x,
    long long &y) {
    if (b == 0) {
        x = 1;
        y = 0;
        return a;
    }
    long long ans = exgcd(b, a % b, x, y);
    long long temp = x;
    x = y;
    y = temp - (a / b) * y;
    return ans;
}
```

```

}
long long inv(long long a) {
    long long x, y;
    long long t = exgcd(a, M, x, y);
    if (t != 1) {
        return -1;
    }
    return (x % M + M) % M;
}
long long fac[maxn];
void getfac() {
    fac[0] = 1;
    for (int i = 1; i < maxn; i++) {
        fac[i] = fac[i - 1] * i % M;
    }
}
long long C(long long n, long long m) {
    if (n < 0 || m < 0 || n < m) {
        return 0;
    }
    return fac[n] * inv(fac[m]) % M * inv(fac[n - m]) % M;
}
long long lucas(long long n, long long m) {
    if (m == 0) {
        return 1;
    }
    return (lucas(n / M, m / M) * C(n % M, m % M)) % M;
}

```

```

    for (int i = 0; i <= 1; i++) {
        for (int j = 0; j <= 1; j++)
            cout << x.mat[i][j] << " ";
        cout << endl;
    }
}
Matrix operator * (Matrix x, Matrix y) {
    Matrix t;
    for (int i = 0; i <= 1; i++)
        for (int j = 0; j <= 1; j++)
            for (int k = 0; k <= 1; k++)
                t.mat[i][j] = (t.mat[i][j] + x.mat[i][k]
                    * y.mat[k][j]) % mod;
    return t;
}
Matrix Ksm(Matrix x, long long b) {
    Matrix t; t.init();
    while(b) {
        if(b & 1) t = t * x;
        x = x * x;
        b >>= 1;
    }
    return t;
}
int main() {
    long long x0, x1, a, b;
    scanf("%lld %lld %lld %lld", &x0, &x1, &a, &b);
    char s[maxn];
    scanf("%s%lld", s, &mod);
    int len = strlen(s);
    reverse(s, s + len);
    Matrix t, ans; t.init(a, b);
    ans.mat[0][0] = x0; ans.mat[0][1] = x1;
    Matrix res;
    res.init();
    for (int i = 0; i < len; i++) {
        res = res * Ksm(t, s[i] - '0');
        t = Ksm(t, 10);
    }
    ans = ans * res;
    printf("%lld\n", ans.mat[0][0]);
    return 0;
}

```

2.14 十进制快速幂

```

const int maxn = 1e6 + 5; //矩阵
long long mod;
struct Matrix{
    long long mat[2][2];
    Matrix() {memset(mat, 0, sizeof(mat));};
    void init() {
        mat[0][0] = mat[1][1] = 1;
    }
    void init(long long a, long long b) {
        mat[0][0] = 0; mat[0][1] = b;
        mat[1][0] = 1; mat[1][1] = a;
    }
    void operator = (Matrix x) {
        for (int i = 0; i <= 1; i++)
            for (int j = 0; j <= 1; j++)
                mat[i][j] = x.mat[i][j];
    }
};
void Print(Matrix x) {

```

2.15 二次剩余

```

struct T{
    long long p, d;
};
long long Ksm(long long a, long long b, long long p) {
    long long res = 1;

```

```

    while(b) {
        if(b & 1) res = res * a % p;
        a = a * a % p;
        b >>= 1;
    }
    return res;
}
long long w;
T Mul_er(T a, T b, long long p) { //二次域乘法
    T ans;
    ans.p = (a.p * b.p + a.d * b.d % p * w % p) % p;
    ans.d = (a.p * b.d % p + a.d * b.p % p) % p;
    return ans;
}
T Ksm_er(T a, long long b, long long p) { //二次域快速幂
    T ans;
    ans.p = 1; ans.d = 0;
    while(b) {
        if(b & 1) ans = Mul_er(ans, a, p);
        a = Mul_er(a, a, p);
        b >>= 1;
    }
    return ans;
}
long long Legendre(long long a, long long p) { //求勒让德符号
    return Ksm(a, (p-1)>>1, p);
}
long long Recever(long long a, long long p) {
    a %= p;
    if(a < 0) a += p;
    return a;
}
long long solve(long long n, long long p) {
    if(n % p == 0) return 0;
    if(p == 2) return 1;
    if(Legendre(n, p) + 1 == p) return -1;
    long long a = -1, t;
    while(1) {
        a = rand() % p;
        t = a * a - n;
        w = Recever(t, p);
        if(Legendre(w, p) + 1 == p) break;
    }
    T tmp;
    tmp.p = a; tmp.d = 1;
    T ans = Ksm_er(tmp, (p+1)>>1, p);
    return ans.p;
}

```

2.16 三分

```

double Com(double X) {
    return sqrt((X - x) * (X - x) + (a * X * X + b * X +
        c - y) * (a * X * X + b * X + c - y));
}
void Binary(double l, double r) {
    if(l + eps <= r) {
        double lm, rm;
        double k = r - l;
        lm = l + (1./3) * k;
        rm = r - (1./3) * k;
        if(fabs(Com(lm) - Com(rm)) <= eps) {
            printf("%.31f\n", Com(lm));
            return ;
        }
        if(Com(lm) < Com(rm))
            Binary(l, rm);
        else Binary(lm, r);
    }
}

```

2.17 min25 筛

```

#define inv_2 (Mod+1)/2
#define inv_6 (Mod+1)/6
long long sqr, m, w[maxn], g[maxn], h[maxn];
long long sumg[maxn], sumh[maxn], id1[maxn], id2[maxn];
long long prim[maxn], tot;
bool mark[maxn];
long long Add(long long a, long long b) {
    return (a + b) % Mod;
}
long long Sup(long long a, long long b) {
    return (a - b + Mod) % Mod;
}
long long Pow(long long a, long long b) {
    long long res = 1;
    while(b) {
        if(b & 1) res = res * a % Mod;
        a = a * a % Mod;
        b >>= 1;
    }
    return res;
}
void init(long long n) {
    mark[1] = 1;
    for (long long i = 2; i <= n; i++) {
        if(!mark[i]) {
            prim[++tot] = i;
            sumg[tot] = (sumg[tot-1] + i * i) % Mod;
            sumh[tot] = (sumh[tot-1] + i) % Mod;
        }
    }
}

```



```

        for (long long j = 1; j <= tot; j++) {
            if(i * prim[j] > n) break;
            mark[i * prim[j]] = 1;
            if(i % prim[j] == 0) break;
        }
    }
}

void GetW(long long n) {
    for (long long i = 1, j; i <= n; i = j + 1) {
        j = n / (n / i);
        w[++m] = n / i;
        long long t = w[m] % Mod;
        g[m] = t * (t + 1) % Mod * ((2LL * t + 1) % Mod)
            % Mod * inv_6 % Mod;
        g[m] —;
        h[m] = t * (t + 1) % Mod * inv_2 % Mod;
        h[m] —;
        if(w[m] <= sqr) id1[w[m]] = m;
        else id2[n/w[m]] = m;
    }
}

void GetG(long long n) {
    for (long long i = 1; i <= tot; i++) {
        for (long long j = 1; j <= m && prim[i] * prim[i]
            <= w[j]; j++) {
            long long d = w[j] / prim[i];
            long long id = d <= sqr ? id1[d] : id2[n/d];
            g[j] = Sup(g[j], prim[i] * prim[i] % Mod * ((
                g[id] - sumg[i-1] + Mod) % Mod) % Mod);
            h[j] = Sup(h[j], prim[i] * ((h[id] - sumh[i-1]
                + Mod) % Mod) % Mod);
        }
    }
}

long long S(long long x, long long y, long long n) {
    if(x <= prim[y-1] || x <= 1) return 0;
    long long id = x <= sqr ? id1[x] : id2[n/x];
    long long res = (g[id] - h[id] + Mod - sumg[y-1] +
        sumh[y-1] + Mod) % Mod;
    for (long long i = y; i <= tot && prim[i] * prim[i]
        <= x; i++) {
        long long t = prim[i];
        for (long long j = 1; t <= x; j++, t = t * prim[
            i]) {
            long long p1 = t % Mod;
            res = Add(res, p1 * (p1 - 1) % Mod * (S(x/t,
                i+1, n) + (j != 1) % Mod);
        }
    }
    return res % Mod;
}

int main(int argc, char *args[]) {
    long long n;
    scanf("%lld", &n);

```

```

    sqr = sqrt(n);
    init(sqr);
    GetW(n);
    GetG(n);
    printf("%lld\n", (S(n, 1, n) + 1) % Mod);
    return 0;
}

```

2.18 SG 函数

```

int SG[maxn], S[maxn];
int f[maxn];
void ff() { //f是每一次走的步数
    f[0] = 1;
    for (int i = 1; i <= 10; i++)
        f[i] = f[i-1] * 2;
}

void getSG(int n) {
    ff();
    for (int i = 1; i <= n; i++) {
        memset(S, 0, sizeof(S));
        for (int j = 0; f[j] <= i && j <= 10; j++)
            S[SG[i-f[j]]] = 1;
        for (int j = 0; ; j++)
            if(!S[j]) {
                SG[i] = j;
                break;
            }
    }
}

int main() {
    int n;
    getSG(1000);
    while(cin >> n) {
        if(SG[n]) cout << "Kiki\n";
        else cout << "Cici\n";
    }
    return 0;
}

```

2.19 Pollard Rho

```

long long factor[1000005];
int tot;
const int S=50;
long long Ksc(long long a, long long b, long long mod) {
    a %= mod, b %= mod;
    return ((a * b - (long long)((long long)((long double)
        )a / mod * b + 1e-3) * mod)) % mod + mod) % mod;
}

```

```

}
long long Ksm(long long a, long long b, long long mod) {
    long long res = 1;
    while(b) {
        if(b & 1) res = Ksc(res, a, mod);
        a = Ksc(a, a, mod);
        b >>= 1;
    }
    return res;
}
bool check(long long a, long long n, long long x, long
long t) {
    long long ret = Ksm(a, x, n);
    long long last = ret;
    for(int i = 1; i <= t; i++) {
        ret = Ksc(ret, ret, n);
        if(ret == 1 && last != 1 && last != n-1) return
            true; //是合数
        last = ret;
    }
    if(ret != 1) return true;
    return false;
}
bool Miller_Rabin(long long n) { //判素数
    if(n < 2) return false;
    if(n == 2) return true;
    if((n&1) == 0) return false;
    long long x = n - 1;
    long long t = 0;
    while((x&1) == 0) {
        x >>= 1;
        t++;
    }
    for(int i = 0; i < S; i++) {
        long long a = rand() % (n-1) + 1;
        if(check(a, n, x, t)) //如果检查出来是合数
            return false;
    }
    return true;
}
long long gcd(long long a, long long b) {
    if(a == 0) return 1;
    if(a < 0) return gcd(-a, b);
    while(b) {
        long long t = a % b;
        a = b;
        b = t;
    }
    return a;
}
long long pollard_rho(long long x, long long c) {
    long long i = 1, k = 2;
    long long x0 = rand() % x;
    long long y = x0;

```

```

    while(1) {
        i++;
        x0 = (Ksc(x0, x0, x) + c) % x;
        long long d = gcd(y-x0, x);
        if(d != 1 && d != x) return d;
        if(y == x0) return x;
        if(i == k) {
            y = x0;
            k += k;
        }
    }
}
void findphi(long long n) {
    if(Miller_Rabin(n)) {
        factor[tot++] = n;
        return;
    }
    long long p = n;
    while(p >= n) {
        p = pollard_rho(p, rand() % (n-1) + 1);
    }
    findphi(p);
    findphi(n/p);
}
int main() {
    long long n;
    while(scanf("%I64d", &n) != EOF) {
        tot = 0;
        findphi(n);
        for(int i = 0; i < tot; i++)
            printf("%I64d", factor[i]), printf("\n");
        if(Miller_Rabin(n)) printf("yes\n");
        else printf("no\n");
    }
    return 0;
}

```

2.20 NTT

```

const int maxn = 1e5 + 5;
const int inf = 0x3f3f3f3f;
const int mod = 998244353;
#define Mod(x) ((x) >= mod ? (x) - mod : (x))
#define g 3
int rnk[maxn];
long long a[maxn], b[maxn];
long long Ksm(long long a, long long b) {
    long long res = 1;
    while(b) {
        if(b & 1) res = res * a % mod;
        a = a * a % mod;
    }
}

```

```

        b >>= 1;
    }
    return res;
}
void init(int n) {
    memset(rnk, 0, sizeof(rnk));
    int lim = 0;
    while((1<<lim) < n) lim++;
    for (int i = 0; i < n; i++)
        rnk[i] = (rnk[i>>1]>>1) | ((i&1) << (lim-1));
}
void ntt(long long *a, int op, int n) {
    for (int i = 0; i < n; i++)
        if(i < rnk[i]) swap(a[i], a[rnk[i]]);
    for (int i = 2; i <= n; i <= 1) {
        int nw = Ksm(g, (mod-1)/i);
        if(op == -1) nw = Ksm(nw, mod-2);
        for (int j = 0, m = i >> 1; j < n; j += i)
            for (int k = 0, w = 1; k < m; k++) {
                int t = 1ll * a[j+k+m] * w % mod;
                a[j+k+m] = Mod(a[j+k]-t+mod);
                a[j+k] = Mod(a[j+k]+t);
                w = 1ll * w * nw % mod;
            }
    }
    if(op == -1)
        for (int i = 0, inv = Ksm(n, mod-2); i < n; i++)
            a[i] = 1ll * a[i] * inv % mod;
}
char s1[maxn], s2[maxn];
long long ans[maxn];
int main() {
    scanf("%s", s1);
    scanf("%s", s2);
    int len1 = strlen(s1), len2 = strlen(s2);
    int n = 1;
    while(n < len1 + len2) n <= 1;
    init(n);
    for (int i = 0; i < len1; i++) a[len1-i-1] = s1[i]-'0';
    for (int i = 0; i < len2; i++) b[len2-i-1] = s2[i]-'0';
    ntt(a, 1, n); ntt(b, 1, n);
    for (int i = 0; i < n; i++)
        a[i] = (1ll * a[i] * b[i]) % mod;
    ntt(a, -1, n);
    for (int i = 0; i < n; i++)
        cout << a[i] << " ";
    cout << endl;
    for (int i = 0; i < n; i++) {
        ans[i+1] += ans[i] / 10;
        ans[i] %= 10;
    }
    int pos = n-1;

```

```

    while(!a[pos]) pos--;
    for (int i = pos; i >= 0; i--) cout << a[i];
    cout << endl;
    return 0;
}
//三模NTT
#define long long long long
const long long maxn = 3 * 1e6 + 10;
#define swap(x,y) x ^= y, y ^= x, x ^= y
using namespace std;
long long a[maxn], b[maxn];
long long Mul(long long a, long long b, long long mod) {
    a %= mod, b %= mod;
    return ((a * b - (long long)((long long)((long double)
        a / mod * b + 1e-3) * mod)) % mod + mod) % mod;
}
long long Ksm(long long a, long long p, long long mod) {
    long long base = 1;
    while(p) {
        if(p & 1) base = 1ll * a * base % mod;
        a = 1ll * a * a % mod; p >>= 1;
    }
    return base % mod;
}
namespace NTT{

    const long long P1 = 469762049, P2 = 998244353, P3 =
        1004535809, g = 3;
    const long long PP = 1ll * P1 * P2;
    long long n, m, p, len = 1, lim;
    long long tmp1[maxn], tmp2[maxn], ans[3][maxn], r[
        maxn];
    long long res[maxn], tmp[maxn], base[maxn];
    /*
        传的参数n,m都比实际个数少一
        n——m——;
        输入两个数n=1
        输入一个数n=0;
    */
    void init(long long n) { //初始化, 传入alen+blen,得到
        最小的len
        len = 1; lim = 0;
        while(len <= n) len <= 1, lim++;
        for(long long i = 0; i <= len; i++) r[i] = (r[i
            >> 1] >> 1) | ((i & 1) << (lim - 1));
    }
    void ntt_Mod(long long *a, const long long n, const
        long long type, const long long mod) { //ntt
        for(long long i = 0; i < n; i++) if(i < r[i])
            swap(a[i], a[r[i]]);
        for(long long mid = 1; mid < n; mid <= 1) {
            long long W = Ksm(type == 1 ? g : Ksm(g, mod
                - 2, mod), (mod - 1) / (mid <= 1), mod)
                ;

```

```

        for(long long j = 0; j < n; j += (mid << 1))
        {
            long long w = 1;
            for(long long k = 0; k < mid; k++, w = 1ll
                * w * W % mod) {
                long long x = a[j + k], y = 1ll * w *
                    a[j + k + mid] % mod;
                a[j + k] = (x + y) % mod;
                a[j + k + mid] = (x - y + mod) % mod;
            }
        }
    }
    if(type == -1) {
        long long inv = Ksm(n, mod - 2, mod);
        for(long long i = 0; i < n; i++)
            a[i] = 1ll * a[i] * inv % mod;
    }
}

void Out(long long *a, long long len) {
    for (int i = 0; i <= len; i++)
        cout << a[i] << " ";
    cout << endl;
}

int ntt_Mul(long long *a, long long *b, long long
    alen, long long blen, long long mod) {
    init(alen + blen);
    memcpy(tmp1, a, sizeof(tmp1)); memcpy(tmp2, b,
        sizeof(tmp2));
    ntt_Mod(tmp1, len, 1, P1); ntt_Mod(tmp2, len, 1,
        P1);
    for(long long i = 0; i <= len; i++) ans[0][i] = 1
        ll * tmp1[i] * tmp2[i] % P1;
    memcpy(tmp1, a, sizeof(tmp1)); memcpy(tmp2, b,
        sizeof(tmp2));
    ntt_Mod(tmp1, len, 1, P2); ntt_Mod(tmp2, len, 1,
        P2);
    for(long long i = 0; i <= len; i++) ans[1][i] = 1
        ll * tmp1[i] * tmp2[i] % P2;
    memcpy(tmp1, a, sizeof(tmp1)); memcpy(tmp2, b,
        sizeof(tmp2));
    ntt_Mod(tmp1, len, 1, P3); ntt_Mod(tmp2, len, 1,
        P3);
    for(long long i = 0; i <= len; i++) ans[2][i] = 1
        ll * tmp1[i] * tmp2[i] % P3;
    ntt_Mod(ans[0], len, -1, P1);
    ntt_Mod(ans[1], len, -1, P2);
    ntt_Mod(ans[2], len, -1, P3);
    for(long long i = 0; i <= alen + blen; i++) {
        long long t = (Mul(1ll * ans[0][i] * P2 % PP,
            Ksm(P2 % P1, P1 - 2, P1), PP) +
            Mul(1ll * ans[1][i] * P1 % PP, Ksm(P1
                % P2, P2 - 2, P2), PP) ) % PP;
        long long K = ((ans[2][i] - t) % P3 + P3) %
            P3 * Ksm(PP % P3, P3 - 2, P3) % P3;

```

```

        a[i] = (t % mod + ((K % mod) * (PP % mod)) %
            mod) % mod;
    }
    return alen + blen;
}

int ntt_Ksm(long long *a, long long b, int blen, long
    long mod) {
    memcpy(base, a, sizeof(base));
    memset(a, 0, maxn*sizeof(a));
    a[0] = 1; int alen = 0;
    while(b) {
        if(b & 1) alen = ntt_Mul(a, base, alen, blen,
            mod);
        memcpy(tmp, base, sizeof(tmp));
        blen = ntt_Mul(base, tmp, blen, blen, mod);
        b >>= 1;
    }
    return alen;
}

int main() {
    long long n, m, p;
    scanf("%lld %lld %lld", &n, &m, &p);
    for(long long i = 0; i <= n; i++) scanf("%lld", &a[i]
        );
    for(long long i = 0; i <= m; i++) scanf("%lld", &b[i]
        );
    NTT::ntt_Mul(a, b, n, m, p);
    for (int i = 0; i <= n + m; i++)
        printf("%lld ", a[i]);
    printf("\n");
    return 0;
}

```

2.21 Miller Rabin

```

#define random(a, b) (((double)rand()/RAND_MAX)*(b-a)+a)
long long Ksc(long long a, long long b, long long mod) {
    a %= mod, b %= mod;
    return ((a * b - (long long)((long long)((long double)
        )a / mod * b + 1e-3) * mod)) % mod + mod) % mod;
}

long long Ksm(long long a, long long b, long long mod) {
    long long res = 1;
    while(b) {
        if(b & 1) res = Ksc(res, a, mod);
        a = Ksc(a, a, mod);
        b >>= 1;
    }
    return res;
}

```

```

bool Miller_Rabin(long long n) {
    if(n <= 2) {
        if(n == 2) return true;
        return false;
    }
    if(n % 2 == 0) return false;
    long long u = n - 1;
    while(u % 2 == 0) u /= 2;
    int S = 100;
    srand((long long)time(0));
    for (int i = 1; i <= S; i++){
        long long a = rand() % (n - 2) + 2;
        long long x = Ksm(a, u, n);
        while(u < n) {
            long long y = Ksm(x, 2, n);
            if(y == 1 && x != 1 && x != n - 1)
                return false;
            x = y;
            u = u * 2;
        }
        if(x != 1) return false;
    }
    return true;
}

```

2.22 BigInteger

```

#define MAXN 999
#define MAXSIZE 100240
#define DLEN 3
struct BigInt{
    int a[MAXSIZE],len;
    bool flag;
    BigInt() {
        len = 1;
        memset(a, 0, sizeof(a));
        flag = 0;
    }
    BigInt (const int b) {
        int c , d = b;
        len = 0;
        memset(a, 0, sizeof(a));
        if(!b) {
            len = 1;
            return ;
        }
        while(d) {
            a[len++] = d % (MAXN + 1);
            d /= (MAXN+1);
        }
    }
}

```

```

BigInt(const char *s) {
    int t, k, index, l;
    memset(a, 0, sizeof(a));
    l = strlen(s);
    len = l/DLEN;
    if(l % DLEN) len ++;
    index = 0;
    for (int i = l - 1; i >= 0; i -= DLEN) {
        t = 0;
        k = i - DLEN + 1;
        if(k < 0) k = 0;
        for (int j = k; j <= i; j++) t = t * 10 + s[j] - '0';
        a[index++] = t;
    }
}

BigInt (const BigInt& T) {
    memset(a, 0, sizeof(a));
    len = T.len;
    for (int i = 0; i < len; i++) a[i] = T.a[i];
}

bool operator < (const BigInt &T) const {
    int ln;
    if(len < T.len) return 233;
    if(len == T.len) {
        ln = len - 1;
        while(ln >= 0 && a[ln] == T.a[ln]) -- ln;
        if(ln >= 0 && a[ln] < T.a[ln]) return 233;
        return 0;
    }
    return 0;
}

inline bool operator < (const int &t) const {
    BigInt tee(t);
    return *this < tee;
}

BigInt& operator = (const BigInt &T) {
    memset(a, 0, sizeof(a));
    len = T.len;
    for (int i = 0; i < len; i++) a[i] = T.a[i];
    return *this;
}

BigInt operator + (const BigInt &T) const {
    BigInt t(*this);
    int big = len;
    if(T.len > len) big = T.len;
    for (int i = 0; i < big; i++) {
        t.a[i] += T.a[i];
        if(t.a[i] > MAXN) {
            ++t.a[i + 1];
            t.a[i] -= MAXN + 1;
        }
    }
    if(t.a[big]) t.len = big + 1;
}

```

```

        else t.len = big;
        return t;
    }
    BigInt operator - (const BigInt &T) const {
        int big;
        bool ctf;
        BigInt t1, t2;
        if(*this < T) {
            t1 = T;
            t2 = *this;
            ctf = 1;
        } else {
            t1 = *this;
            t2 = T;
            ctf = 0;
        }
        big = t1.len;
        int j = 0;
        for (int i = 0; i < big; i++) {
            if(t1.a[i] < t2.a[i]) {
                j = i + 1;
                while(t1.a[j] == 0) ++j;
                -- t1.a[j--];
                while(j > i) t1.a[j --] += MAXN;
                t1.a[i] += MAXN + 1 - t2.a[i];
            } else t1.a[i] -= t2.a[i];
        }
        t1.len = big;
        while(t1.len > 1 && t1.a[t1.len - 1] == 0) {
            -- t1.len;
            -- big;
        }
        if(ctf) t1.a[big - 1] = -t1.a[big - 1];
        return t1;
    }
    BigInt operator * (const BigInt &T) const {
        BigInt res;
        int up;
        int te, tee;
        for (int i = 0; i < len; i++) {
            up = 0;
            for (int j = 0; j < T.len; j++) {
                te = a[i] * T.a[j] + res.a[i + j] + up;
                if(te > MAXN) {
                    tee = te - te / (MAXN + 1) * (MAXN + 1);
                    up = te / (MAXN + 1);
                    res.a[i + j] = tee;
                } else {
                    up = 0;
                    res.a[i + j] = te;
                }
            }
            if(up) res.a[i + T.len] = up;
        }
    }

```

```

    }
    res.len = len + T.len;
    while(res.len > 1 && res.a[res.len - 1] == 0) --
        res.len;
    return res;
}
    BigInt operator / (const int &b) {
        BigInt res;
        int sum = 0, newlen = 0;
        for (int i = len-1; i >= 0; i --) {
            sum = sum * (MAXN+1) + a[i];
            if(sum < b) res.a[i] = 0;
            else {
                if(!newlen) newlen = i + 1;
                res.a[i] = sum / b;
                sum %= b;
            }
        }
        res.len = max(newlen, 1);
        return res;
    }
    int operator % (const int &b) const {
        int d = 0;
        for (int i = len - 1; i >= 0; i --)
            d = (d * (MAXN + 1) % b + a[i]) % b;
        return d;
    }
    BigInt operator ^ (const int &n) const {
        BigInt t(n), res(1);
        int y = n;
        while(y) {
            if(y & 1) res = res * t;
            t = t * t;
            y >>= 1;
        }
        return res;
    }
    inline void print() {
        printf("%d", a[len - 1]);
        for (int i = len - 2; i >= 0; i --)
            printf("%03d", a[i]);
        printf("\n");
    }
};

```

2.23 BSGS

```

map<long long, long long> Hash;
long long Mul(long long a, long long b, long long p) {
    long long L = a * (b >> 25LL) % p * (1LL << 25) % p;
    long long R = a * (b & ((1LL << 25) - 1)) % p;
}

```

```

    return (L + R) % p;
}
long long Pow(long long a, long long b, long long p) {
    a %= p;
    long long res = 1;
    while(b) {
        if(b & 1) res = Mul(res, a, p);
        a = Mul(a, a, p);
        b >>= 1;
    }
    return res;
}
/*
get ans for a^ans = b % p
A^{iS-j} = B mod p  A^{iS} = B*A^{j} mod p
A^{iS+j} = B mod p
*/
long long BSGS(long long a, long long b, long long p) {
    long long m = sqrt(p) + 1;
    long long res = 1;
    for (int j = 0; j <= m; j++) {
        Hash[Mul(b, res, p)] = j;
        res = Mul(res, a, p);
    }
    for (int i = 1; i <= m; i++) {
        long long k = Pow(a, i * m, p);
        if(Hash.count(k))
            return i * m - Hash[k];
    }
}

```

2.24 BM

```

//BM模板
//a[n] = f[1]a[n-1] + f[2]a[n-2] + f[3]a[n-3] + ... + f[k]a[n-k]
//有限项
const long long mod = 998244353;
#define sz(x) ((int)(x).size())
typedef vector<long long> VI;
long long Ksm(long long a, long long b) {
    long long res = 1; a %= mod;
    assert(b >= 0);
    while(b) {
        if(b & 1) res = res * a % mod;
        a = a * a % mod;
        b >>= 1;
    }
    return res;
}
int _, n;

```

```

namespace Linear_Seq{
    const int N = 10010;
    long long res[N], base[N], _c[N], _md[N];
    vector<int> Md;
    void Mul(long long *a, long long *b, int k) {
        for (int i = 0; i < k+k; i++) _c[i] = 0;
        for (int i = 0; i < k; i++)
            if(a[i]) for (int j = 0; j < k; j++)
                _c[i+j] = (_c[i+j] + a[i]*b[j]) % mod;
        for (int i = k+k-1; i >= k; i--)
            if(_c[i]) for (int j = 0; j < sz(Md); j++)
                _c[i-k+Md[j]] = (_c[i-k+Md[j]] - _c[i] *
                    _md[Md[j]]) % mod;
        for (int i = 0; i < k; i++)
            a[i] = _c[i];
    }
    int solve(long long n, VI a, VI b) {
        long long ans = 0, pnt = 0;
        int k = sz(a);
        assert(sz(a) == sz(b));
        for (int i = 0; i < k; i++) _md[k-1-i] = -a[i];
        _md[k] = 1; Md.clear();
        for (int i = 0; i < k; i++)
            if(_md[i]) Md.push_back(i);
        for (int i = 0; i < k; i++) res[i] = base[i] = 0;
        res[0] = 1;
        while((1ll<pnt) <= n) pnt++;
        for (int p = pnt; p >= 0; p--) {
            Mul(res, res, k);
            if((n>>p) & 1) {
                for (int i = k-1; i >= 0; i--) res[i+1]
                    = res[i];
                res[0] = 0;
                for (int j = 0; j < sz(Md); j++)
                    res[Md[j]] = (res[Md[j]] - res[k] *
                        _md[Md[j]]) % mod;
            }
        }
        for (int i = 0; i < k; i++) ans = (ans + res[i]
            * b[i]) % mod;
        if(ans < 0) ans += mod;
        return ans;
    }
    VI BM(VI s) {
        VI C(1, 1), B(1, 1);
        int L = 0, m = 1, b = 1;
        for (int n = 0; n < sz(s); n++) {
            long long d = 0;
            for (int i = 0; i < L+1; i++) d = (d + (
                long long)C[i] * s[n-i]) % mod;
            if (d == 0) ++m;
            else if(2 * L <= n) {
                VI T = C;
            }
        }
    }
}

```

```

        long long c = mod - d * Ksm(b, mod-2) %
            mod;
        while(sz(C) < sz(B) + m) C.push_back(0);
        for (int i = 0; i < sz(B); i++) C[i+m] =
            (C[i+m] + c * B[i]) % mod;
        L = n + 1 - L; B = T;
        b = d; m = 1;
    }else {
        long long c = mod - d * Ksm(b, mod-2) %
            mod;
        while(sz(C) < sz(B) + m) C.push_back(0);
        for (int i = 0; i < sz(B); i++) C[i+m] =
            (C[i+m] + c * B[i]) % mod;
        ++ m;
    }
}
return C;
}
int Gao(VI a, long long n) { //得到第n项
    VI c = BM(a);
    c.erase(c.begin());
    for (int i = 0; i < sz(c); i++) c[i] = (mod-c[i]
        ]) % mod;
    return solve(n, c, VI(a.begin(), a.begin()+sz(c))
        );
}
};
using namespace Linear_Seq;
void solve() { //预处理前3k项
    long long n, k;
    scanf("%lld %lld", &n, &k);
    VI v, f;
    f.push_back(0);
    for (int i = 0; i < k; i++) { //f只有k项
        long long x;
        scanf("%lld", &x);
        f.push_back(x);
    }
    for (int i = 0; i < k; i++) { //a的前k项
        long long x;
        scanf("%lld", &x);
        v.push_back(x);
    }
    for (int i = k; i <= 2 * k; i++) { //a的前3k项
        long long x = 0;
        for (int j = 1; j <= k; j++)
            x = (x + f[j] * v[i-j]) % mod;
        v.push_back(x);
    }
    printf("%lld\n", Gao(v, n));
}
int main() {
    solve();
    return 0;
}

```

```

}
//另一个板子
#define maxk 100005
#define maxn 200005
const int mod = 998244353;
#define mul(x, y) static_cast<long long>(x) * (y) % mod
namespace Math {
    inline int pw(int base, int p) {
        static int res; res = 1;
        while(p) {
            if(p & 1) res = mul(res, base);
            base = mul(base, base);
            p >>= 1;
        }
        return res;
    }
    inline int inv(int x) { return pw(x, mod - 2); }
}
inline void reduce(int &x) { x += x >> 31 & mod; }
namespace Poly {
#define N maxn
    int lim, s, rev[N], Wn[N];
    inline void init(const int n) { //初始化
        lim = 1, s = -1;
        while (lim < n) lim <<= 1, ++s;
        for (register int i = 1; i < lim; ++i)
            rev[i] = rev[i >> 1] >> 1 | (i & 1) << s;
        const int t = Math::pw(3, (mod - 1) / lim
            ); *Wn = 1;
        for (register int *i = Wn + 1; i != Wn + lim; ++i
            )
            *i = mul(*(i - 1), t);
    }
    inline void FFT(int *A, const int op = 1) { //FFT
        for (register int i = 1; i < lim; ++i)
            if (i < rev[i]) std::swap(A[i], A[rev[i]]);
        for (register int mid = 1; mid < lim; mid
            <<= 1) {
            const int t = lim / mid >> 1;
            for (register int i = 0; i < lim;
                i += mid << 1)
                for (register int j = 0;
                    j < mid; ++j) {
                    const int X = A[i
                        + j], Y =
                        mul(A[i + j
                            + mid], Wn[t
                                * j]);
                    reduce(A[i + j]
                        += Y - mod),
                        reduce(A[i
                            + j + mid] =
                                X - Y);
                }
            }
        }
    }
}

```



```

    }
    if (!op) {
        const int ilim = Math::inv(lim);
        for (register int *i = A; i != A
            + lim; ++i) *i = mul(*i,
                ilim);
        std::reverse(A + 1, A + lim);
    }
}
void INV(int *A, int *B, int n) { //多项式A求逆
    到B, [0,n-1]
    if (n == 1) { *B = Math::inv(*A); return
        ; }
    static int C[N], D[N];
    const int len = n + 1 >> 1;
    INV(A, B, len), init(len * 3);
    std::memcpy(C, A, n << 2), std::memset(C
        + n, 0, lim - n << 2);
    std::memcpy(D, B, len << 2), std::memset(
        D + len, 0, lim - len << 2);
    FFT(C), FFT(D);
    for (int i = 0; i < lim; ++i) D[i] = (2 -
        mul(D[i], C[i]) + mod) * D[i] % mod
        ;
    FFT(D, 0);
    std::memcpy(B + len, D + len, n - len <<
        2);
}
int G[N], INVG[N];
void DIV(int *A, int *Q, int n, int m) {
    static int C[N];
    const int len = n - m + 1;
    std::reverse_copy(A, A + n, C), std::
        memset(C + len, 0, lim - len << 2);
    FFT(C);
    for (int i = 0; i < lim; ++i) Q[i] = mul(
        C[i], INVG[i]);
    FFT(Q, 0), std::reverse(Q, Q + len);
}
void DIV_MOD(int *A, int *R, int n, int m) {
    static int Q[N];
    const int len = n - m + 1;
    DIV(A, Q, n, m), std::memset(Q + len, 0,
        lim - len << 2);
    FFT(Q);
    for (int i = 0; i < lim; ++i) R[i] = mul(
        G[i], Q[i]);
    FFT(R, 0);
    for (int i = 0; i < m; ++i) reduce(R[i] =
        A[i] - R[i]);
}
void POW(int *A, int p, int m) {
    if (!p) return ;
    POW(A, p >> 1, m);

```

```

    static int T[N];
    std::memcpy(T, A, m << 2), std::memset(T
        + m, 0, lim - m << 2);
    FFT(T);
    for (int i = 0; i < lim; ++i) T[i] = mul(
        T[i], T[i]);
    FFT(T, 0);
    if (p & 1) {
        for (int i = 2 * m - 1; ~i; ~i)
            T[i] = T[i - 1];
        T[0] = 0;
    }
    DIV_MOD(T, A, 2 * m, m + 1);
}
int solve(int *f, int *a, int n, int k) { //a为递
    推式0~k-1项, f为转移数组1~k项
    static int A[maxn], B[maxn];
    for (int i = 1; i <= k; ++i) reduce(G[k -
        i] = -f[i]);
    G[k] = A[0] = 1;
    std::reverse_copy(G, G + k + 1, B), B[k]
        = 0;
    INV(B, INVG, k), init(k << 1);
    FFT(G), FFT(INVG);
    Poly::POW(A, n, k);
    int ans = 0;
    for (int i = 0; i < k; ++i) reduce(ans +=
        mul(A[i], a[i]) - mod);
    return ans;
}
#undef N
}
int n, k;
int f[maxn], a[maxn];
int main() {
    /* 能求线性递推和mod 998244353的多项式求逆, 其他
        的好
        像可以求, 但是不会, 先打个板子, 以后再说把*/
    // int n;
    // scanf("%d", &n);
    // for (int i = 0; i < n; i++)
    //     scanf("%d", &a[i]);
    // Poly::INV(a, f, n);
    // for (int i = 0; i < n; i++)
    //     printf("%d ", f[i]);
    // printf("\n");
    // a(n)=f(i)*a(n-i) {1<=i<=k}
    std::ios::sync_with_stdio(false), std::cin.tie(0)
        , std::cout.tie(0);
    std::cin >> n >> k;
    for (int i = 1; i <= k; ++i) std::cin >> f[i];
    for (int i = 0; i < k; ++i) std::cin >> a[i],
        reduce(a[i]);
    std::cout << Poly::solve(f, a, n, k) << '\n';
}

```

```

    return 0;
}

```

3 数据结构

3.1 线段树套伸展树

```

/* BZOJ 3196 (线段树套伸展树)
1. 查询k在区间内的排名
2. 查询区间内排名为k的值
3. 修改某一位值上的数值
4. 查询k在区间内的前驱(前驱定义为小于x, 且最大的数)
5. 查询k在区间内的后继(后继定义为大于x, 且最小的数) */
#include <bits/stdc++.h>
const int inf = 2147483647;
const int maxn = 5e4 + 5;
const int maxm = maxn * 25;
int n;
int arr[maxn];
namespace SplayTree {
    int rt[maxn], tot;
    int fa[maxn], son[maxn][2];
    int val[maxn], cnt[maxn];
    int sz[maxn];
    void Push(int o) {
        sz[o] = sz[son[o][0]] + sz[son[o][1]] + cnt[o];
    }
    bool Get(int o) {
        return o == son[fa[o]][1];
    }
    void Clear(int o) {
        son[o][0] = son[o][1] = fa[o] = val[o] = sz[o] = cnt[o] = 0;
    }
    void Rotate(int o) {
        int p = fa[o], q = fa[p], ck = Get(o);
        son[p][ck] = son[o][ck ^ 1];
        fa[son[o][ck ^ 1]] = p;
        son[o][ck ^ 1] = p;
        fa[p] = o; fa[o] = q;
        if (q) son[q][p == son[q][1]] = o;
        Push(p); Push(o);
    }
    void Splay(int &root, int o) {
        for (int f = fa[o]; (f = fa[o]); Rotate(o))
            if (fa[f]) Rotate(Get(o) == Get(f) ? f : o);
        root = o;
    }
    void Insert(int &root, int x) {
        if (!root) {
            val[++tot] = x;
            cnt[tot]++;
            root = tot;
            Push(root);
            return;
        }
    }
}

```

```

}
int cur = root, f = 0;
while (true) {
    if (val[cur] == x) {
        cnt[cur]++;
        Push(cur); Push(f);
        Splay(root, cur);
        break;
    }
    f = cur;
    cur = son[cur][val[cur] < x];
    if (!cur) {
        val[++tot] = x;
        cnt[tot]++;
        fa[tot] = f;
        son[f][val[f] < x] = tot;
        Push(tot); Push(f);
        Splay(root, tot);
        break;
    }
}
}
int GetRank(int &root, int x) {
    int ans = 0, cur = root;
    while (cur) {
        if (x < val[cur]) {
            cur = son[cur][0];
            continue;
        }
        ans += sz[son[cur][0]];
        if (x == val[cur]) {
            Splay(root, cur);
            return ans;
        }
        if (x > val[cur]) {
            ans += cnt[cur];
            cur = son[cur][1];
        }
    }
    return ans;
}
int GetKth(int &root, int k) {
    int cur = root;
    while (true) {
        if (son[cur][0] && k <= sz[son[cur][0]]) cur = son[
            cur][0];
        else {
            k -= cnt[cur] + sz[son[cur][0]];
            if (k <= 0) return cur;
            cur = son[cur][1];
        }
    }
}
int Find(int &root, int x) {

```

```

    int ans = 0, cur = root;
    while (cur) {
        if (x < val[cur]) {
            cur = son[cur][0];
            continue;
        }
        ans += sz[son[cur][0]];
        if (x == val[cur]) {
            Splay(root, cur);
            return ans + 1;
        }
        ans += cnt[cur];
        cur = son[cur][1];
    }
}
int GetPrev(int &root) {
    int cur = son[root][0];
    while (son[cur][1]) cur = son[cur][1];
    return cur;
}
int GetPrevVal(int &root, int x) {
    int ans = -inf, cur = root;
    while (cur) {
        if (x > val[cur]) {
            ans = std::max(ans, val[cur]);
            cur = son[cur][1];
            continue;
        }
        cur = son[cur][0];
    }
    return ans;
}
int GetNext(int &root) {
    int cur = son[root][1];
    while (son[cur][0]) cur = son[cur][0];
    return cur;
}
int GetNextVal(int &root, int x) {
    int ans = inf, cur = root;
    while (cur) {
        if (x < val[cur]) {
            ans = std::min(ans, val[cur]);
            cur = son[cur][0];
            continue;
        }
        cur = son[cur][1];
    }
    return ans;
}
void Delete(int &root, int x) {
    Find(root, x);
    if (cnt[root] > 1) {
        cnt[root]--;
        Push(root);
    }
}

```

```

    return;
}
if (!son[root][0] && !son[root][1]) {
    Clear(root);
    root = 0;
    return;
}
if (!son[root][0]) {
    int cur = root;
    root = son[root][1];
    fa[root] = 0;
    Clear(cur);
    return;
}
if (!son[root][1]) {
    int cur = root;
    root = son[root][0];
    fa[root] = 0;
    Clear(cur);
    return;
}
int p = GetPrev(root), cur = root;
Splay(root, p);
fa[son[cur][1]] = p;
son[p][1] = son[cur][1];
Clear(cur);
Push(root);
}
};

namespace SegTree {
    int tree[maxn * 4];
    void Build(int o, int l, int r) {
        for (int i = l; i <= r; ++i) SplayTree::Insert(tree[o], arr[i - 1]);
        if (l == r) return;
        int m = (l + r) / 2;
        Build(o * 2, l, m);
        Build(o * 2 + 1, m + 1, r);
    }
    void Modify(int o, int l, int r, int ll, int rr, int u, int v) {
        SplayTree::Delete(tree[o], u); SplayTree::Insert(tree[o], v);
        if (l == r) return;
        int m = (l + r) / 2;
        if (ll <= m) Modify(o * 2, l, m, ll, rr, u, v);
        if (rr > m) Modify(o * 2 + 1, m + 1, r, ll, rr, u, v);
    }
    int QueryRank(int o, int l, int r, int ll, int rr, int v) {
        if (ll <= l && rr >= r) return SplayTree::GetRank(tree[o], v);

```

```

        int m = (l + r) / 2, ans = 0;
        if (ll <= m) ans += QueryRank(o * 2, l, m, ll, rr, v);
        if (rr > m) ans += QueryRank(o * 2 + 1, m + 1, r, ll, rr, v);
        return ans;
    }
    int QueryPrev(int o, int l, int r, int ll, int rr, int v) {
        if (ll <= l && rr >= r) return SplayTree::GetPrevVal(tree[o], v);
        int m = (l + r) / 2, ans = -inf;
        if (ll <= m) ans = std::max(ans, QueryPrev(o * 2, l, m, ll, rr, v));
        if (rr > m) ans = std::max(ans, QueryPrev(o * 2 + 1, m + 1, r, ll, rr, v));
        return ans;
    }
    int QueryNext(int o, int l, int r, int ll, int rr, int v) {
        if (ll <= l && rr >= r) return SplayTree::GetNextVal(tree[o], v);
        int m = (l + r) / 2, ans = inf;
        if (ll <= m) ans = std::min(ans, QueryNext(o * 2, l, m, ll, rr, v));
        if (rr > m) ans = std::min(ans, QueryNext(o * 2 + 1, m + 1, r, ll, rr, v));
        return ans;
    }
    int QueryKth(int ll, int rr, int v) {
        int l = 0, r = 1e8 + 10;
        while (l < r) {
            int m = ((l + r) / 2) + 1;
            if (QueryRank(1, 1, n, ll, rr, m) < v) l = m;
            else r = m - 1;
        }
        return l;
    }
};

int main() {
    std::ios::sync_with_stdio(false);
    std::cout.tie(0);
    std::cin.tie(0);
    int m;
    std::cin >> n >> m;
    for (int i = 0; i < n; ++i) std::cin >> arr[i];
    SplayTree::tot = 0;
    SegTree::Build(1, 1, n);
    for (int i = 0, op, l, r, pos, k; i < m; ++i) {
        std::cin >> op;
        if (op == 1) {
            std::cin >> l >> r >> k;
            std::cout << SegTree::QueryRank(1, 1, n, l, r, k) + 1 << '\n';

```

```

}
else if (op == 2) {
    std::cin >> l >> r >> k;
    std::cout << SegTree::QueryKth(l, r, k) << '\n';
}
else if (op == 3) {
    std::cin >> pos >> k;
    SegTree::Modify(1, 1, n, pos, pos, arr[pos - 1], k);
    ;
    arr[pos - 1] = k;
}
else if (op == 4) {
    std::cin >> l >> r >> k;
    std::cout << SegTree::QueryPrev(1, 1, n, l, r, k)
        << '\n';
}
else if (op == 5) {
    std::cin >> l >> r >> k;
    std::cout << SegTree::QueryNext(1, 1, n, l, r, k)
        << '\n';
}
}
return 0;
}

```

```

long long ans1, ans2;
long long ans;
int Build(int l, int r, int c) {
    tree[++tot].sz = 1;
    if (l == r) return tot;
    int m = (l + r) / 2, o = tot;
    if (c <= m) tree[o].lson = Build(l, m, c);
    else tree[o].rson = Build(m + 1, r, c);
    return o;
}
int Merge(int l, int r, int x, int y) {
    if (!x || !y) return x + y;
    if (l == r) {
        tree[++tot].sz = tree[x].sz + tree[y].sz;
        return tot;
    }
    ans1 += 1ll * tree[tree[x].rson].sz * tree[tree[y].lson]
        .sz;
    ans2 += 1ll * tree[tree[x].lson].sz * tree[tree[y].rson]
        .sz;
    int m = (l + r) / 2, o = ++tot;
    tree[o].lson = Merge(l, m, tree[x].lson, tree[y].lson);
    tree[o].rson = Merge(m + 1, r, tree[x].rson, tree[y].
        rson);
    tree[o].sz = tree[x].sz + tree[y].sz;
    return o;
}
int Dfs() {
    int c = 0;
    Read(c);
    if (c) return Build(1, n, c);
    int o = Merge(1, n, Dfs(), Dfs());
    ans += std::min(ans1, ans2);
    ans1 = ans2 = 0;
    return o;
}
int main() {
    Read(n);
    Dfs();
    printf("%lld", ans);
    return 0;
}

```

3.2 线段树

3.2.1 线段树合并

```

// BZOJ2212: 交换左右子树后最小逆序对
#include <bits/stdc++.h>
const int maxn = 1e7 + 5;
template <typename t>
inline bool Read(t &ret) {
    char c; int sgn;
    if (c = getchar(), c == EOF) return false;
    while (c != '-' && (c < '0' || c > '9')) c = getchar();
    sgn = (c == '-') ? -1 : 1;
    ret = (c == '-') ? 0 : (c - '0');
    while (c = getchar(), c >= '0' && c <= '9') ret = ret *
        10 + (c - '0');
    ret *= sgn;
    return true;
}
struct node {
    int sz, lson, rson;
    node() { sz = lson = rson = 0; }
};
int n;
int tot;
node tree[maxn];

```

3.2.2 线段树

```

const int maxn = "Edit";
struct SegTree {
    int n;
    long long sum[maxn * 4], lazy[maxn * 4];
    long long Unite(const long long &k1, const long long &
        k2) {
        return k1 + k2;
    }
};

```

```

}
void Pull(int o) {
    sum[o] = Unite(sum[o * 2], sum[o * 2 + 1]);
}
void Push(int o, int l, int r) {
    int m = (l + r) / 2;
    if (lazy[o] != 0) {
        sum[o * 2] += (m - l + 1) * lazy[o];
        sum[o * 2 + 1] += (r - m) * lazy[o];
        lazy[o * 2] += lazy[o];
        lazy[o * 2 + 1] += lazy[o];
        lazy[o] = 0;
    }
}
void Build(int o, int l, int r, long long arr[]) {
    sum[o] = lazy[o] = 0;
    if (l == r) {
        sum[o] = arr[l];
        return;
    }
    int m = (l + r) / 2;
    Build(o * 2, l, m, arr);
    Build(o * 2 + 1, m + 1, r, arr);
    Pull(o);
}
void Init(int _n, long long arr[]) {
    n = _n;
    Build(1, 1, n, arr);
}
void Modify(int o, int l, int r, int ll, int rr, long
    long v) {
    if (ll <= l && rr >= r) {
        sum[o] += (r - l + 1) * v;
        lazy[o] += v;
        return;
    }
    Push(o, l, r);
    int m = (l + r) / 2;
    if (ll <= m) Modify(o * 2, l, m, ll, rr, v);
    if (rr > m) Modify(o * 2 + 1, m + 1, r, ll, rr, v);
    Pull(o);
}
void Modify(int ll, int rr, long long v) {
    Modify(1, 1, n, ll, rr, v);
}
long long Query(int o, int l, int r, int ll, int rr) {
    if (ll <= l && rr >= r) return sum[o];
    Push(o, l, r);
    int m = (l + r) / 2;
    long long ret = 0;
    if (ll <= m) ret = Unite(ret, Query(o * 2, l, m, ll,
        rr));
    if (rr > m) ret = Unite(ret, Query(o * 2 + 1, m + 1,
        r, ll, rr));
}

```

```

return ret;
}
long long Query(int ll, int rr) {
    return Query(1, 1, n, ll, rr);
}
};

```

3.2.3 矩形面积异或并

```

// CodeForces GYM 101982 F 矩形面积异或并
#include <bits/stdc++.h>
std::vector<int> x;
int Get(int k) {
    return std::lower_bound(x.begin(), x.end(), k) - x.
        begin();
}
struct SegTree {
    struct node {
        int v, lazy;
        node() { v = lazy = 0; }
    };
    int n;
    std::vector<node> tree;
    node Unite(const node &k1, const node &k2) {
        node ans;
        ans.v = k1.v + k2.v;
        return ans;
    }
    void Pull(int o) {
        tree[o] = Unite(tree[o * 2], tree[o * 2 + 1]);
    }
    void Push(int o, int l, int r) {
        int m = (l + r) / 2;
        if (tree[o].lazy != 0) {
            tree[o * 2].v = x[m] - x[l - 1] - tree[o * 2].v;
            tree[o * 2 + 1].v = x[r] - x[m] - tree[o * 2 + 1].v
                ;
            tree[o * 2].lazy ^= 1;
            tree[o * 2 + 1].lazy ^= 1;
            tree[o].lazy = 0;
        }
    }
    void Build(int o, int l, int r) {
        if (l == r) return;
        int m = (l + r) / 2;
        Build(o * 2, l, m);
        Build(o * 2 + 1, m + 1, r);
        Pull(o);
    }
    SegTree(int _n): n(_n) {
        tree.resize(n << 2);
        Build(1, 1, n);
    }
}

```

```

}
void Modify(int o, int l, int r, int ll, int rr) {
    if (ll <= l && rr >= r) {
        tree[o].v = x[r] - x[l - 1] - tree[o].v;
        tree[o].lazy ^= 1;
        return;
    }
    Push(o, l, r);
    int m = (l + r) / 2;
    if (ll <= m) Modify(o * 2, l, m, ll, rr);
    if (rr > m) Modify(o * 2 + 1, m + 1, r, ll, rr);
    Pull(o);
}
void Modify(int ll, int rr) {
    Modify(1, 1, n, ll, rr);
}
node Query(int o, int l, int r, int ll, int rr) {
    if (ll <= l && rr >= r) return tree[o];
    Push(o, l, r);
    int m = (l + r) / 2;
    node ans;
    if (ll <= m) ans = Unite(ans, Query(o * 2, l, m, ll, rr));
    if (rr > m) ans = Unite(ans, Query(o * 2 + 1, m + 1, r, ll, rr));
    Pull(o);
    return ans;
}
node Query() {
    return Query(1, 1, n, 1, n);
}
};
struct seg { int l, r, h, flag; };
bool operator < (seg k1, seg k2) { return k1.h < k2.h; }
std::vector<seg> s;
int main() {
    std::ios::sync_with_stdio(false);
    std::cout.tie(nullptr);
    std::cin.tie(nullptr);
    int n; std::cin >> n;
    for (int i = 0, x1, y1, x2, y2; i < n; ++i) {
        std::cin >> x1 >> y1 >> x2 >> y2;
        if (x1 > x2) std::swap(x1, x2);
        if (y1 > y2) std::swap(y1, y2);
        x.emplace_back(x1); x.emplace_back(x2);
        s.emplace_back((seg){x1, x2, y1, 1});
        s.emplace_back((seg){x1, x2, y2, -1});
    }
    sort(s.begin(), s.end());
    sort(x.begin(), x.end());
    x.erase(unique(x.begin(), x.end()), x.end());
    SegTree tree((int)x.size());
    long long ans = 0;
    for (int i = 0, l, r; i < (int)s.size() - 1; ++i) {

```

```

        l = Get(s[i].l), r = Get(s[i].r);
        tree.Modify(l + 1, r);
        ans += (long long)tree.Query().v * (s[i + 1].h - s[i].h);
    }
    std::cout << ans << '\n';
    return 0;
}

```

3.2.4 矩形面积并

```

// HDU 1542 矩形面积并
#include <bits/stdc++.h>
typedef double db;
const int maxn = 1e2 + 5;
const db eps = 1e-9;
int Sgn(db k) {
    return std::fabs(k) < eps ? 0 : (k < 0 ? -1 : 1);
}
int Cmp(db k1, db k2) {
    return Sgn(k1 - k2);
}
struct seg {
    db l, r, h;
    int flag;
};
bool operator < (seg &k1, seg &k2) {
    return Cmp(k1.h, k2.h) < 0;
}
std::vector<seg> segs;
std::vector<db> pos;
int BinarySearch(db k) {
    int ret = (int)pos.size() - 1, l = 0, r = (int)pos.size() - 1;
    while (l <= r) {
        int m = (l + r) >> 1;
        if (Cmp(pos[m], k) >= 0) {
            ret = m;
            r = m - 1;
        }
        else l = m + 1;
    }
    return ret;
}
struct node {
    int l, r, cnt;
    db len;
};
node seg_tree[maxn * 10];
void Pull(int o) {
    if (seg_tree[o].cnt) seg_tree[o].len = pos[seg_tree[o].r + 1] - pos[seg_tree[o].l];
}

```

```

    else if (seg_tree[o].l == seg_tree[o].r) seg_tree[o].
        len = 0.0;
    else seg_tree[o].len = seg_tree[o << 1].len + seg_tree[
        o << 1 | 1].len;
}
void Build(int l, int r, int o) {
    seg_tree[o].l = l; seg_tree[o].r = r;
    seg_tree[o].cnt = 0; seg_tree[o].len = 0.0;
    if (l == r) return;
    int Mid = (l + r) >> 1;
    Build(l, Mid, o << 1);
    Build(Mid + 1, r, o << 1 | 1);
    Pull(o);
}
void Update(int l, int r, int v, int o) {
    if (l <= seg_tree[o].l && r >= seg_tree[o].r) {
        seg_tree[o].cnt += v;
        Pull(o);
        return;
    }
    int Mid = (seg_tree[o].l + seg_tree[o].r) >> 1;
    if (r <= Mid) Update(l, r, v, o << 1);
    else if (l > Mid) Update(l, r, v, o << 1 | 1);
    else {
        Update(l, Mid, v, o << 1);
        Update(Mid + 1, r, v, o << 1 | 1);
    }
    Pull(o);
}
int cas;
int n;
db x1, y1, x2, y2;
db ans;
int main() {
    while (~scanf("%d", &n) && n) {
        segs.clear();
        pos.clear();
        for (int i = 0; i < n; ++i) {
            scanf("%lf%lf%lf%lf", &x1, &y1, &x2, &y2);
            segs.push_back((seg){x1, x2, y1, 1});
            segs.push_back((seg){x1, x2, y2, -1});
            pos.push_back(x1);
            pos.push_back(x2);
        }
        std::sort(segs.begin(), segs.end());
        std::sort(pos.begin(), pos.end(), [&](db k1, db k2) {
            return Cmp(k1, k2) < 0; });
        int cur = 1;
        for (int i = 1; i < (int)pos.size(); ++i)
            if (Cmp(pos[i], pos[i - 1]) != 0)
                pos[cur++] = pos[i];
        pos.erase(pos.begin() + cur, pos.end());
        Build(0, (int)pos.size(), 1);
        ans = 0.0;

```

```

        for (int i = 0; i < (int)segs.size() - 1; ++i) {
            int l = BinarySearch(segs[i].l), r = BinarySearch(
                segs[i].r);
            Update(l, r - 1, segs[i].flag, 1);
            ans += (segs[i + 1].h - segs[i].h) * seg_tree[1].
                len;
        }
        printf("Test case #%d\n", ++cas);
        printf("Total explored area: %.21f\n\n", ans);
    }
    return 0;
}

```

3.3 树链剖分

```

const int maxn = "Edit";
int n;
long long val[maxn];
int fa[maxn], dep[maxn];
int sz[maxn], son[maxn];
int rk[maxn], top[maxn];
int id[maxn];
int dfs_clock;
std::vector<int> g[maxn];
void Dfs1(int u, int p, int d) {
    fa[u] = p;
    dep[u] = d;
    sz[u] = 1;
    for (int &v : g[u]) {
        if (v == p) continue;
        Dfs1(v, u, d + 1);
        sz[u] += sz[v];
        if (sz[v] > sz[son[u]]) son[u] = v;
    }
}
Dfs2(int u, int tp) {
    top[u] = tp;
    id[u] = ++dfs_clock;
    rk[dfs_clock] = u;
    if (!son[u]) return;
    Dfs2(son[u], tp);
    for (int &v : g[u]) {
        if (v == son[u] || v == fa[u]) continue;
        Dfs2(v, v);
    }
}
long long Modify(int u, int v, long long c) {
    while (top[u] != top[v]) {
        if (dep[top[u]] < dep[top[v]]) std::swap(u, v);
        /* modify c from [id[top[u]], id[u]] in val */
        u = fa[top[u]];
    }
}

```



```

}
if (id[u] > id[v]) std::swap(u, v);
/* modify c from [id[u], id[v]] in val */
}
long long Query(int u, int v) {
    long long ret = 0;
    while (top[u] != top[v]) {
        if (dep[top[u]] < dep[top[v]]) std::swap(u, v);
        ret += /* query from [id[top[u]], id[u]] in val */
        u = fa[top[u]];
    }
    if (id[u] > id[v]) std::swap(u, v);
    ret += /* query from [id[u], id[v]] in val */
    return ret;
}

```

3.4 树状数组

3.4.1 树状数组

```

const int maxn = "Edit";
struct BitTree {
    int tree[maxn];
    void Init() {
        memset(tree, 0, sizeof(tree));
    }
    void Modify(int x, int v) {
        for (int i = x; i < maxn; i += i & (-i))
            tree[i] += v;
    }
    int Query(int x) {
        int ret = 0;
        for (int i = x; i > 0; i -= i & (-i))
            ret += tree[i];
        return ret;
    }
    int GetRank(int v) {
        int ret = 1;
        --v;
        for (int i = v; i > 0; i -= i & (-i))
            ret += tree[i];
        return ret;
    }
    int GetKth(int k) { // kth min
        int ret = 0, cnt = 0, max = log2(maxn);
        for (int i = max; i >= 0; --i) {
            ret += (1 << i);
            if (ret >= maxn || cnt += tree[ret] >= k) ret -= (1 << i);
            else cnt += tree[ret];
        }
    }
}

```

```

return ++ret;
}
int GetPrev(int v) {
    return GetKth(GetRank(v) - 1);
}
int GetNext(int v) {
    return GetKth(GetRank(v) + 1);
}
};

```

3.4.2 二维树状数组

```

const int maxn = "Edit";
struct BitTree2D {
    int tree[4][maxn][maxn];
    void Modify(int x, int y, int v) {
        for (int i = x; i < maxn; i += i & (-i)) {
            for (int j = y; j < maxn; j += j & (-j)) {
                tree[0][i][j] += v;
                tree[1][i][j] += v * y;
                tree[2][i][j] += v * x;
                tree[3][i][j] += v * x * y;
            }
        }
    }
    int Query(int x, int y) {
        int ret = 0;
        for (int i = x; i > 0; i -= i & (-i)) {
            for (int j = y; j > 0; j -= j & (-j)) {
                ret += tree[0][i][j] * (x + 1) * (y + 1);
                ret -= tree[1][i][j] * (x + 1);
                ret -= tree[2][i][j] * (y + 1);
                ret += tree[3][i][j];
            }
        }
        return ret;
    }
};

```

3.5 最近公共祖先

3.5.1 欧拉序 + RMQ

```

const int maxn = "Edit";
const int maxlog = "Edit";
int n;
std::vector<int> g[maxn];
int ele[maxn * 2], dep[maxn * 2];
int fi[maxn], fa[maxn];

```

```

int tot;
int dp[maxn * 2][maxlog];
void Dfs(int u, int p, int d) {
    ele[++tot] = u;
    fi[u] = tot;
    dep[tot] = d;
    fa[u] = p;
    for (int &v : g[u]) {
        if (v == p) continue;
        Dfs(v, u, d + 1);
        ele[++tot] = u;
        dep[tot] = d;
    }
}
void Init() {
    for(int i = 1; i <= 2 * n - 1; ++i) dp[i][0] = i;
    for (int j = 1; (1 << j) <= 2 * n - 1; ++j)
        for (int i = 1; i + (1 << j) - 1 <= 2 * n - 1; ++i)
            dp[i][j] = dep[dp[i][j - 1]] < dep[dp[i + (1 << j - 1)][j - 1]] ? dp[i][j - 1] : dp[i + (1 << (j - 1))[j - 1];
}
int Query(int l, int r) {
    if (l > r) std::swap(l, r);
    int len = log2(r - l + 1);
    return dep[dp[l][len]] <= dep[dp[r - (1 << len) + 1][len]] ? dp[l][len] : dp[r - (1 << len) + 1][len];
}
int GetLCA(int u, int v) {
    return ele[Query(fi[u], fi[v])];
}

```

3.5.2 倍增

```

const int maxn = "Edit";
const int maxlog = "Edit";
int n, k; // k = log2(n) + 1
std::vector<int> g[maxn];
int anc[maxn][maxlog];
int dep[maxn];
// 从根节点开始深搜预处理
void Dfs(int u, int p, int d) {
    anc[u][0] = p;
    dep[u] = d;
    for (int &v : g[u]) {
        if (v == p) continue;
        Dfs(v, u, d + 1);
    }
}
void Swim(int &u, int h) {
    for (int i = 0; h > 0; ++i) {
        if (h & 1) u = anc[u][i];
    }
}

```

```

    h >>= 1;
}
}
int GetLCA(int u, int v) {
    if (dep[u] < dep[v]) std::swap(u, v);
    Swim(u, dep[u] - dep[v]);
    if (u == v) return v;
    for (int i = k - 1; i >= 0; --i) {
        if (anc[u][i] != anc[v][i]) {
            u = anc[u][i];
            v = anc[v][i];
        }
    }
    return anc[u][0];
}

```

3.5.3 tarjan

```

const int maxn = "Edit";
const int maxm = "Edit";
int n;
int pre[maxn];
int Find(int o) {
    return pre[o] == o ? o : pre[o] = Find(pre[o]);
}
void Union(int u, int v) {
    if (Find(u) != Find(v)) pre[Find(u)] = Find(v);
}
std::vector<int> g[maxn];
bool vis[maxn];
struct query { int v, id; };
std::vector<query> qry[maxm];
void Init() {
    for (int i = 1; i <= n; ++i) {
        pre[i] = i;
        vis[i] = false;
    }
}
void Tarjan(int u) {
    vis[u] = true;
    for (int &v : g[u]) {
        if (vis[v]) continue;
        Tarjan(v);
        Union(v, u);
    }
    for (query &q : qry[u]) {
        if (vis[q.v]) ans[q.id] = Find(q.v);
    }
}

```

3.6 伸展树

```

const int inf = "Edit"
const int maxn = "Edit";
struct SplayTree {
    int rt, tot;
    int fa[maxn], son[maxn][2];
    int val[maxn], cnt[maxn];
    int sz[maxn];
    bool lazy[maxn];
    void Pull(int o) {
        sz[o] = sz[son[o][0]] + sz[son[o][1]] + cnt[o];
    }
    void Push(int o) {
        if (lazy[o]) {
            std::swap(son[o][0], son[o][1]);
            if (son[o][0]) lazy[son[o][0]] ^= 1;
            if (son[o][1]) lazy[son[o][1]] ^= 1;
            lazy[o] = 0;
        }
    }
    bool Get(int o) {
        return o == son[fa[o]][1];
    }
    void Clear(int o) {
        son[o][0] = son[o][1] = fa[o] = val[o] = sz[o] = cnt[
            o] = 0;
    }
    void Rotate(int o) {
        int p = fa[o], q = fa[p], ck = Get(o);
        son[p][ck] = son[o][ck ^ 1];
        fa[son[o][ck ^ 1]] = p;
        son[o][ck ^ 1] = p;
        fa[p] = o; fa[o] = q;
        if (q) son[q][p == son[q][1]] = o;
        Pull(p); Pull(o);
    }
    void Splay(int o) {
        for (int f = fa[o]; f = fa[o], f; Rotate(o))
            if (fa[f]) Rotate(Get(o) == Get(f) ? f : o);
        rt = o;
    }
    // 旋转o节点到节点tar
    void Splay(int o, int tar = 0) {
        for (int f = fa[o]; (f = fa[o]) != tar; Rotate(o)) {
            Pull(fa[f]); Pull(f); Pull(o);
            if (fa[f] != tar) {
                if (Get(o) == Get(f)) Rotate(f);
                else Rotate(o);
            }
        }
        if (!tar) rt = o;
    }
}

```

```

void Insert(int x) {
    if (!rt) {
        val[++tot] = x;
        cnt[tot]++;
        rt = tot;
        Pull(rt);
        return;
    }
    int cur = rt, f = 0;
    while (true) {
        if (val[cur] == x) {
            cnt[cur]++;
            Pull(cur); Pull(f);
            Splay(cur);
            break;
        }
        f = cur;
        cur = son[cur][val[cur] < x];
        if (!cur) {
            val[++tot] = x;
            cnt[tot]++;
            fa[tot] = f;
            son[f][val[f] < x] = tot;
            Pull(tot); Pull(f);
            Splay(tot);
            break;
        }
    }
}

int GetRank(int x) {
    int ans = 0, cur = rt;
    while (true) {
        if (x < val[cur]) cur = son[cur][0];
        else {
            ans += sz[son[cur][0]];
            if (x == val[cur]) {
                Splay(cur);
                return ans + 1;
            }
            ans += cnt[cur];
            cur = son[cur][1];
        }
    }
}

int GetKth(int k) {
    int cur = rt;
    while (true) {
        if (son[cur][0] && k <= sz[son[cur][0]]) cur = son[
            cur][0];
        else {
            k -= cnt[cur] + sz[son[cur][0]];
            if (k <= 0) return cur;
            cur = son[cur][1];
        }
    }
}

```

```

    }
}
// 获取以r为根节点Splay Tree中的第k大个元素在Splay Tree
// 中的位置
int Kth(int r, int k) {
    Pull(r);
    int tmp = sz[son[r][0]] + 1;
    if (tmp == k) return r;
    if (tmp > k) return Kth(son[r][0], k);
    else return Kth(son[r][1], k - tmp);
}
// Insert之后求前驱后继
int GetPrev() {
    int cur = son[rt][0];
    while (son[cur][1]) cur = son[cur][1];
    return cur;
}
int GetNext() {
    int cur = son[rt][1];
    while (son[cur][0]) cur = son[cur][0];
    return cur;
}
// 获取Splay Tree中以o为根节点子树的最小值位置
int GetMin(int o) {
    Pull(o);
    while (son[o][0]) {
        o = son[o][0];
        Pull(o);
    }
    return o;
}
// 获取Splay Tree中以o为根节点子树的最大值位置
int GetMax(int o) {
    Pull(o);
    while (son[o][1]) {
        o = son[o][1];
        Pull(o);
    }
    return o;
}
void Delete(int x) {
    GetRank(x);
    if (cnt[rt] > 1) {
        cnt[rt]--;
        Pull(rt);
        return;
    }
    if (!son[rt][0] && !son[rt][1]) {
        Clear(rt);
        rt = 0;
        return;
    }
    if (!son[rt][0]) {
        int cur = rt;

```

```

        rt = son[rt][1];
        fa[rt] = 0;
        Clear(cur);
        return;
    }
    if (!son[rt][1]) {
        int cur = rt;
        rt = son[rt][0];
        fa[rt] = 0;
        Clear(cur);
        return;
    }
    int p = GetPrev(), cur = rt;
    Splay(p);
    fa[son[cur][1]] = p;
    son[p][1] = son[cur][1];
    Clear(cur);
    Pull(rt);
}
/* 维护数组操作 */
// 翻转Splay Tree中l~r区间
void Reverse(int l, int r) {
    int o = Kth(rt, l), Y = Kth(rt, r);
    Splay(o, 0); Splay(Y, o);
    lazy[son[Y][0]] ^= 1;
}
// 建立Splay Tree
void Build(int l, int r, int o) {
    if (l > r) return;
    int m = (l + r) >> 1;
    Build(l, m - 1, m);
    Build(m + 1, r, m);
    fa[m] = o;
    val[m] = /* 节点权值 */;
    lazy[m] = 0;
    Push(m);
    if (m < o) son[o][0] = m;
    else son[o][1] = m;
}
// 输出Splay Tree
void Print(int o) {
    Pull(o);
    if (son[o][0]) Print(son[o][0]);
    // 哨兵节点判断
    if (val[o] != -inf && val[o] != inf) printf("%d ",
        val[o]);
    if (val[son[o][1]]) Print(son[o][1]);
}
};

```

3.7 主席树

```

const int maxn = "Edit";
struct FuncSegTree {
    int tot;
    int rt[maxn];
    int lson[maxn * 40], rson[maxn * 40];
    int cnt[maxn * 40];
    int Build(int l, int r) {
        int o = ++tot, m = (l + r) / 2;
        cnt[o] = 0;
        if (l != r) {
            lson[o] = Build(l, m);
            rson[o] = Build(m + 1, r);
        }
        return o;
    }
    int Modify(int prev, int l, int r, int v) {
        int o = ++tot, m = (l + r) / 2;
        lson[o] = lson[prev];
        rson[o] = rson[prev];
        cnt[o] = cnt[prev] + 1;
        if (l != r) {
            if (v <= m) lson[o] = Modify(lson[o], l, m, v);
            else rson[o] = Modify(rson[o], m + 1, r, v);
        }
        return o;
    }
    // 区间[u+1,v]静态第k小
    int Query(int u, int v, int l, int r, int k) {
        if (l == r) return l;
        int m = (l + r) / 2;
        int num = cnt[lson[v]] - cnt[lson[u]];
        if (num >= k) return Query(lson[u], lson[v], l, m, k);
        else return Query(rson[u], rson[v], m + 1, r, k - num);
    }
    // 区间[u+1,v]内[s,t]数量
    int Query(int u, int v, int s, int t, int l, int r) {
        if (s <= l && t >= r) return cnt[v] - cnt[u];
        int m = (l + r) / 2, ret = 0;
        if (s <= m) ret += Query(lson[u], lson[v], s, t, l, m);
        if (t > m) ret += Query(rson[u], rson[v], s, t, m + 1, r);
        return ret;
    }
};

```

3.8 dfs 序

```

const int maxn = "Edit";

```

```

std::vector<int> g[maxn];
int in[maxn], out[maxn];
int ele[maxn];
int dfs_clock;
void DfsSeq(int u, int p) {
    in[u] = ++dfs_clock;
    ele[dfs_clock] = u;
    for (int &v : g[u]) {
        if (v == p) continue;
        DfsSeq(v, u);
    }
    out[u] = dfs_clock;
}

```

3.9 ST 表

```

const int maxn = "Edit";
const int maxlog = "Edit";
int n;
int max[maxn][maxlog], min[maxn][maxlog];
void Init(int arr[]) {
    int m = log2(n) + 1;
    for (int i = 1; i <= n; ++i) max[i][0] = min[i][0] = arr[i];
    for (int j = 1; j < m; ++j) {
        for (int i = 1; i + (1 << j) - 1 <= n; ++i) {
            max[i][j] = std::max(max[i][j - 1], max[i + (1 << (j - 1))][j - 1]);
            min[i][j] = std::min(min[i][j - 1], min[i + (1 << (j - 1))][j - 1]);
        }
    }
}
// 区间[l,r]最大值
int QueryMax(int l, int r) {
    int k = log2(r - l + 1);
    return std::max(max[l][k], max[r - (1 << k) + 1][k]);
}
// 区间[l,r]最小值
int QueryMin(int l, int r) {
    int k = log2(r - l + 1);
    return std::min(min[l][k], min[r - (1 << k) + 1][k]);
}

```

3.10 Link Cut Tree

```

const int maxn = "Edit";
struct LCT {
    int fa[maxn], son[maxn][2];
}

```

```

int val[maxn], sum[maxn];
int rev[maxn], stk[maxn];
void Init(int n) {
    for (int i = 1; i <= n; ++i) scanf("%d", &val[i]);
    for (int i = 1; i <= n; ++i) fa[i] = son[i][0] = son[i][1] = rev[i] = 0;
}
bool IsRoot(int o) {
    return son[fa[o]][0] != o && son[fa[o]][1] != o;
}
bool Get(int o) {
    return son[fa[o]][1] == o;
}
// 更新所需维护的信息
void Pull(int o) {
    sum[o] = val[o] ^ sum[son[o][0]] ^ sum[son[o][1]];
}
void Push(int o) {
    if (rev[o] != 0) {
        std::swap(son[o][0], son[o][1]);
        if (son[o][0]) rev[son[o][0]] ^= 1;
        if (son[o][1]) rev[son[o][1]] ^= 1;
        rev[o] ^= 1;
    }
}
void Rotate(int o) {
    int p = fa[o], q = fa[p], ck = Get(o);
    if (!IsRoot(p)) son[q][Get(p)] = o;
    fa[o] = q;
    son[p][ck] = son[o][ck ^ 1];
    fa[son[p][ck]] = p;
    son[o][ck ^ 1] = p;
    fa[p] = o;
    Pull(p);
    Pull(o);
}
void Splay(int o) {
    int top = 0;
    stk[++top] = o;
    for (int i = o; !IsRoot(i); i = fa[i]) stk[++top] = fa[i];
    for (int i = top; i; --i) Push(stk[i]);
    for (int f = fa[o]; !IsRoot(o); Rotate(o), f = fa[o])
        if (!IsRoot(f)) Rotate(Get(o) == Get(f) ? f : o);
}
// 将使o成为一条实路径并在同一棵Splay内
void Access(int o) {
    for (int p = 0; o; p = o, o = fa[o]) {
        Splay(o);
        son[o][1] = p;
        Pull(o);
    }
}
// 返回o所在树的根节点编号

```

```

int Find(int o) {
    Access(o);
    Splay(o);
    while (son[o][0]) o = son[o][0];
    return o;
}
// 使o成为其所在树的根
void MakeRoot(int o) {
    Access(o);
    Splay(o);
    rev[o] ^= 1;
}
// u,v之间连边,先判不能在同一棵树内
void Link(int u, int v) {
    MakeRoot(u);
    fa[u] = v;
    Splay(u);
}
// 删除u,v之间的边
void Cut(int u, int v) {
    MakeRoot(u);
    Access(v);
    Splay(v);
    fa[u] = son[v][0] = 0;
}
// o节点单点修改
void Modify(int o, int v) {
    val[o] = v;
    Access(o);
    Splay(o);
}
// u,v路径信息
int Query(int u, int v) {
    MakeRoot(v);
    Access(u);
    Splay(u);
    return sum[u];
}
};

```

4 字符串

4.1 最小表示法

```
int minRepresent(char *s, int len) {
    int i = 0, j = 1, k = 0;
    while (i < len && j < len && k < len) {
        int t = s[(i+k) % len] - s[(j+k) % len];
        if (t == 0) k++;
        else {
            if (t < 0) j = max(j+k+1, i+1);
            else i = max(i+k+1, j+1);
            k = 0;
        }
    }
    return min(i, j);
}

int minRepresent(int start, int end, int len) { // 判断[
    strat, end]是否为最小表示
    int i = 0+start, j = 1+start, k = 0;
    while (i < end && j < end && k < len) {
        int l = i + k; if (l >= end) l = l - end + start;
        int r = j + k; if (r >= end) r = r - end + start;
        int t = s[l] - s[r];
        if (t == 0) k++;
        else {
            if (t < 0) j = max(j+k+1, i+1);
            else i = max(i+k+1, j+1);
            k = 0;
        }
    }
    return min(i, j) == start;
}
```

4.2 扩展 kmp

```
struct exKmp{
    // 字符串下标从0开始
    int nex[maxn], ex[maxn]; // 模式串nex, 匹配串ex
    void getNext(char *str, int len) {
        int i = 0, j, pos;
        nex[0] = len;
        while (str[i] == str[i+1] && i+1 < len) ++i;
        nex[1] = i;
        pos = 1;
        for (int i = 2; i < len; ++i) {
            if (nex[i-pos] + i < nex[pos] + pos) nex[i] =
                nex[i-pos];
        }
    }
}
```

```
else {
    j = nex[pos] + pos - i;
    if (j < 0) j = 0;
    while (i+j < len && str[j] == str[j+i])
        ++j;
    nex[i] = j;
    pos = i;
}
}

void getNext(char *s1, char *s2) { // s1匹配s2
    int i = 0, j, pos;
    int len1 = strlen(s1);
    int len2 = strlen(s2);
    getNext(s2, len2);
    while (s1[i] == s2[i] && i < len1 && i < len2) ++
        i;
    ex[0] = i;
    pos = 0;
    for (int i = 1; i < len1; ++i) {
        if (nex[i-pos] + i < ex[pos] + pos) ex[i] =
            nex[i-pos];
        else {
            j = ex[pos] + pos - i;
            if (j < 0) j = 0;
            while (i+j < len1 && j < len2 && s1[i+j]
                == s2[j]) ++j;
            ex[i] = j;
            pos = i;
        }
    }
}

}exkmp;
```

4.3 字典树

```
struct Trie{
    int nex[maxn][26], cnt[maxn], end[maxn];
    int p, root; // root = 0
    int newNode() {
        memset(nex[p], 0, sizeof(nex[p]));
        cnt[p] = end[p] = 0;
        return p++;
    }
    void init() {
        p = 0;
        root = newNode();
    }
    void add(char *s) {
        int now = root;
        for (int i = 0; s[i]; ++i) {
            int u = s[i] - 'a';
            if (!nex[now][u]) nex[now][u] = newNode();
            now = nex[now][u];
        }
        end[now] = 1;
    }
}
```

```

        if (nex[now][s[i] - 'a'] == 0) nex[now][s[i]
            - 'a'] = newnode();
        now = nex[now][s[i] - 'a'];
        cnt[now]++;
    }
    end[now] = 1;
}
int find(char *s) {
    int now = root;
    for (int i = 0; s[i]; ++i) {
        if (nex[now][s[i] - 'a'] == 0) return 0;
        now = nex[now][s[i] - 'a'];
    }
    return cnt[now];
}
}
}trie;

```

4.4 回文树

```

struct Palindrome_Tree{
    int nex[maxn][26];
    int fail[maxn], cnt[maxn], num[maxn]; // num 记录每个
        节点右端点的表示回文串的个数
    int len[maxn], S[maxn];
        // cnt 记录每个节点表示的回文串出现的次
        数
    int last, n, p;
    int newnode(int l) { // 新建节点
        for (int i = 0; i < 26; ++i) nex[p][i] = 0;
        cnt[p] = num[p] = 0;
        len[p] = l;
        return p++;
    }
    void init() { // 初始化
        p = 0;
        newnode(0), newnode(-1); // 新建奇根和偶根
        last = n = 0;
        S[n] = -1;
        fail[0] = 1; // 偶根指向
    }
    int get_fail(int x) { // 求fail
        while (S[n - len[x] - 1] != S[n]) x = fail[x];
        return x;
    }
    void add(int c) { // 添加节点
        c -= 'a';
        S[++n] = c;
        int cur = get_fail(last);
        if (!nex[cur][c]) {
            int now = newnode(len[cur] + 2);
            fail[now] = nex[get_fail(fail[cur])][c];

```

```

        nex[cur][c] = now;
        num[now] = num[fail[now]] + 1;
    }
    last = nex[cur][c];
    cnt[last]++;
}
void count() { // 求cnt
    for (int i = p - 1; i >= 0; --i) cnt[fail[i]] +=
        cnt[i];
}
}Tree;

```

4.5 哈希

```

struct Hash{
    // mod 402653189, 805306457, 1610612741, 1e9+7
    // base 131, 233
    long long p[maxn], hash[maxn], base = 131;
    long long getHash(int l, int r) {
        long long ans = (hash[r] - hash[l-1] * p[r-l+1])
            % mod;
        return (ans + mod) % mod;
    }
    void init(string s) {
        int n = s.size();
        p[0] = 1;
        for (int i = 1; i <= n; ++i) p[i] = p[i-1] *
            base % mod;
        for (int i = 1; i <= n; ++i) {
            hash[i] = (hash[i-1] * base % mod + (s[i-1]
                - 'a' + 1)) % mod;
        }
    }
}hash;

```

4.6 后缀自动机

```

struct SAM{
    int trans[maxn<<1][26], slink[maxn<<1], maxlen[maxn
        <<1];
    // 用来求endpos
    int indegree[maxn<<1], endpos[maxn<<1], rank[maxn
        <<1], ans[maxn<<1];
    // 计算所有子串的和(0-9表示)
    long sum[maxn<<1];
    int last, now, root, len;
    inline void newnode (int v) {
        maxlen[++now] = v;
    }
}

```



```

inline void extend(int c) {
    newnode(maxlen[last] + 1);
    int p = last, np = now;
    // 更新trans
    while (p && !trans[p][c]) {
        trans[p][c] = np;
        p = slink[p];
    }
    if (!p) slink[np] = root;
    else {
        int q = trans[p][c];
        if (maxlen[p] + 1 != maxlen[q]) {
            // 将q点拆出nq, 使得maxlen[p] + 1 ==
            // maxlen[q]
            newnode(maxlen[p] + 1);
            int nq = now;
            memcpy(trans[nq], trans[q], sizeof(trans[
                q]));
            slink[nq] = slink[q];
            slink[q] = slink[np] = nq;
            while (p && trans[p][c] == q) {
                trans[p][c] = nq;
                p = slink[p];
            }
        } else slink[np] = q;
    }
    last = np;
    // 初始状态为可接受状态
    endpos[np] = 1;
}

inline void build(char *s) {
    // scanf("%s", s);
    len = strlen(s);
    root = last = now = 1;
    for (int i = 0; i < len; ++i) extend(s[i] - '0');
    // extend(s[i] - '1');
}

// 计算所有子串的和 (0-9表示)
inline long getSum() {
    // 拓扑排序
    for (int i = 1; i <= now; ++i) indegree[ maxlen[i]
        ]++;
    for (int i = 1; i <= now; ++i) indegree[i] +=
        indegree[i-1];
    for (int i = 1; i <= now; ++i) rank[ indegree[
        maxlen[i] ] - 1 ] = i;
    mem(endpos, 0);
    endpos[1] = 1; // 从根节点向后求有效的入度
    for (int i = 1; i <= now; ++i) {
        int x = rank[i];
        for (int j = 0; j < 10; ++j) {
            int nex = trans[x][j];
            if (!nex) continue;
            endpos[nex] += endpos[x]; // 有效入度
        }
    }
}

```

```

        long num = (sum[x] * 10 + endpos[x] * j)
            % mod;
        sum[nex] = (sum[nex] + num) % mod; // 状
            态转移
    }
}

long long ans = 0;
for (int i = 2; i <= now; ++i) ans = (ans + sum[i]
    ]) % mod;
return ans;
}

inline void getEndpos() {
    // topsort
    for (int i = 1; i <= now; ++i) indegree[ maxlen[i]
        ]++; // 统计相同度数的节点的个数
    for (int i = 1; i <= now; ++i) indegree[i] +=
        indegree[i-1]; // 统计度数小于等于 i 的节点
        的总数
    for (int i = 1; i <= now; ++i) rank[ indegree[
        maxlen[i] ] - 1 ] = i; // 为每个节点编号, 节
        点度数越大编号越靠后
    // 从下往上按照slink更新
    for (int i = now; i >= 1; --i) {
        int x = rank[i];
        endpos[slink[x]] += endpos[x];
    }
}

// 求不同的子串种类
inline long long all () {
    long long ans = 0;
    for (int i = root+1; i <= now; ++i) {
        ans += maxlen[i] - maxlen[ slink[i] ];
    }
    return ans;
}

// 长度为K的字符串有多种, 求出现次数最多的次数
inline void get_Maxk() {
    getEndpos();
    for (int i = 1; i <= now; ++i) {
        ans[maxlen[i]] = max(ans[maxlen[i]], endpos[i]
            );
    }
    for (int i = len; i >= 1; --i) ans[i] = max(ans[i]
        ], ans[i+1]);
    for (int i = 1; i <= len; ++i) //cout << ans[i]
        << endl;
    printf("%d\n", ans[i]);
}

} sam;

```

4.7 后缀数组

```

int cntA[maxn], cntB[maxn], A[maxn], B[maxn];
int Sa[maxn], tsa[maxn], height[maxn], Rank[maxn];
char s[maxn];
int n;
void SuffixArray () {
    for (int i = 0; i < 1000; ++i) cntA[i] = 0;
    for (int i = 1; i <= n; ++i) cntA[(int)s[i]]++;
    for (int i = 1; i < 1000; ++i) cntA[i] += cntA[i-1];
    for (int i = n; i >= 1; --i) Sa[ cntA[(int)s[i]]-- ] = i;
    Rank[ Sa[1] ] = 1;
    for (int i = 2; i <= n; ++i) {
        Rank[ Sa[i] ] = Rank[ Sa[i-1] ];
        if (s[ Sa[i] ] != s[ Sa[i-1] ]) Rank[ Sa[i] ]++;
    }
    for (int l = 1; Rank[ Sa[n] ] < n; l <= 1) {
        for (int i = 0; i <= n; ++i) cntA[i] = 0;
        for (int i = 0; i <= n; ++i) cntB[i] = 0;
        for (int i = 1; i <= n; ++i) {
            cntA[ A[i] = Rank[ i ] ]++;
            cntB[ B[i] = (i + l <= n) ? Rank[ i+l ] : 0 ]++;
        }
        for (int i = 1; i <= n; ++i) cntB[i] += cntB[i-1];
        for (int i = n; i >= 1; --i) tsa[ cntB[B[i]]-- ] = i;
        for (int i = 1; i <= n; ++i) cntA[i] += cntA[i-1];
        for (int i = n; i >= 1; --i) Sa[ cntA[A[ tsa[i]]]-- ] = tsa[i];
        Rank[ Sa[1] ] = 1;
        for (int i = 2; i <= n; ++i) {
            Rank[ Sa[i] ] = Rank[ Sa[i-1] ];
            if (A[ Sa[i] ] != A[ Sa[i-1] ] || B[ Sa[i] ] != B[ Sa[i-1] ]) Rank[ Sa[i] ]++;
        }
    }
    for (int i = 1, j = 0; i <= n; ++i) {
        if (j) --j;
        int tmp = Sa[ Rank[i] - 1 ];
        while (i + j <= n && tmp + j <= n && s[i+j] == s[tmp+j]) ++j;
        height[ Rank[i] ] = j;
    }
}

```

4.8 kmp

```

struct KMP{ // 下标0
    int nex[maxn];
    void get_nex(char *buf, int len) {
        nex[0] = -1;
        int i = 0, j = -1;
        while (i < len) {
            if (j == -1 || buf[i] == buf[j])
                nex[++i] = ++j;
            else j = nex[j];
        }
    }
    int get_kmp(char *buf1, char *buf2) { // buf1匹配串, buf2模式串
        int len1 = strlen(buf1), len2 = strlen(buf2);
        get_nex(buf2, len2);
        int cnt = 0, i = 0, j = 0;
        while (i < len1) {
            if (j == -1 || buf1[i] == buf2[j]) ++i, ++j;
            else j = nex[j];
            if (j == len2) cnt++, j = nex[j];
        }
        return cnt; // 匹配个数
    }
}kmp;

```

4.9 AC 自动机

```

struct Trie{
    int nex[maxn][26], fail[maxn], end[maxn];
    int root, p;
    inline int newnode() {
        for (int i = 0; i < 26; ++i)
            nex[p][i] = -1;
    }
    end[p++] = 0;
    return p - 1;
}
inline void init() {
    p = 0;
    root = newnode();
}
inline void insert(char *buf) {
    int now = root;
    for (int i = 0; buf[i]; ++i) {
        if (nex[now][buf[i]-'a'] == -1)
            nex[now][buf[i]-'a'] = newnode();
        now = nex[now][buf[i]-'a'];
    }
    end[now] = 1;
}

```

```

    }
    end[now]++;
}
inline void build() {
    queue<int> que;
    fail[root] = root;
    for (int i = 0; i < 26; ++i) {
        if (nex[root][i] == -1)
            nex[root][i] = root;
        else {
            fail[nex[root][i]] = root;
            que.push(nex[root][i]);
        }
    }
    while (!que.empty()) {
        int now = que.front();
        que.pop();
        for (int i = 0; i < 26; ++i) {
            if (nex[now][i] == -1)
                nex[now][i] = nex[fail[now]][i];
            else {
                fail[nex[now][i]] = nex[fail[now]][i];
                que.push(nex[now][i]);
            }
        }
    }
}
long long num[maxn], dp[maxn]; // num记录节点i匹配的
                             // 个数, dp辅助得到所有匹配数量
long long dfs(int now) {
    if (now == root) return 0;
    if (dp[now] != -1) return dp[now];
    return dp[now] = end[now] + dfs(fail[now]);
}
inline void solve(char *buf) {
    fill(num, num+maxn, 0);
    fill(dp, dp+maxn, -1);
    int now = root;
    for (int i = 0; buf[i]; ++i) {
        now = nex[now][buf[i]-'a'];
        num[i] = dfs(now);
    }
}
inline long long query(char *buf) {
    int now = root;
    long long cnt = 0;
    for (int i = 0; buf[i]; ++i) {
        now = nex[now][buf[i]-'a'];
        int tmp = now;
        while (tmp != root && end[tmp] != -1) {
            cnt += end[tmp];
            end[tmp] = -1; // 统计种类, 加速
            tmp = fail[tmp];
        }
    }
}

```

```

    }
    }
    return cnt;
}
}L, R;

```

5 图论

5.1 次小生成树

```
// Kruskal
int n, m;
struct ac{
    int u, v, w, flag;
    bool operator <(ac t) {
        return w < t.w;
    }
}g[maxn*maxn];
vector<int> son[maxn];
int pre[maxn], dis[maxn][maxn];
int find(int x) {
    return (pre[x] == x) ? x : pre[x] = find(pre[x]);
}
void Kruskal() {
    for (int i = 0; i <= n; ++i) {
        son[i].clear();
        son[i].push_back(i);
        pre[i] = i;
    }
    sort(g, g+m);
    int sum = 0;
    int cnt = 0;
    for (int i = 0; i < m; ++i) {
        if (cnt == n+1) break;
        int fx = find(g[i].u);
        int fy = find(g[i].v);
        if (fx == fy) continue;
        g[i].flag = 1;
        sum += g[i].w;
        cnt++;
        int lenx = son[fx].size();
        int leny = son[fy].size();
        if (lenx < leny) {
            swap(lenx, leny);
            swap(fx, fy);
        }
        // 更新两点的距离最大值
        for (int j = 0; j < lenx; ++j) {
            for (int k = 0; k < leny; ++k) {
                dis[son[fx][j]][son[fy][k]] = dis[son[fy][k]][son[fx][j]] = g[i].w;
            }
        }
        pre[fy] = fx;
        //合并子树
        for (int j = 0; j < leny; ++j) {
```

```
            son[fx].push_back(son[fy][j]);
        }
        son[fy].clear();
    }
    int ans = inf;
    for (int i = 0; i < m; ++i) {
        if (g[i].flag) continue;
        ans = min(ans, sum + g[i].w - dis[g[i].u][g[i].v]);
    }
    printf("%d %d\n", sum, ans);
}
// Prim
int n, m;
int g[maxn][maxn], val[maxn], vis[maxn], dis[maxn];
int pre[maxn], maxd[maxn][maxn];
bool used[maxn][maxn];
void prim(int s) {
    mem(maxd, 0);
    mem(vis, 0);
    mem(used, 0);
    for (int i = 1; i <= n; ++i) {
        dis[i] = g[s][i];
        pre[i] = s;
    }
    vis[s] = 1;
    int sum = 0, cnt = 0;
    for (int i = 1; i < n; ++i) {
        int u = -1, MIN = inf;
        for (int j = 1; j <= n; ++j) {
            if (vis[j]) continue;
            if (MIN > dis[j]) {
                MIN = dis[j];
                u = j;
            }
        }
        if (u == -1) break;
        vis[u] = 1;
        sum += MIN;
        cnt++;
        used[pre[u]][u] = used[u][pre[u]] = 1;
        maxd[u][pre[u]] = maxd[pre[u]][u] = MIN;
        for (int j = 1; j <= n; ++j) {
            if (j == u) continue;
            if (vis[j]) {
                maxd[u][j] = maxd[j][u] = max(maxd[pre[u]][j], MIN);
            }
            if (vis[j] == 0 && dis[j] > g[u][j]) {
                dis[j] = g[u][j];
                pre[j] = u;
            }
        }
    }
}
```

```

    if (cnt != n-1) {
        puts("No way");
    }
    int ans = inf;
    for (int i = 1; i <= n; ++i) {
        for (int j = i+1; j <= n; ++j) {
            if (used[i][j]) continue;
            ans = min(ans, sum + g[i][j] - maxd[i][j]);
        }
    }
    printf("%d %d\n", sum, ans);
}

```

5.2 最小树形图

```

struct ac{
    int u, v, w;
};
vector<ac> g(maxn);
int pre[maxn], vis[maxn], id[maxn], in[maxn];
int zhuliu(int rt, int n, int m) {
    int ans = 0, u, v, w;
    while (1) {
        for (int i = 0; i < n; ++i) in[i] = inf;
        for (int i = 0; i < m; ++i) {
            u = g[i].u; v = g[i].v; w = g[i].w;
            if (u != v && w < in[v]) {
                pre[v] = u;
                in[v] = w;
                // if (u == rt) pos = i; // 记录前驱, 输出序号最小的根
            }
        }
        for (int i = 0; i < n; ++i) {
            if (i != rt && in[i] == inf) return -1;
        }
        int cnt = 0;
        mem(id, -1);
        mem(vis, -1);
        in[rt] = 0;
        for (int i = 0; i < n; ++i) {
            ans += in[i];
            u = i;
            while (vis[u] != i && id[u] == -1 && u != rt) {
                vis[u] = i;
                u = pre[u];
            }
            if (u != rt && id[u] == -1) {
                v = pre[u];
                while (v != u) {

```

```

                    id[v] = cnt;
                    v = pre[v];
                }
                id[u] = cnt++;
            }
        }
        if (cnt == 0) break;
        for (int i = 0; i < n; ++i) {
            if (id[i] == -1) id[i] = cnt++;
        }
        for (int i = 0; i < m; ++i) {
            v = g[i].v;
            g[i].u = id[g[i].u];
            g[i].v = id[g[i].v];
            if (g[i].u != g[i].v) g[i].w -= in[v];
        }
        n = cnt;
        rt = id[rt];
    }
    return ans;
}

```

5.3 拓扑排序

```

vector<int> g[maxn];
struct Topsort{ // 下标1
    priority_queue<int, vector<int>, greater<int>> q1;
    // 字典序小, 正向建图
    priority_queue<int, vector<int>> q2; // 编号小的
    // 优先级高, 反向建图
    int in[maxn], order[maxn], n, cnt;
    void init () {
        fill(in, in+n+1, 0);
        for (int i = 1; i <= n; ++i) {
            for (int j = 0; j < (int)g[i].size(); ++j) {
                in[g[i][j]]++;
            }
        }
    }
    int min_lex (int len) {
        n = len;
        cnt = 0;
        init();
        for (int i = 1; i <= n; ++i)
            if (in[i] == 0) q1.push(i);
        while (!q1.empty()) {
            int u = q1.top();
            q1.pop();
            order[++cnt] = u;

```

```

        for (int j = 0; j < (int)g[u].
            size(); ++j) {
            int v = g[u][j];
            in[v]--;
            if (in[v] == 0) q1.push(v);
        }
        return cnt == n;
    }
    int min_num (int len) {
        cnt = n = len;
        init();
        for (int i = 1; i <= n; ++i)
            if (in[i] == 0) q2.push(i);
        while (!q2.empty()) {
            int u = q2.top();
            q2.pop();
            order[cnt++] = u;
            for (int j = 0; j < (int)g[u].
                size(); ++j) {
                int v = g[u][j];
                if (--in[v] == 0) q2.push(v);
            }
        }
        return cnt == 0;
    }
}
} topsort;

```

```

        // 在栈中表示可以形成一个强连通分量, 更新
        // 根节点的low, 继续找
        if (!dfn[y]) tarjan(y), low[x] = min(low[x], low[y]);
        else if (inStack[y]) low[x] = min(low[x], low[y]);
    }
    // 回溯, 如果当前节点的dfn = low 表示栈中形成一个
    // 强连通分量
    if (dfn[x] == low[x]) {
        ++cnt; // 统计个数
        int top;
        while (Stack[len] != x) {
            top = Stack[len--];
            belong[top] = cnt;
            inStack[top] = 0;
        }
        top = Stack[len--];
        belong[top] = cnt; // 记录每个点的隶属关系
        inStack[top] = 0;
    }
}
for (int i = 1; i <= n; ++i) {
    if (!dfn[i]) tarjan(i);
}

```

5.4 Tarjan

```

int Stack[maxn], low[maxn], dfn[maxn], inStack[maxn],
    belong[maxn];
int now, len, cnt;
// now: 时间戳, len: 栈的大小, cnt 强连通的个数
void init() {
    now = len = cnt = 0;
    mem(inStack, 0);
    mem(belong, 0);
    mem(dfn, 0);
    mem(low, 0);
}
void tarjan(int x) {
    // 打上标记, 入栈
    low[x] = dfn[x] = ++now;
    Stack[++len] = x;
    inStack[x] = 1;
    for (int i = 0; i < (int)g[x].size(); ++i) {
        int y = g[x][i];
        // 没有访问过, 继续递归
    }
}

```

5.5 Dinic

```

struct ac{
    int v, c, pre;
}edge[maxn<<6];
int s, e;
int head[maxn<<1], dis[maxn<<1], curedge[maxn<<1], cnt;
void init() {
    mem(head, -1);
    cnt = 0;
}
void addedge(int u, int v, int c) { // 记得双向边
    edge[cnt] = {v, c, head[u]};
    head[u] = cnt++;
}
bool bfs() {
    queue<int> que;
    que.push(s);
    mem(dis, 0);
    dis[s] = 1;
    while (!que.empty()) {
        int f = que.front();
        que.pop();
        for (int i = head[f]; i != -1; i = edge[i].pre) {

```

```

        if (dis[edge[i].v] || edge[i].c == 0)
            continue;
        dis[edge[i].v] = dis[f] + 1;
        que.push(edge[i].v);
    }
}
return dis[e] > 0;
}
int dfs(int now, int flow) {
    if (now == e || flow == 0) return flow;
    for (int &i = curedge[now]; i != -1; i = edge[i].pre)
        { // 当前弧优化
            if (dis[edge[i].v] != dis[now] + 1 || edge[i].c
                == 0) continue;
            int d = dfs(edge[i].v, min(flow, edge[i].c));
            if (d > 0) {
                edge[i].c -= d;
                edge[i^1].c += d;
                return d;
            }
        }
    dis[now] = -1; // // 炸点优化
    return 0;
}
int Dinic() {
    int sum = 0, d;
    while (bfs()) {
        for (int i = 0; i <= e; ++i) curedge[i] = head[i];
        while (d = dfs(s, inf)) sum += d;
    }
    return sum;
}

```

6 其它

6.1 闰年

```

bool IsLeapYear(int y) {
    return (!(y % 4) && (y % 100)) || !(y % 400);
}

```

6.2 蔡勒公式

```

// 返回y年m月d日是星期几
int Zeller(int y, int m, int d) {
    if (m == 1 || m == 2) {
        --y;
        m += 12;
    }
    int c = y / 100;
    y %= 100;
    //1582年10月4日之前
    return ((y + y / 4 + c / 4 - 2 * c + 13 * (m + 1) / 5 +
        d + 2) % 7) + 7 % 7;
    //1582年10月4日之后
    return ((y + y / 4 + c / 4 - 2 * c + 26 * (m + 1) / 10
        + d - 1) % 7 + 7) % 7;
}

```

6.3 莫队算法

6.3.1 静态莫队

```

const int maxn = "Edit";
// 静态莫队算法求区间不同数字数量
struct MoCap {
    int n, m;
    int block;
    int arr[maxn];
    struct query { int l, r, id; };
    query q[maxn];
    int cnt[maxn << 1];
    int cur;
    int ans[maxn];
    void Add(int x) {
        cur += (++cnt[arr[x]] == 1);
    }
    void Del(int x) {
        cur -= (--cnt[arr[x]] == 0);
    }
}

```

```

void Solve() {
    scanf("%d%d", &n, &m);
    block = std::sqrt(n);
    for (int i = 1; i <= n; ++i) scanf("%d", &arr[i]);
    for (int i = 1; i <= m; ++i) {
        scanf("%d%d", &q[i].l, &q[i].r);
        q[i].id = i;
    }
    std::sort(q + 1, q + m + 1, [&](query k1, query k2) {
        return (k1.l / block) == (k2.l / block) ? k1.r
            < k2.r : k1.l < k2.l; });
    int l = 0, r = 0;
    for (int i = 1; i <= m; ++i) {
        while (l < q[i].l) Del(l++);
        while (l > q[i].l) Add(--l);
        while (r < q[i].r) Add(++r);
        while (r > q[i].r) Del(r--);
        ans[q[i].id] = cur;
    }
    for (int i = 1; i <= m; ++i) printf("%d\n", ans[i]);
}
}mo;

```

6.3.2 带修莫队

```

const int maxn = "Edit";
// 动态莫队算法求区间不同数字数量 (支持单点修改)
struct MoCap {
    int n, m;
    int block;
    int arr[maxn];
    struct query { int l, r, pre, id; };
    int q_tot;
    query q[maxn];
    struct change { int pos, val; };
    int c_tot;
    change c[maxn];
    int cnt[maxn << 7];
    int cur;
    int ans[maxn];
    void Add(int x) {
        cur += (++cnt[arr[x]] == 1);
    }
    void Del(int x) {
        cur -= (--cnt[arr[x]] == 0);
    }
    void Modify(int x, int i) {
        if (c[x].pos >= q[i].l && c[x].pos <= q[i].r) {
            cur -= (--cnt[arr[c[x].pos]] == 0);
            cur += (++cnt[c[x].val] == 1);
        }
        std::swap(c[x].val, arr[c[x].pos]);
    }
}

```

```

}
void Solve() {
    scanf("%d%d", &n, &m);
    block = std::sqrt(n);
    for (int i = 1; i <= n; ++i) scanf("%d", &arr[i]);
    for (int i = 1; i <= m; ++i) {
        char op; getchar();
        scanf("%c", &op);
        if (op == 'Q') {
            int l, r; scanf("%d%d", &l, &r);
            q[++q_tot] = (query){l, r, c_tot, q_tot};
        }
        else {
            int p, v; scanf("%d%d", &p, &v);
            c[++c_tot] = (change){p, v};
        }
    }
    std::sort(q + 1, q + q_tot + 1, [&](query k1, query
        k2) {
        if ((k1.l / block) == (k2.l / block) {
            if ((k1.r / block) == (k2.r / block)) return k1.
                pre < k2.pre;
            return k1.r < k2.r;
        }
        return k1.l < k2.l;
    });
    int l = 1, r = 0, t = 0;
    for (int i = 1; i <= q_tot; ++i) {
        while (l < q[i].l) Del(l++);
        while (l > q[i].l) Add(--l);
        while (r < q[i].r) Add(++r);
        while (r > q[i].r) Del(r--);
        while (t < q[i].pre) Modify(++t, i);
        while (t > q[i].pre) Modify(t--, i);
        ans[q[i].id] = cur;
    }
    for (int i = 1; i <= q_tot; ++i) printf("%d\n", ans[i
        ]);
}
}mo;

```

6.4 快读

```

// 普通快读
template <typename t>
inline bool Read(t &ret) {
    char c; int sgn;
    if (c = getchar(), c == EOF) return false;
    while (c != '-' && (c < '0' || c > '9')) c = getchar();
    sgn = (c == '-') ? -1 : 1;
    ret = (c == '-') ? 0 : (c - '0');
}

```



```

while (c = getchar(), c >= '0' && c <= '9') ret = ret *
    10 + (c - '0');
ret *= sgn;
return true;
}
// 牛逼快读
namespace FastIO {
    const int MX = 4e7;
    char buf[MX];
    int c, sz;
    void Begin() {
        c = 0;
        sz = fread(buf, 1, MX, stdin);
    }
    template <class T>
    inline bool Read(T &t) {
        while (c < sz && buf[c] != '-' && (buf[c] < '0' ||
            buf[c] > '9')) c++;
        if (c >= sz) return false;
        bool flag = 0;
        if (buf[c] == '-') {
            flag = 1;
            c++;
        }
        for (t = 0; c < sz && '0' <= buf[c] && buf[c] <= '9';
            ++c) t = t * 10 + buf[c] - '0';
        if (flag) t = -t;
        return true;
    }
};
using namespace FastIO;

```

6.5 对拍

```

// windows
:loop
data.exe > in.txt
main.exe < in.txt > out.txt
std.exe < in.txt > std.txt
fc out.txt std.txt
if not errorlevel 1 goto loop
pause
:end
// Linux
declare -i n=1
while (true)
do
./dtmk
./my < 1.in > my.out
./force < 1.in > for.out
if diff my.out for.out

```

```

then
echo right $n
n=n+1
else
exit
fi
done

```

6.6 vimrc

```

set nu et mouse=a cin
nmap<F9> : w <cr> :!g++ % -o %< -Wall -O2 <cr> : !./%< <
cr>

```

6.7 int128

```

using namespace std;
inline __int128 read(){
    __int128 x=0,f=1;
    char ch=getchar();
    while(ch<'0' || ch>'9'){
        if(ch=='-')
            f=-1;
        ch=getchar();
    }
    while(ch>='0' && ch<='9'){
        x=x*10+ch-'0';
        ch=getchar();
    }
    return x*f;
}
inline void print(__int128 x){
    if(x<0){
        putchar('-');
        x=-x;
    }
    if(x>9)
        print(x/10);
    putchar(x%10+'0');
}
int main(){
    __int128 a = read();
    __int128 b = read();
    print(a + b);
    cout<<endl;
    return 0;
}

```