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## 1 Basic

### 1.1 vimrc

```
se nu rnu bs=2 ru mouse=a cin et ts=4 sw=4 sts=4 syn on filetype indent on inoremap
<CR> <CR><Esc>O
```

### 1.2 IncreaseStackSize

```
//stack resize(change esp to rsp if 64-bit system)
asm( "mov %0,%esp\n" :: "g"(mem+10000000) );
// craziest way
static void run_stack_sz(void(*func)(),size_t stsize){
    char *stack, *send;
    stack=(char *)malloc(stsize);
    send=stack+stsize-16;
    send=(char *)((uintptr_t)send/16*16);
    asm volatile(
        "mov %%rsp, (%0)\n"
        "mov %0, %%rsp\n"
        :
        : "r" (send));
    func();
    asm volatile(
        "mov (%0), %%rsp\n"
        :
        : "r" (send));
    free(stack);
}
```

### 1.3 Pragma optimization

```
#pragma GCC optimize("Ofast,no-stack-protector")
#pragma GCC optimize("no-math-errno,unroll-loops")
#pragma GCC target("sse,sse2,sse3,ssse3,sse4")
#pragma GCC target("popcnt,abm,mmx,avx,tune=native")
```

### 1.4 Debugger

```
#!/usr/bin/env python3
import subprocess as sp
os_name = __import__('platform').system()
cmd,prefix = [], ""
if os_name == 'Windows':
    cmd=["cmd", "/C"]
else:
    cmd = ["bash", "-c"]
    prefix = "./"
def GetTestData(exe):
    myout=sp.check_output(cmd+["%s%s"%(prefix, exe)])
    return myout.decode("utf8")
def Judge(a,b,testdata):
    f = open("test.in", "w+")
    f.write(testdata)
    f.close()
    c=sp.check_output(cmd+["%s%s<test.in"%(prefix, a)])
    d=sp.check_output(cmd+["%s%s<test.in"%(prefix, b)])
    if not c == d:
        print("answer: %s"%c.decode("utf8"),end="")
        print("output: %s"%d.decode("utf8"),end="")
        print("WA!")
        return False
    return True
if __name__ == '__main__':
    cnt = 0
    isOK = True
    while isOK:
        cnt += 1
        print(cnt)
        isOK=Judge("sol", "mysol", GetTestData("gen"))
```

### 1.5 Quick Random

```
template<class T,T x1,T x2,T x3,int y1,int y2,int y3>
struct PRNG {
    using S = typename std::make_signed<T>::type;
```

```

T s;
PRNG(T _s = 0) : s(_s) {}
T next() {
    T z = (s += x1);
    z = (z ^ (z >> y1)) * x2;
    z = (z ^ (z >> y2)) * x3;
    return z ^ (z >> y3);
}
T next(T n) { return next() % n; }
S next(S l, S r){return l+next(r-l+1);}
T operator()() { return next(); }
T operator()(T n) { return next(n); }
S operator()(S l, S r) { return next(l, r); }
static T gen(T s) { return PRNG(s)(); }
template<class U>
void shuffle(U first,U last){
    size_t n=last-first;
    for(size_t i=0;i<n;i++)
        swap(first[i],first[next(i+1)]);
}
};
using R32=PRNG<uint32_t,0x9E3779B1,0x85EBCA6B,
0xC2B2AE35,16,13,16>;
R32 r32;
using R64=PRNG<uint64_t,0x9E3779B97F4A7C15,
0xBF58476D1CE4E5B9,0x94D049BB133111EB,30,27,31>;
R64 r64;

```

## 1.6 IO Optimization

```

static inline int gc() {
    static char buf[ 1 << 20 ], *p = buf, *end = buf;
    if ( p == end ) {
        end = buf + fread( buf, 1, 1 << 20, stdin );
        if ( end == buf ) return EOF;
        p = buf;
    }
    return *p++;
}
template < typename T >
static inline bool gn( T &_ ) {
    register int c = gc(); register T __ = 1; _ = 0;
    while (('0'<c||c>'9') && c!=EOF && c!='-') c = gc();
    if(c == '-') { __ = -1; c = gc(); }
    if(c == EOF) return false;
    while ('0'<=c&&c<='9') _ = _ * 10 + c - '0', c = gc();
    _ *= __;
    return true;
}
template < typename T, typename ...Args >
static inline bool gn( T &x, Args &...args )
{ return gn(x) && gn(args...); }

```

## 2 Data Structure

### 2.1 BigInt

```

class BigInt{
private:
    using lld = int_fast64_t;
    #define PRINTF_ARG PRIdFAST64
    #define LOG_BASE_STR "9"
    static constexpr lld BASE = 1000000000;
    static constexpr int LOG_BASE = 9;
    vector<lld> dig;
    bool neg;
    inline int len() const { return (int) dig.size(); }
    inline int cmp_minus(const BigInt& a) const {
        if(len() == 0 && a.len() == 0) return 0;
        if(neg ^ a.neg) return (int)a.neg*2 - 1;
        if(len() != a.len())
            return neg?a.len()-len():len()-a.len();
        for(int i=len()-1;i>=0;i--) if(dig[i]!=a.dig[i])
            return neg?a.dig[i]-dig[i]:dig[i]-a.dig[i];
        return 0;
    }
    inline void trim(){
        while(!dig.empty()&&!dig.back())dig.pop_back();
        if(dig.empty()) neg = false;
    }
}

```

```

public:
    BigInt(): dig(vector<lld>()), neg(false){}
    BigInt(lld a): dig(vector<lld>()){
        neg = a<0; dig.push_back(abs(a));
        trim();
    }
    BigInt(const string& a): dig(vector<lld>()){
        assert(!a.empty()); neg = (a[0]=='-');
        for(int i=((int)a.size()-1;i>=neg;i-=LOG_BASE){
            lld cur = 0;
            for(int j=min(LOG_BASE-1,i-neg);j>=0;j--){
                cur = cur*10+a[i-j]-'0';
                dig.push_back(cur);
            } trim();
        }
        inline bool operator<(const BigInt& a) const
            {return cmp_minus(a)<0;}
        inline bool operator<=(const BigInt& a) const
            {return cmp_minus(a)<=0;}
        inline bool operator==(const BigInt& a) const
            {return cmp_minus(a)==0;}
        inline bool operator!=(const BigInt& a) const
            {return cmp_minus(a)!=0;}
        inline bool operator>(const BigInt& a) const
            {return cmp_minus(a)>0;}
        inline bool operator>=(const BigInt& a) const
            {return cmp_minus(a)>=0;}
    }
    BigInt operator-() const {
        BigInt ret = *this;
        ret.neg ^= 1;
        return ret;
    }
    BigInt operator+(const BigInt& a) const {
        if(neg) return -(-(*this)+(-a));
        if(a.neg) return (*this)-(-a);
        int n = max(a.len(), len());
        BigInt ret; ret.dig.resize(n);
        lld pro = 0;
        for(int i=0;i<n;i++) {
            ret.dig[i] = pro;
            if(i < a.len()) ret.dig[i] += a.dig[i];
            if(i < len()) ret.dig[i] += dig[i];
            pro = 0;
            if(ret.dig[i] >= BASE) pro = ret.dig[i]/BASE;
            ret.dig[i] -= BASE*pro;
        }
        if(pro != 0) ret.dig.push_back(pro);
        return ret;
    }
    BigInt operator-(const BigInt& a) const {
        if(neg) return -(-(*this) - (-a));
        if(a.neg) return (*this) + (-a);
        int diff = cmp_minus(a);
        if(diff < 0) return -(a - (*this));
        if(diff == 0) return 0;
        BigInt ret; ret.dig.resize(len(), 0);
        for(int i=0;i<len();i++) {
            ret.dig[i] += dig[i];
            if(i < a.len()) ret.dig[i] -= a.dig[i];
            if(ret.dig[i] < 0){
                ret.dig[i] += BASE;
                ret.dig[i+1]--;
            }
        }
        ret.trim();
        return ret;
    }
    BigInt operator*(const BigInt& a) const {
        if(!len()||!a.len()) return 0;
        BigInt ret; ret.dig.resize(len()+a.len()+1);
        ret.neg = neg ^ a.neg;
        for(int i=0;i<len();i++){
            for(int j=0;j<a.len();j++){
                ret.dig[i+j] += dig[i] * a.dig[j];
                if(ret.dig[i+j] >= BASE) {
                    lld x = ret.dig[i+j] / BASE;
                    ret.dig[i+j+1] += x;
                    ret.dig[i+j] -= x * BASE;
                }
            }
        }
        ret.trim();
        return ret;
    }
    BigInt operator/(const BigInt& a) const {
        assert(a.len());
        if(len() < a.len()) return 0;
    }

```

```

    BigInt ret; ret.dig.resize(len()-a.len()+1);
    ret.neg = a.neg;
    for(int i=len()-a.len();i>=0;i--){
        lld l = 0, r = BASE;
        while(r-l > 1){
            lld mid = (l+r)>>1;
            ret.dig[i] = mid;
            if(ret*a<=(neg?-(*this):(*this))) l = mid;
            else r = mid;
        }
        ret.dig[i] = l;
    }
    ret.neg ^= neg; ret.trim();
    return ret;
}

BigInt operator%(const BigInt& a) const {
    return (*this) - (*this) / a * a;
}

friend BigInt abs(BigInt a){
    a.neg = 1; return a;
}

friend void swap(BigInt& a, BigInt& b){
    swap(a.dig, b.dig); swap(a.neg, b.neg);
}

friend istream& operator>>(istream& ss, BigInt& a){
    string s; ss >> s; a = s;
    return ss;
}

friend ostream& operator<<(ostream& ss, BigInt& a){
    if(a.len() == 0) return ss << '0';
    if(a.neg) ss << '-';
    ss << a.dig.back();
    for(int i=a.len()-2;i>=0;i--){
        ss<<setw(LOG_BASE)<<setfill('0')<<a.dig[i];
        return ss;
    }
}

inline void print() const {
    if(len() == 0){putchar('0');return;}
    if(neg) putchar('-');
    printf("%s" PRINTF_ARG, dig.back());
    for(int i=len()-2;i>=0;i--){
        printf("%0" LOG_BASE_STR PRINTF_ARG, dig[i]);
    }
}

#undef PRINTF_ARG
#undef LOG_BASE_STR
};

```

## 2.2 Dark Magic

```

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/priority_queue.hpp>
using __gnu_pbds::pairing_heap_tag;
using __gnu_pbds::binary_heap_tag;
using __gnu_pbds::binomial_heap_tag;
using __gnu_pbds::rc_binomial_heap_tag;
using __gnu_pbds::thin_heap_tag;
template<typename T>
using pbds_heap=__gnu_pbds::prioity_queue<T,less<T>,\
    pairing_heap_tag>;

using __gnu_pbds::rb_tree_tag;
using __gnu_pbds::ov_tree_tag;
using __gnu_pbds::splay_tree_tag;
template<typename T>
using ordered_set = __gnu_pbds::tree<T,\
    __gnu_pbds::null_type,less<T>,rb_tree_tag,\
    __gnu_pbds::tree_order_statistics_node_update>;
template<typename A,typename B>
using hTable1=__gnu_pbds::cc_hash_table<A,B>;
template<typename A,typename B>
using hTable2=__gnu_pbds::gp_hash_table<A,B>;

int main(){
    ordered_set<int> ss;
    ss.insert(1); ss.insert(5);
    assert(*ss.find_by_order(0)==1);
    assert(ss.order_of_key(-1)==0);
    pbds_heap pq1, pq2;
    pq1.push(1); pq2.push(2);
    pq1.join(pq2);
    assert(pq2.size()==0);
    auto it = pq1.push(87);
    pq1.modify(it, 19);
    return 0;
}

```

## 2.3 SkewHeap

```

template < typename T, typename cmp = less< T > >
class SkewHeap{
private:
    struct SkewNode{
        T x;
        SkewNode *lc, *rc;
        SkewNode( T a = 0 ) : x( a ), lc( 0 ), rc( 0 ) {}
    } *root;
    cmp CMP_;
    size_t count;
    SkewNode* Merge( SkewNode* a, SkewNode* b ) {
        if ( !a or !b ) return a ? a : b;
        if ( CMP_( a->x, b->x ) ) swap( a, b );
        a -> rc = Merge( a->rc, b );
        swap( a -> lc, a->rc );
        return a;
    }
public:
    SkewHeap(): root( 0 ), count( 0 ) {}
    size_t size() { return count; }
    bool empty() { return count == 0; }
    T top() { return root->x; }
    void clear(){ root = 0; count = 0; }
    void push ( const T& x ) {
        SkewNode* a = new SkewNode( x );
        count += 1; root = Merge( root, a );
    }
    void join( SkewHeap& a ) {
        count += a.count; a.count = 0;
        root = Merge( root, a.root );
    }
    void pop() {
        count--; root = Merge( root->lc, root->rc );
    }
    friend void swap( SkewHeap& a, SkewHeap& b ) {
        swap( a.root, b.root ); swap( a.count, b.count );
    }
};

```

## 2.4 Disjoint Set

```

class DJS{
private:
    vector< int > fa, sz, sv;
    vector< pair< int*, int > > opt;
    inline void assign( int *k, int v ) {
        opt.emplace_back( k, *k );
        *k = v;
    }
public:
    inline void init( int n ) {
        fa.resize( n ); iota( fa.begin(), fa.end(), 0 );
        sz.resize( n ); fill( sz.begin(), sz.end(), 1 );
        opt.clear();
    }
    int query( int x ) {
        return ( fa[ x ] == x ) ? x : query( fa[ x ] );
    }
    inline void merge( int a, int b ) {
        int af = query( a ), bf = query( b );
        if( af == bf ) return;
        if( sz[ af ] < sz[ bf ] ) swap( af, bf );
        assign( &fa[ bf ], fa[ af ] );
        assign( &sz[ af ], sz[ af ] + sz[ bf ] );
    }
    inline void save() {sv.push_back( (int)opt.size() );}
    inline void undo() {
        int ls = sv.back(); sv.pop_back();
        while ( ( int ) opt.size() > ls ) {
            pair< int*, int > cur = opt.back();
            *cur.first = cur.second;
            opt.pop_back();
        }
    }
};

```

## 2.5 Treap

```

namespace Treap{
#define sz( x ) ( ( x ) ? ( ( x )->size ) : 0 )
struct node{
    int size;
    uint32_t pri;
    node *lc, *rc;
    node() : size(0), pri(rand()), lc( 0 ), rc( 0 ) {}
    void pull() {
        size = 1;
        if ( lc ) size += lc->size;
        if ( rc ) size += rc->size;
    }
};
node* merge( node* L, node* R ) {
    if ( not L or not R ) return L ? L : R;
    if ( L->pri > R->pri ) {
        L->rc = merge( L->rc, R );
        L->pull();
        return L;
    } else {
        R->lc = merge( L, R->lc );
        R->pull();
        return R;
    }
}
void split_by_size( node*rt, int k, node*&L, node*&R ) {
    if ( not rt ) L = R = nullptr;
    else if( sz( rt->lc ) + 1 <= k ) {
        L = rt;
        split_by_size( rt->rc, k-sz(rt->lc)-1, L->rc, R );
        L->pull();
    } else {
        R = rt;
        split_by_size( rt->lc, k, L, R->lc );
        R->pull();
    }
}
}
#undef sz
}

```

## 2.6 SparseTable

```

template < typename T, typename Cmp_ = less< T > >
class SparseTable {
private:
    vector< vector< T > > tbl;
    vector< int > lg;
    T cv( T a, T b ) {
        return Cmp_()( a, b ) ? a : b;
    }
public:
    void init( T arr[], int n ) {
        // 0-base
        lg.resize( n + 1 );
        lg[ 0 ] = -1;
        for( int i=1 ; i<=n ; ++i ) lg[i] = lg[i>>1] + 1;
        tbl.resize( lg[n] + 1 );
        tbl[ 0 ].resize( n );
        copy( arr, arr + n, tbl[ 0 ].begin() );
        for ( int i = 1 ; i <= lg[ n ] ; ++i ) {
            int len = 1 << ( i - 1 ), sz = 1 << i;
            tbl[ i ].resize( n - sz + 1 );
            for ( int j = 0 ; j <= n - sz ; ++j )
                tbl[i][j] = cv(tbl[i-1][j], tbl[i-1][j+len]);
        }
    }
    T query( int l, int r ) {
        // 0-base [l, r)
        int wh = lg[ r - l ], len = 1 << wh;
        return cv( tbl[ wh ][ l ], tbl[ wh ][ r - len ] );
    }
};

```

## 2.7 Linear Basis

```

struct LinearBasis {
private:
    int n, sz;
    vector< llu > B;
    inline llu two( int x ){ return ( ( llu ) 1 ) << x; }
public:
    void init( int n_ ) {

```

```

        n = n_ ; B.clear();
        B.resize( n ); sz = 0;
    }
    void insert( llu x ) {
        // add x into B
        for ( int i = n-1; i >= 0 ; --i ) if( two(i) & x ){
            if ( B[ i ] ) x ^= B[ i ];
            else {
                B[ i ] = x; sz++;
                for ( int j = i - 1 ; j >= 0 ; --j )
                    if( B[ j ] && ( two( j ) & B[ i ] ) )
                        B[ i ] ^= B[ j ];
                for (int j = i + 1 ; j < n ; ++j )
                    if ( two( i ) & B[ j ] )
                        B[ j ] ^= B[ i ];
                break;
            }
        }
    }
    inline int size() { return sz; }
    bool check( llu x ) {
        // is x in span(B) ?
        for ( int i = n-1 ; i >= 0 ; --i ) if( two(i) & x )
            if( B[ i ] ) x ^= B[ i ];
        else return false;
        return true;
    }
    llu kth_small(llu k) {
        /** 1-base would always > 0 **/
        /** should check it **/
        /** if we choose at least one element
            but size(B)(vectors in B)==N(original elements)
            then we can't get 0 */
        llu ret = 0;
        for ( int i = 0 ; i < n ; ++i ) if( B[ i ] ) {
            if( k & 1 ) ret ^= B[ i ];
            k >>= 1;
        }
        return ret;
    }
} base;

```

## 3 Graph

### 3.1 BCC Edge

```

class BCC{
private:
    vector< int > low, dfn;
    int cnt;
    vector< bool > bridge;
    vector< vector< PII > > G;
    void dfs( int w, int f ) {
        dfn[ w ] = cnt++;
        low[ w ] = dfn[ w ];
        for ( auto [ u, t ] : G[ w ] ) {
            if ( u == f ) continue;
            if ( dfn[ u ] != 0 ) {
                low[ w ] = min( low[ w ], dfn[ u ] );
            } else {
                dfs( u, w );
                low[ w ] = min( low[ w ], low[ u ] );
                if ( low[ u ] > dfn[ w ] ) bridge[ t ] = true;
            }
        }
    }
public:
    void init( int n, int m ) {
        G.resize( n );
        fill( G.begin(), G.end(), vector< PII >() );
        bridge.clear(); bridge.resize( m );
        low.clear(); low.resize( n );
        dfn.clear(); dfn.resize( n );
        cnt = 0;
    }
    void add_edge( int u, int v ) {
        // should check for multiple edge
        G[ u ].emplace_back( v, cnt );
        G[ v ].emplace_back( u, cnt ++ );
    }
    void solve(){ cnt = 1; dfs( 0, 0 ); }
    // the id will be same as insert order, 0-base

```

```
bool is_bridge( int x ) { return bridge[ x ]; }
} bcc;
```

## 3.2 BCC Vertex

```
class BCC{
private:
    int n, ecnt;
    vector< vector< pair< int, int > > > G;
    vector< int > low, dfn, id;
    vector< bool > vis, ap;
    void dfs( int u, int f, int d ) {
        int child = 0;
        dfn[ u ] = low[ u ] = d; vis[ u ] = true;
        for ( auto e : G[ u ] ) if ( e.first != f ) {
            if ( vis[ e.first ] ) {
                low[ u ] = min( low[ u ], dfn[ e.first ] );
            } else {
                dfs( e.first, u, d + 1 ); child ++;
                low[ u ] = min( low[ u ], low[ e.first ] );
                if ( low[ e.first ] >= d ) ap[ u ] = true;
            }
        }
        if ( u == f and child <= 1 ) ap[ u ] = false;
    }
    void mark( int u, int idd ) {
        // really????????
        if ( ap[ u ] ) return;
        for ( auto e : G[ u ] )
            if ( id[ e.second ] != -1 ) {
                id[ e.second ] = idd;
                mark( e.first, idd );
            }
    }
public:
    void init( int n_ ) {
        ecnt = 0, n = n_;
        G.clear(); G.resize( n );
        low.resize( n ); dfn.resize( n );
        ap.clear(); ap.resize( n );
        vis.clear(); vis.resize( n );
    }
    void add_edge( int u, int v ) {
        G[ u ].emplace_back( v, ecnt );
        G[ v ].emplace_back( u, ecnt ++ );
    }
    void solve() {
        for ( int i = 0 ; i < n ; ++ i )
            if ( not vis[ i ] ) dfs( i, i, 0 );
        id.resize( ecnt );
        fill( id.begin(), id.end(), -1 );
        ecnt = 0;
        for ( int i = 0 ; i < n ; ++ i )
            if ( ap[ i ] ) for ( auto e : G[ i ] )
                if ( id[ e.second ] != -1 ) {
                    id[ e.second ] = ecnt;
                    mark( e.first, ecnt ++ );
                }
    }
    int get_id( int x ) { return id[ x ]; }
    int count() { return ecnt; }
    bool is_ap( int u ) { return ap[ u ]; }
} bcc;
```

## 3.3 Bipartite Matching

```
class BipartiteMatching{
private:
    vector<int> X[N], Y[N];
    int fX[N], fY[N], n;
    bitset<N> walked;
    bool dfs( int x ) {
        for ( auto i : X[x] ) {
            if ( walked[i] ) continue;
            walked[i] = 1;
            if ( fY[i] == -1 || dfs( fY[i] ) ) {
                fY[i] = x; fX[x] = i;
                return 1;
            }
        }
    }
    return 0;
}
```

```
public:
    void init( int _n ) {
        n = _n;
        for ( int i = 0; i < n; i ++ ) {
            X[i].clear();
            Y[i].clear();
            fX[i] = fY[i] = -1;
        }
        walked.reset();
    }
    void add_edge( int x, int y ) {
        X[x].push_back( y );
        Y[y].push_back( x );
    }
    int solve() {
        int cnt = 0;
        for ( int i = 0; i < n; i ++ ) {
            walked.reset();
            if ( dfs(i) ) cnt ++;
        }
        // return how many pair matched
        return cnt;
    }
};
```

## 3.4 Minimum Cost Maximum Flow

```
class MiniCostMaxiFlow{
using CapT = int;
using WeiT = int64_t;
using PCW = pair<CapT, WeiT>;
static constexpr CapT INF_CAP = 1 << 30;
static constexpr WeiT INF_WEI = 1LL << 60;
private:
    struct Edge{
        int to, back;
        WeiT wei;
        CapT cap;
        Edge() {}
        Edge( int a, int b, WeiT c, CapT d ) :
            to( a ), back( b ), wei( c ), cap( d ) {}
    };
    int ori, edd;
    vector< vector< Edge > > G;
    vector< int > fa, wh;
    vector< bool > inq;
    vector< WeiT > dis;
    PCW SPFA() {
        fill( inq.begin(), inq.end(), false );
        fill( dis.begin(), dis.end(), INF_WEI );
        queue< int > qq; qq.push( ori );
        dis[ori] = 0;
        while ( !qq.empty() ) {
            int u = qq.front(); qq.pop();
            inq[u] = 0;
            for ( int i = 0; i < SZ( G[u] ); ++ i ) {
                Edge e = G[u][i];
                int v = e.to;
                WeiT d = e.wei;
                if ( e.cap <= 0 || dis[v] <= dis[u] + d )
                    continue;
                dis[v] = dis[u] + d;
                fa[v] = u, wh[v] = i;
                if ( inq[v] ) continue;
                qq.push( v );
                inq[v] = 1;
            }
        }
        if ( dis[ed] == INF_WEI )
            return { -1, -1 };
        CapT mw = INF_CAP;
        for ( int i = edd; i != ori; i = fa[i] )
            mw = min( mw, G[fa[i]][wh[i]].cap );
        for ( int i = edd; i != ori; i = fa[i] ) {
            auto &eg = G[fa[i]][wh[i]];
            eg.cap -= mw;
            G[eg.to][eg.back].cap += mw;
        }
        return { mw, dis[ed] };
    }
public:
    void init( int a, int b, int n ) {
        ori = a, edd = b;
    }
};
```

```

G.clear();G.resize(n);
fa.resize(n);wh.resize(n);
inq.resize(n); dis.resize(n);
}
void add_edge(int st,int ed,WeiT w,CapT c){
    G[st].emplace_back(ed,SZ(G[ed]),w,c);
    G[ed].emplace_back(st,SZ(G[st])-1,-w,0);
}
PCW solve(){
    /* might modify to
    cc += ret.first * ret.second
    or
    ww += ret.first * ret.second
    */
    CapT cc=0; WeiT ww=0;
    while(true){
        PCW ret=SPFA();
        if(ret.first== -1) break;
        cc+=ret.first;
        ww+=ret.second;
    }
    return {cc,ww};
}
} mcmf;

```

### 3.5 MaximumFlow

```

class Dinic{
private:
    using CapT = int64_t;
    struct Edge{
        int to, rev;
        CapT cap;
    };
    int n, st, ed;
    vector<vector<Edge>> G;
    vector<int> lv;
    bool BFS(){
        fill(lv.begin(), lv.end(), -1);
        queue<int> bfs;
        bfs.push(st);
        lv[st] = 0;
        while(!bfs.empty()){
            int u = bfs.front(); bfs.pop();
            for(auto e: G[u]){
                if(e.cap <= 0 or lv[e.to] != -1) continue;
                lv[e.to] = lv[u] + 1;
                bfs.push(e.to);
            }
        }
        return (lv[ed] != -1);
    }
    CapT DFS(int u, CapT f){
        if(u == ed) return f;
        CapT ret = 0;
        for(auto& e: G[u]){
            if(e.cap <= 0 or lv[e.to] != lv[u] + 1) continue;
            CapT nf = DFS(e.to, min(f, e.cap));
            ret += nf; e.cap -= nf; f -= nf;
            G[e.to][e.rev].cap += nf;
            if(f == 0) return ret;
        }
        if(ret == 0) lv[u] = -1;
        return ret;
    }
public:
    void init(int n_, int st_, int ed_){
        n = n_, st = st_, ed = ed_;
        G.resize(n); lv.resize(n);
        fill(G.begin(), G.end(), vector<Edge>());
    }
    void add_edge(int u, int v, CapT c){
        G[u].push_back({v, (int)G[v].size(), c});
        G[v].push_back({u, ((int)G[u].size())-1, 0});
    }
    CapT max_flow(){
        CapT ret = 0;
        while(BFS()){
            CapT f = DFS(st, numeric_limits<CapT>::max());
            ret += f;
            if(f == 0) break;
        }
        return ret;
    }
}

```

```

} flow;

```

### 3.6 Kuhn Munkres

```

struct KM{
    static constexpr lld INF = 1LL<<60;
    lld w[N][N], lx[N], ly[N], slack[N];
    int match[N], n, vx[N], vy[N], step_;
    void init(int n_){
        n=n_, step_=0;
        memset(w,0,sizeof(w));
        memset(lx,0,sizeof(lx));
        memset(ly,0,sizeof(ly));
        memset(slack,0,sizeof(slack));
        memset(match,0,sizeof(match));
        memset(vx,0,sizeof(vx));
        memset(vy,0,sizeof(vy));
    }
    void add_edge(int u,int v,lld w){w[u][v]=w;}
    bool dfs(int x){
        vx[x] = step_;
        for (int i = 0; i < n; ++i) {
            if (vy[i]==step_) continue;
            if (lx[x] + ly[i] > w[x][i]) {
                slack[i] = min(slack[i], lx[x] + ly[i] - w[x][i]);
            }
            continue;
        }
        vy[i] = step_;
        if (match[i] == -1 || dfs(match[i])) {
            match[i] = x;
            return true;
        }
    }
    return false;
}
lld solve() {
    fill_n(match, n, -1);
    fill_n(lx, n, -INF);
    fill_n(ly, n, 0);
    for (int i = 0; i < n; ++i)
        for (int j = 0; j < n; ++j)
            lx[i] = max(lx[i], w[i][j]);
    for (int i = 0; i < n; ++i) {
        fill_n(slack, n, INF);
        while (true) {
            step_++;
            if (dfs(i)) break;
            lld dlt = INF;
            for (int j = 0; j < n; ++j) if (vy[j] != step_)
                dlt = min(dlt, slack[j]);
            for (int j = 0; j < n; ++j) {
                if (vx[j]==step_) lx[j] -= dlt;
                if (vy[j]==step_) ly[j] += dlt;
                else slack[j] -= dlt;
            }
        }
    }
    lld res = 0;
    for (int i = 0; i < n; ++i) res += w[match[i]][i];
    return res;
}
} km;

```

### 3.7 2-SAT

```

class TwoSat{
private:
    int n;
    vector<vector<int>> rG,G,sccs;
    vector<int> ord,idx;
    vector<bool> vis,result;
    void dfs(int u){
        vis[u]=true;
        for(int v:G[u])
            if(!vis[v])
                dfs(v);
        ord.push_back(u);
    }
    void rdfs(int u){
        vis[u]=false;
        idx[u]=sccs.size()-1;
    }
}

```

```

        sccs.back().push_back(u);
        for(int v:rG[u])
            if(vis[v])
                rdfs(v);
    }
    public:
        void init(int n_){
            n=n_;
            G.clear();
            G.resize(n);
            rG.clear();
            rG.resize(n);
            sccs.clear();
            ord.clear();
            idx.resize(n);
            result.resize(n);
        }
        void add_edge(int u,int v){
            G[u].push_back(v);
            rG[v].push_back(u);
        }
        void orr(int x,int y){
            if ((x^y)==1) return;
            add_edge(x^1,y);
            add_edge(y^1,x);
        }
        bool solve(){
            vis.clear();
            vis.resize(n);
            for(int i=0;i<n;++i)
                if(not vis[i])
                    dfs(i);
            reverse(ord.begin(),ord.end());
            for (int u:ord){
                if(!vis[u])
                    continue;
                sccs.push_back(vector<int>());
                rdfs(u);
            }
            for(int i=0;i<n;i+=2)
                if(idx[i]==idx[i+1])
                    return false;
            vector<bool> c(sccs.size());
            for(size_t i=0;i<sccs.size();++i){
                for(size_t j=0;j<sccs[i].size();++j){
                    result[sccs[i][j]]=c[i];
                    c[idx[sccs[i][j]^1]]=!c[i];
                }
            }
            return true;
        }
        bool get(int x){return result[x];}
        inline int get_id(int x){return idx[x];}
        inline int count(){return sccs.size();}
    } sat2;

```

### 3.8 Lowbit Decomposition

```

class LowbitDecomp{
private:
    int time_, chain_, LOG_N;
    vector< vector< int > > G, fa;
    vector< int > tl, tr, chain, chain_st;
    // chain_ : number of chain
    // tl, tr[ u ] : subtree interval in the seq. of u
    // chain_st[ u ] : head of the chain contains u
    // chain[ u ] : chain id of the chain u is on
    inline int lowbit( int x ) {
        return x & ( -x );
    }
    void predfs( int u, int f ) {
        chain[ u ] = 0;
        for ( int v : G[ u ] ) {
            if ( v == f ) continue;
            predfs( v, u );
            if( lowbit( chain[ u ] ) < lowbit( chain[ v ] ) )
                chain[ u ] = chain[ v ];
        }
        if ( not chain[ u ] )
            chain[ u ] = chain_ ++;
    }
    void dfschain( int u, int f ) {
        fa[ u ][ 0 ] = f;
        for ( int i = 1 ; i < LOG_N ; ++ i )

```

```

        fa[ u ][ i ] = fa[ fa[ u ][ i - 1 ] ][ i - 1 ];
        tl[ u ] = time_ ++;
        if ( not chain_st[ chain[ u ] ] )
            chain_st[ chain[ u ] ] = u;
        for ( int v : G[ u ] )
            if ( v != f and chain[ v ] == chain[ u ] )
                dfschain( v, u );
        for ( int v : G[ u ] )
            if ( v != f and chain[ v ] != chain[ u ] )
                dfschain( v, u );
        tr[ u ] = time_ ;
    }
    inline bool anc( int u, int v ) {
        return tl[ u ] <= tl[ v ] \
            and tr[ v ] <= tr[ u ];
    }
    public:
        inline int lca( int u, int v ) {
            if ( anc( u, v ) ) return u;
            for ( int i = LOG_N - 1 ; i >= 0 ; -- i )
                if ( not anc( fa[ u ][ i ], v ) )
                    u = fa[ u ][ i ];
            return fa[ u ][ 0 ];
        }
        void init( int n ) {
            n ++;
            for ( LOG_N = 0 ; ( 1 << LOG_N ) < n ; ++ LOG_N );
            fa.clear();
            fa.resize( n, vector< int >( LOG_N ) );
            G.clear(); G.resize( n );
            tl.clear(); tl.resize( n );
            tr.clear(); tr.resize( n );
            chain.clear(); chain.resize( n );
            chain_st.clear(); chain_st.resize( n );
        }
        void add_edge( int u , int v ) {
            // 1-base
            G[ u ].push_back( v );
            G[ v ].push_back( u );
        }
        void decompose(){
            chain_ = 1;
            predfs( 1, 1 );
            time_ = 0;
            dfschain( 1, 1 );
        }
        PII get_inter( int u ) { return {tl[ u ], tr[ u ]}; }
        vector< PII > get_path( int u , int v ){
            vector< PII > res;
            int g = lca( u, v );
            while ( chain[ u ] != chain[ g ] ) {
                int s = chain_st[ chain[ u ] ];
                res.emplace_back( tl[ s ], tl[ u ] + 1 );
                u = fa[ s ][ 0 ];
            }
            res.emplace_back( tl[ g ], tl[ u ] + 1 );
            while ( chain[ v ] != chain[ g ] ) {
                int s = chain_st[ chain[ v ] ];
                res.emplace_back( tl[ s ], tl[ v ] + 1 );
                v = fa[ s ][ 0 ];
            }
            res.emplace_back( tl[ g ] + 1, tl[ v ] + 1 );
            return res;
        }
        /* res : list of intervals from u to v
        * ( note only nodes work, not edge )
        * usage :
        * vector< PII >& path = tree.get_path( u , v )
        * for( auto [ l, r ] : path ) {
        *     0-base [ l, r )
        * }
        */
    } tree;

```

### 3.9 MaxClique

```

#define N 111
struct MaxClique{ // 0-base
    typedef bitset< N > Int;
    Int linkto[ N ], v[ N ];
    int n;
    void init( int _n ){
        n = _n;
        for( int i = 0 ; i < n ; i ++ ){

```



```

    linkto[ i ].reset();
    v[ i ].reset();
}
}
void add_edge( int a , int b ){
    v[ a ][ b ] = v[ b ][ a ] = 1;
}
int popcount(const Int& val)
{ return val.count(); }
int lowbit(const Int& val)
{ return val._Find_first(); }
int ans , stk[ N ];
int id[ N ] , di[ N ] , deg[ N ];
Int cans;
void maxclique(int elem_num, Int candi){
    if(elem_num > ans){
        ans = elem_num;
        cans.reset();
        for( int i = 0 ; i < elem_num ; i ++ )
            cans[ id[ stk[ i ] ] ] = 1;
    }
    int potential = elem_num + popcount(candi);
    if(potential <= ans) return;
    int pivot = lowbit(candi);
    Int smaller_candi = candi & (~linkto[pivot]);
    while(smaller_candi.count() && potential>ans){
        int next = lowbit(smaller_candi);
        candi[ next ] = !candi[ next ];
        smaller_candi[next] = !smaller_candi[next];
        potential --;
        if(next!=pivot
            &&!(smaller_candi&linkto[next]).count()){
            continue;
        }
        stk[elem_num] = next;
        maxclique(elem_num+1, candi&linkto[next]);
    }
}
int solve(){
    for( int i = 0 ; i < n ; i ++ ){
        id[ i ] = i;
        deg[ i ] = v[ i ].count();
    }
    sort( id , id + n , [&](int id1, int id2){
        return deg[id1] > deg[id2]; } );
    for( int i = 0 ; i < n ; i ++ )
        di[ id[ i ] ] = i;
    for( int i = 0 ; i < n ; i ++ )
        for( int j = 0 ; j < n ; j ++ )
            if( v[ i ][ j ] )
                linkto[ di[ i ] ][ di[ j ] ] = 1;
    Int cand; cand.reset();
    for( int i = 0 ; i < n ; i ++ )
        cand[ i ] = 1;
    ans = 1;
    cans.reset(); cans[ 0 ] = 1;
    maxclique(0, cand);
    return ans;
}
} solver;

```

## 4 Math

### 4.1 Prime Table

```

1002939109, 1020288887, 1028798297, 1038684299,
1041211027, 1051762951, 1058585963, 1063020809,
1147930723, 1172520109, 1183835981, 1187659051,
1241251303, 1247184097, 1255940849, 1272759031,
1287027493, 1288511629, 1294632499, 1312650799,
1868732623, 1884198443, 1884616807, 1885059541,
1909942399, 1914471137, 1923951707, 1925453197,
1979612177, 1980446837, 1989761941, 2007826547,
2008033571, 2011186739, 2039465081, 2039728567,
2093735719, 2116097521, 2123852629, 2140170259,
3148478261, 3153064147, 3176351071, 3187523093,
3196772239, 3201312913, 3203063977, 3204840059,
3210224309, 3213032591, 3217689851, 3218469083,
3219857533, 3231880427, 3235951699, 3273767923,
3276188869, 3277183181, 3282463507, 3285553889,
3319309027, 3327005333, 3327574903, 3341387953,
3373293941, 3380077549, 3380892997, 3381118801

```

### 4.2 $\lfloor \frac{n}{i} \rfloor$ Enumeration

$$T_0 = 1, T_{i+1} = \lfloor \frac{n}{T_i+1} \rfloor$$

### 4.3 $ax+by=gcd$

```

// ax+ny = 1, ax+ny == ax == 1 (mod n)
void exgcd(lld x, lld y, lld &g, lld &a, lld &b) {
    if (y == 0) g=x, a=1, b=0;
    else
        exgcd(y, x%y, g, b, a), b-=(x/y)*a;
}

```

### 4.4 Pollard Rho

```

// does not work when n is prime
// return any non-trivial factor
llu pollard_rho(llu n){
    static auto f=[](llu x, llu k, llu m){
        return add(k, mul(x, x, m), m);
    };
    if (!(n&1)) return 2;
    mt19937 rnd(120821011);
    while(true){
        llu y=2, yy=y, x=rdn()%n, t=1;
        for(llu sz=2; t==1; sz<=1) {
            for(llu i=0; i<sz; ++i){
                if(t!=1) break;
                yy=f(yy, x, n);
                t=gcd(yy>y?yy-y:y-yy, n);
            }
            y=yy;
        }
        if(t!=1&&t!=n) return t;
    }
}

```

### 4.5 Pi Count (Linear Sieve)

```

static constexpr int N = 1000000 + 5;
lld pi[N];
vector<int> primes;
bool sieved[N];
lld cube_root(lld x){
    lld s=cbrt(x-static_cast<long double>(0.1));
    while(s*s*s <= x) ++s;
    return s-1;
}
lld square_root(lld x){
    lld s=sqrt(x-static_cast<long double>(0.1));
    while(s*s <= x) ++s;
    return s-1;
}
void init(){
    primes.reserve(N);
    primes.push_back(1);
    for(int i=2; i<N; i++) {
        if(!sieved[i]) primes.push_back(i);
        pi[i] = !sieved[i] + pi[i-1];
        for(int p: primes) if(p > 1) {
            if(p * i >= N) break;
            sieved[p * i] = true;
            if(p % i == 0) break;
        }
    }
}
lld phi(lld m, lld n) {
    static constexpr int MM = 80000, NN = 500;
    static lld val[MM][NN];
    if(m<MM&&n<NN&&val[m][n]) return val[m][n]-1;
    if(n == 0) return m;
    if(primes[n] >= m) return 1;
    lld ret = phi(m, n-1)-phi(m/primes[n], n-1);
    if(m<MM&&n<NN) val[m][n] = ret+1;
    return ret;
}
lld pi_count(lld);
lld P2(lld m, lld n) {
    lld sm = square_root(m), ret = 0;
}

```



```

for (l1d i = n+1; primes[i] <= sm; i++)
    ret += pi_count(m/primes[i]) - pi_count(primes[i]) + 1;
return ret;
}

l1d pi_count(l1d m) {
    if (m < N) return pi[m];
    l1d n = pi_count(cube_root(m));
    return phi(m, n) + n - 1 - P2(m, n);
}

```

## 4.6 Range Sieve

```

const int MAX_SQRT_B = 50000;
const int MAX_L = 200000 + 5;

bool is_prime_small[MAX_SQRT_B];
bool is_prime[MAX_L];

void sieve(l1d l, l1d r) {
    // [1, r)
    for (l1d i=2; i*i<r; i++) is_prime_small[i] = true;
    for (l1d i=1; i<r; i++) is_prime[i-1] = true;
    if (l==1) is_prime[0] = false;
    for (l1d i=2; i*i<r; i++) {
        if (!is_prime_small[i]) continue;
        for (l1d j=i*i; j*j<r; j+=i) is_prime_small[j] = false;
        for (l1d j=std::max(2LL, (l+i-1)/i)*i; j<r; j+=i)
            is_prime[j-1] = false;
    }
}

```

## 4.7 Miller Rabin

```

bool isprime(llu x) {
    static llu magic[] = {2, 325, 9375, 28178, \
        450775, 9780504, 1795265022};
    static auto witn = [](llu a, ll u, ll n, int t) {
        a = mpow(a, u, n);
        if (!a) return 0;
        while (t--) {
            ll u2 = mul(a, a, n);
            if (u2 == 1 && a != 1 && a != n-1)
                return 1;
            a = u2;
        }
        return a != 1;
    };
    if (x < 2) return 0;
    if (!(x & 1)) return x == 2;
    ll u = x-1; int t = 0;
    while (!(u & 1)) u >>= 1, t++;
    for (llu m: magic)
        if (witn(m, u, x, t))
            return 0;
    return 1;
}

```

## 4.8 Inverse Element

```

// x's inverse mod k
long long GetInv(long long x, long long k) {
    // k is prime: euler_phi(k) = k-1
    return qPow(x, euler_phi(k)-1);
}

// if you need [1, x] (most use: [1, k-1])
void solve(int x, long long k) {
    inv[1] = 1;
    for (int i=2; i<x; i++)
        inv[i] = ((long long)(k - k/i) * inv[k % i]) % k;
}

```

## 4.9 Euler Phi Function

```

/*
    extended euler:
    a^b mod p
    if gcd(a, p) == 1: a^(b%phi(p))

```

```

    elif b < phi(p): a^b mod p
    else a^(b%phi(p) + phi(p))
*/
l1d euler_phi(int x) {
    l1d r = 1;
    for (int i=2; i*i<=x; ++i) {
        if (x%i==0) {
            x /= i;
            r *= (i-1);
            while (x%i==0) {
                x /= i;
                r *= i;
            }
        }
    }
    if (x > 1) r *= x-1;
    return r;
}

vector<int> primes;
bool notprime[N];
l1d phi[N];
void euler_sieve(int n) {
    for (int i=2; i<n; i++) {
        if (!notprime[i]) {
            primes.push_back(i);
            phi[i] = i-1;
        }
        for (auto j: primes) {
            if (i*j >= n) break;
            notprime[i*j] = true;
            phi[i*j] = phi[i] * phi[j];
            if (i % j == 0) {
                phi[i*j] = phi[i] * j;
                break;
            }
        }
    }
}

```

## 4.10 Gauss Elimination

```

typedef long double llf;
const int N = 300;
const llf EPS = 1e-8;

// make m[i][i] = x, m[i][j] = 0
// v is for solving equation:
// for (int i=0; i<n; i++) ans[pos[i]] = val[i]/mtx[i][pos[i]];
// for (int i=0; i<n; i++) cout << ans[i] << '\n';
bool Gauss(llf m[N][N], llf v[N], int n, int pos[N]) {
    for (int i=0; i<n; i++) {
        int x=-1, y=-1; llf e = 0;
        for (int j=i; j<n; j++) for (int k=i; k<n; k++) {
            if (fabs(m[j][pos[k]]) > e) {
                e = fabs(m[j][pos[k]]);
                x = j, y = k;
            }
        }
        if (x == -1 || y == -1) return false;
        swap(m[x], m[y]);
        swap(v[x], v[y]);
        swap(pos[y], pos[i]);
        for (int j=i+1; j<n; j++) {
            llf xi = m[j][pos[i]]/m[i][pos[i]];
            for (int k=0; k<n; k++) m[j][pos[k]] -= xi*m[i][pos[k]];
            v[j] -= xi*v[i];
        }
    }
    for (int i=n-1; i>=0; i--) {
        for (int j=i-1; j>=0; j--) {
            llf xi = m[j][pos[i]]/m[i][pos[i]];
            for (int k=0; k<n; k++) m[j][pos[k]] -= xi*m[i][pos[k]];
            v[j] -= xi*v[i];
        }
    }
    return true;
}

```

## 4.11 Fast Fourier Transform

```

/*
    polynomial multiply:
    DFT(a, len); DFT(b, len);
    for(int i=0;i<len;i++) c[i] = a[i]*b[i];
    iDFT(c, len);
    (len must be 2^k and >= 2*(max(a, b)))
    Hand written Cplx would be 2x faster
*/
Cplx omega[2][N];
void init_omega(int n) {
    static constexpr llf PI=acos(-1);
    const llf arg=(PI+PI)/n;
    for(int i=0;i<n;++i)
        omega[0][i]={cos(arg*i),sin(arg*i)};
    for(int i=0;i<n;++i)
        omega[1][i]=conj(omega[0][i]);
}
void tran(Cplx arr[],int n,Cplx omg[]) {
    for(int i=0,j=0;i<n;++i){
        if(i>j)swap(arr[i],arr[j]);
        for(int l=n>>1;(j^=1)<l;l>>=1);
    }
    for (int l=2;l<=n;l<=1){
        int m=l>>1;
        for(auto p=arr;p!=arr+n;p+=l){
            for(int i=0;i<m;++i){
                Cplx t=omg[n/l*i]*p[m+i];
                p[m+i]=p[i]-t;
                p[i]+=t;
            }
        }
    }
}
void DFT(Cplx arr[],int n){
    tran(arr,n,omega[0]);
}
void iDFT(Cplx arr[],int n){
    tran(arr,n,omega[1]);
    for(int i=0;i<n;++i)arr[i]/=n;
}

```

## 4.12 Chinese Remainder

```

lld crt(lld ans[], lld pri[], int n){
    lld M = 1;
    for(int i=0;i<n;i++) M *= pri[i];
    lld ret = 0;
    for(int i=0;i<n;i++){
        lld inv = (gcd(M/pri[i], pri[i]).first + pri[i])%
            pri[i];
        ret += (ans[i]*(M/pri[i])%M * inv)%M;
        ret %= M;
    }
    return ret;
}
/*
Another:
x = a1 % m1
x = a2 % m2
g = gcd(m1, m2)
assert((a1-a2)%g==0)
[p, q] = exgcd(m2/g, m1/g)
return a2+m2*(p*(a1-a2)/g)
0 <= x < lcm(m1, m2)
*/

```

## 4.13 Berlekamp Massey

```

// x: 1-base, p[]: 0-base
template<size_t N>
vector<llf> BM(llf x[N],size_t n){
    size_t f[N]={0},t=0;llf d[N];
    vector<llf> p[N];
    for(size_t i=1,b=0;i<=n;++i) {
        for(size_t j=0;j<p[t].size();++j)
            d[i]+=x[i-j-1]*p[t][j];
        if(abs(d[i]-x[i])<=EPS)continue;
        f[t]=i;if(!t){p[++t].resize(i);continue;}
        vector<llf>cur(i-f[b]-1);

```

```

        llf k=-d[i]/d[f[b]];cur.PB(-k);
        for(size_t j=0;j<p[b].size();j++)
            cur.PB(p[b][j]*k);
        if(cur.size()<p[t].size())cur.resize(p[t].size());
        for(size_t j=0;j<p[t].size();j++)cur[j]+=p[t][j];
        if(i-f[b]+p[b].size()>p[t].size()) b=t;
        p[++t]=cur;
    }
    return p[t];
}

```

## 4.14 NTT

```

// Remember coefficient are mod P
/* p=a*2^n+1
n    2^n    p    a    root
16   65536   65537   1    3
20   1048576 7340033   7    3 */
// (must be 2^k)
template<LL P, LL root, int MAXN>
struct NTT{
    static LL bigmod(LL a, LL b) {
        LL res = 1;
        for (LL bs = a; b >= 1; bs = (bs * bs) % P)
            if(b&1) res=(res*bs)%P;
        return res;
    }
    static LL inv(LL a, LL b) {
        if(a==1) return 1;
        return ((LL)(a-inv(b*a,a))*b+1)/a)%b;
    }
    LL omega[MAXN+1];
    NTT() {
        omega[0] = 1;
        LL r = bigmod(root, (P-1)/MAXN);
        for (int i=1; i<=MAXN; i++)
            omega[i] = (omega[i-1]*r)%P;
    }
    // n must be 2^k
    void tran(int n, LL a[], bool inv_ntt=false){
        int basic = MAXN / n, theta = basic;
        for (int m = n; m >= 2; m >= 1) {
            int mh = m >> 1;
            for (int i = 0; i < mh; i++) {
                LL w = omega[i*theta%MAXN];
                for (int j = i; j < n; j += m) {
                    int k = j + mh;
                    LL x = a[j] - a[k];
                    if (x < 0) x += P;
                    a[j] += a[k];
                    if (a[j] > P) a[j] -= P;
                    a[k] = (w * x) % P;
                }
            }
            theta = (theta * 2) % MAXN;
        }
        int i = 0;
        for (int j = 1; j < n - 1; j++) {
            for (int k = n >> 1; k > (i ^ k); k >= 1);
            if (j < i) swap(a[i], a[j]);
        }
        if (inv_ntt) {
            LL ni = inv(n,P);
            reverse(a+1, a+n);
            for (i = 0; i < n; i++)
                a[i] = (a[i] * ni) % P;
        }
    }
};
const LL P=2013265921,root=31;
const int MAXN=4194304;
NTT<P, root, MAXN> ntt;

```

## 4.15 FWT

```

/* xor convolution:
* x = (x0,x1), y = (y0,y1)
* z = (x0y0 + x1y1, x0y1 + x1y0)
* =>
* x' = (x0+x1, x0-x1), y' = (y0+y1, y0-y1)
* z' = ((x0+x1)(y0+y1), (x0-x1)(y0-y1))
* z = (1/2) * z''

```

```

* or convolution:
* x = (x0, x0+x1), inv = (x0, x1-x0) w/o final div
* and convolution:
* x = (x0+x1, x1), inv = (x0-x1, x1) w/o final div */
const LL MOD = 1e9+7;
inline void fwt( LL x[ MAXN ] , int N , bool inv=0 ) {
    for( int d = 1 ; d < N ; d <= 1 ) {
        int d2 = d<<1;
        for( int s = 0 ; s < N ; s += d2 )
            for( int i = s , j = s+d ; i < s+d ; i++, j++ ){
                LL ta = x[ i ] , tb = x[ j ];
                x[ i ] = ta+tb;
                x[ j ] = ta-tb;
                if( x[ i ] >= MOD ) x[ i ] -= MOD;
                if( x[ j ] < 0 ) x[ j ] += MOD;
            }
    }
    if( inv )
        for( int i = 0 ; i < N ; i++ ) {
            x[ i ] *= inv( N, MOD );
            x[ i ] %= MOD;
        }
}

```

## 4.16 DiscreteLog

```

// Baby-step Giant-step Algorithm
lld BSGS(lld P, lld B, lld N) {
    // find B^L = N mod P
    unordered_map<lld, int> R;
    lld sq = (lld)sqrt(P);
    lld t = 1;
    for (int i = 0; i < sq; i++) {
        if (t == N)
            return i;
        if (!R.count(t))
            R[t] = i;
        t = (t * B) % P;
    }
    lld f = inverse(t, P);
    for(int i=0;i<=sq+1;i++) {
        if (R.count(N))
            return i * sq + R[N];
        N = (N * f) % P;
    }
    return -1;
}

```

## 5 Geometry

### 5.1 Point Class

```

template<typename T>
struct Point{
    typedef long double llf;
    static constexpr llf EPS = 1e-8;
    T x, y;
    Point(T __=0, T __=0): x(__), y(__){}
    template<typename T2>
    Point(const Point<T2>& a): x(a.x), y(a.y){}
    inline llf theta() const {
        return atan2((llf)y, (llf)x);
    }
    inline llf dis() const {
        return hypot((llf)x, (llf)y);
    }
    inline llf dis(const Point& o) const {
        return hypot((llf)(x-o.x), (llf)(y-o.y));
    }
    Point operator-(const Point& o) const {
        return Point(x-o.x, y-o.y);
    }
    Point operator+=(const Point& o){
        x+=o.x, y+=o.y;
        return *this;
    }
    Point operator+(const Point& o) const {
        return Point(x+o.x, y+o.y);
    }
    Point operator+=(const Point& o){

```

```

        x+=o.x, y+=o.y;
        return *this;
    }
    Point operator*(const T& k) const {
        return Point(x*k, y*k);
    }
    Point operator*=(const T& k){
        x*=k, y*=k;
        return *this;
    }
    Point operator/(const T& k) const {
        return Point(x/k, y/k);
    }
    Point operator/=(const T& k){
        x/=k, y/=k;
        return *this;
    }
    Point operator-() const {
        return Point(-x, -y);
    }
    Point rot90() const {
        return Point(-y, x);
    }
    template<typename T2>
    bool in(const Circle<T2>& a) const {
        /* Add struct Circle at top */
        return a.o.dis(*this)+EPS <= a.r;
    }
    bool equal(const Point& o, true_type) const {
        return fabs(x-o.x) < EPS and fabs(y-o.y) < EPS;
    }
    bool equal(const Point& o, false_type) const {
        return tie(x, y) == tie(o.x, o.y);
    }
    bool operator==(const Point& o) const {
        return equal(o, is_floating_point<T>());
    }
    bool operator!=(const Point& o) const {
        return !(*this == o);
    }
    bool operator<(const Point& o) const {
        return theta() < o.theta();
        // sort like what pairs did
        // if(is_floating_point<T>()) return fabs(x-o.x)<
        // EPS?y<o.y:x<o.x;
        // else return tie(x, y) < tie(o.x, o.y);
    }
    friend inline T cross(const Point& a, const Point& b)
    {
        return a.x*b.y - b.x*a.y;
    }
    friend inline T dot(const Point& a, const Point &b){
        return a.x*b.x + a.y*b.y;
    }
    friend ostream& operator<<(ostream& ss, const Point&
        o){
        ss<<"("<<o.x<<" , "<<o.y<<" )";
        return ss;
    }
};

```

### 5.2 Circle Class

```

template<typename T>
struct Circle{
    static constexpr llf EPS = 1e-8;
    Point<T> o;
    T r;
    vector<Point<llf>> operator&(const Circle& aa)const{
        // https://www.cnblogs.com/wangzming/p/8338142.html
        llf d=o.dis(aa.o);
        if(d > r+aa.r+EPS or d < fabs(r-aa.r)-EPS) return
            {};
        llf dt = (r*r - aa.r*aa.r)/d, dl = (d+dt)/2;
        Point<llf> dir = (aa.o-o); dir /= d;
        Point<llf> pcers = dir*d1 + o;
        dt=sqrt(max(0.0L, r*r - d1*d1)), dir=dir.rot90();
        return {pcers + dir*dt, pcers - dir*dt};
    }
};

```

### 5.3 Line Class

```

const Point<long double> INF_P(-1e20, 1e20);
const Point<long double> NOT_EXIST(1e20, 1e-20);
template<typename T>
struct Line{
    static constexpr long double EPS = 1e-8;
    // ax+by+c = 0
    T a, b, c;
    Line(): a(0), b(1), c(0){}
    Line(T __, T __, T __): a(__), b(__), c(__){
        assert(fabs(a)>EPS or fabs(b)>EPS);
    }
    template<typename T2>
    Line(const Line<T2>& x): a(x.a), b(x.b), c(x.c){}
    typedef Point<long double> Pt;
    bool equal(const Line& o, true_type) const {
        return fabs(a-o.a) < EPS and fabs(b-o.b) < EPS and
            fabs(c-o.c) < EPS;
    }
    bool euqal(const Line& o, false_type) const {
        return a==o.a and b==o.b and c==o.c;
    }
    bool operator==(const Line& o) const {
        return euqal(o, is_floating_point<T>());
    }
    bool operator!=(const Line& o) const {
        return !(*this == o);
    }
    friend inline bool on_line__(const Point<T>& p, const
        Line& l, true_type){
        return fabs(l.a*p.x + l.b*p.y + l.c) < EPS;
    }
    friend inline bool on_line__(const Point<T>& p, const
        Line& l, false_type){
        return l.a*p.x + l.b*p.y + l.c == 0;
    }
    friend inline bool on_line(const Point<T>&p const
        Line& l){
        return on_line__(p, l, is_floating_point<T>());
    }
    friend inline bool is_parallel__(const Line& x, const
        Line& y, true_type){
        return fabs(x.a*y.b - x.b*y.a) < EPS;
    }
    friend inline bool is_parallel__(const Line& x, const
        Line& y, false_type){
        return x.a*y.b == x.b*y.a;
    }
    friend inline bool is_parallel(const Line& x, const
        Line& y){
        return is_parallel__(x, y, is_floating_point<T>());
    }
    friend inline Pt get_inter(const Line& x, const Line&
        y){
        typedef long double llf;
        if(x==y) return INF_P;
        if(is_parallel(x, y)) return NOT_EXIST;
        llf delta = x.a*y.b - x.b*y.a;
        llf delta_x = x.b*y.c - x.c*y.b;
        llf delta_y = x.c*y.a - x.a*y.c;
        return Pt(delta_x / delta, delta_y / delta);
    }
    friend ostream& operator<<(ostream& ss, const Line& o
        ){
        ss<<o.a<<"x+"<<o.b<<"y+"<<o.c<<"=0";
        return ss;
    }
};

template<typename T>
inline Line<T> get_line(const Point<T>& a, const Point<
    T>& b){
    return Line<T>(a.y-b.y, b.x-a.x, (b.y-a.y)*a.x-(b.x-a
        .x)*a.y);
}

```

## 5.4 Triangle Circumcentre

```

template<typename T>
Circle<llf> get_circum(const Point<T>& a, const Point<T>
    & b, const Point<T>& c){
    llf a1 = a.x-b.x;
    llf b1 = a.y-b.y;
    llf c1 = (a.x+b.x)/2 * a1 + (a.y+b.y)/2 * b1;
    llf a2 = a.x-c.x;
    llf b2 = a.y-c.y;

```

```

    llf c2 = (a.x+c.x)/2 * a2 + (a.y+c.y)/2 * b2;

```

```

    Circle<llf> cc;
    cc.o.x = (c1*b2-b1*c2)/(a1*b2-b1*a2);
    cc.o.y = (a1*c2-c1*a2)/(a1*b2-b1*a2);
    cc.r = hypot(cc.o.x-a.x, cc.o.y-a.y);
    return cc;
}

```

## 5.5 2D Convex Hull

```

template<typename T>
class ConvexHull_2D{
private:
    typedef Point<T> PT;
    vector<PT> dots;
    struct myhash{
        uint64_t operator()(const PT& a) const {
            uint64_t xx=0, yy=0;
            memcpy(&xx, &a.x, sizeof(a.x));
            memcpy(&yy, &a.y, sizeof(a.y));
            uint64_t ret = xx*17+yy*31;
            ret = (ret ^ (ret >> 16))*0x9E3779B1;
            ret = (ret ^ (ret >> 13))*0xC2B2AE35;
            ret = ret ^ xx;
            return (ret ^ (ret << 3)) * yy;
        }
    };
    unordered_set<PT, myhash> in_hull;
public:
    inline void init(){in_hull.clear();dots.clear();}
    void insert(const PT& x){dots.PB(x);}
    void solve(){
        sort(ALL(dots), [](const PT& a, const PT& b){
            return tie(a.x, a.y) < tie(b.x, b.y);
        });
        vector<PT> stk(SZ(dots)<<1);
        int top = 0;
        for(auto p: dots){
            while(top >= 2 and cross(p-stk[top-2], stk[top
                -1]-stk[top-2]) <= 0)
                top--;
            stk[top++] = p;
        }
        for(int i=SZ(dots)-2, t = top+1; i>=0; i--){
            while(top >= t and cross(dots[i]-stk[top-2], stk[
                top-1]-stk[top-2]) <= 0)
                top--;
            stk[top++] = dots[i];
        }
        stk.resize(top-1);
        swap(stk, dots);
        for(auto i: stk) in_hull.insert(i);
    }
    vector<PT> get(){return dots;}
    inline bool in_it(const PT& x){
        return in_hull.find(x)!=in_hull.end();
    }
};

```

## 5.6 2D Farthest Pair

```

// stk is from convex hull
n = (int)(stk.size());
int pos = 1, ans = 0; stk.push_back(arr[0]);
for(int i=0; i<n; i++){
    while(abs(cross(stk[i+1]-stk[i], stk[(pos+1)%n]-stk[i]
        ))) > abs(cross(stk[i+1]-stk[i], stk[pos]-stk[i])) pos
        = (pos+1)%n;
    ans = max({ans, dis(stk[i], stk[pos]), dis(stk[i+1],
        stk[pos])});
}

```

## 5.7 2D Coset Pair

```

struct Point{
    llf x, y;
    llf dis;

```

```

} arr[N];

inline llf get_dis(Point a, Point b){
    return hypot(a.x-b.x, a.y-b.y);
}

llf solve(){
    int cur = rand()%n;
    for(int i=0;i<n;i++) arr[i].dis = get_dis(arr[cur],
        arr[i]);
    sort(arr, arr+n, [](Point a, Point b){return a.dis <
        b.dis;});
    llf ans = 1e50;
    for(int i=0;i<n;i++){
        for(int j=i+1;j<n;j++){
            if(arr[j].dis - arr[i].dis > ans) break;
            ans = min(ans, get_dis(arr[i], arr[j]));
        }
    }
    return ans;
}

```

## 5.8 SimulateAnnealing

```

double getY(double);
int main(){
    int rr, ll;
    default_random_engine rEng(time(NULL));
    uniform_real_distribution<double> Range(-1,1);
    uniform_real_distribution<double> expR(0,1);
    auto Random=bind(Range,rEng), expRand=bind(expR,rEng);
    ;
    int step=0;
    double pace=rr-ll, mini=0.95; // need to search for
    it
    double x=max(min(Random()*pace+ll, rr), ll), y=getY(x);
    ;
    while(pace>=1e-7){
        double newX = max(min(x + Random()*pace, rr), ll);
        double newY = getY(newX);
        if(newY < y || expRand() < exp(-step))
            x=newX, y=newY;
        step++;
        pace*=mini;
    }
}

```

## 5.9 Ternary Search on Integer

```

int TernarySearch(int l, int r) {
    // (l, r]
    while (r - l > 1){
        int mid = (l + r)>>1;
        if (f(mid) > f(mid + 1)) r = mid;
        else l = mid;
    }
    return l+1;
}

```

## 5.10 Minimum Covering Circle

```

template<typename T>
Circle<llf> MinCircleCover(const vector<Point<T>>& pts)
{
    random_shuffle(ALL(pts));
    Circle<llf> c = {pts[0], 0};
    int n = SZ(pts);
    for(int i=0;i<n;i++){
        if(pts[i].in(c)) continue;
        c = {pts[i], 0};
        for(int j=0;j<i;j++){
            if(pts[j].in(c)) continue;
            c.o = (pts[i] + pts[j]) / 2;
            c.r = pts[i].dis(c.o);
            for(int k=0;k<j;k++){
                if(pts[k].in(c)) continue;
                c = get_circum(pts[i], pts[j], pts[k]);
            }
        }
    }
}

```

```

}
return c;
}

```

## 5.11 KDTree (Nearest Point)

```

const int MXN = 100005;
struct KDTree {
    struct Node {
        int x,y,x1,y1,x2,y2;
        int id,f;
        Node *L, *R;
    }tree[MXN];
    int n;
    Node *root;
    LL dis2(int x1, int y1, int x2, int y2) {
        LL dx = x1-x2;
        LL dy = y1-y2;
        return dx*dx+dy*dy;
    }
    static bool cmpx(Node& a, Node& b){ return a.x<b.x; }
    static bool cmpy(Node& a, Node& b){ return a.y<b.y; }
    void init(vector<pair<int,int>> ip) {
        n = ip.size();
        for (int i=0; i<n; i++) {
            tree[i].id = i;
            tree[i].x = ip[i].first;
            tree[i].y = ip[i].second;
        }
        root = build_tree(0, n-1, 0);
    }
    Node* build_tree(int L, int R, int dep) {
        if (L>R) return nullptr;
        int M = (L+R)/2;
        tree[M].f = dep%2;
        nth_element(tree+L, tree+M, tree+R+1, tree[M].f ?
            cmpy : cmpx);
        tree[M].x1 = tree[M].x2 = tree[M].x;
        tree[M].y1 = tree[M].y2 = tree[M].y;

        tree[M].L = build_tree(L, M-1, dep+1);
        if (tree[M].L) {
            tree[M].x1 = min(tree[M].x1, tree[M].L->x1);
            tree[M].x2 = max(tree[M].x2, tree[M].L->x2);
            tree[M].y1 = min(tree[M].y1, tree[M].L->y1);
            tree[M].y2 = max(tree[M].y2, tree[M].L->y2);
        }
        tree[M].R = build_tree(M+1, R, dep+1);
        if (tree[M].R) {
            tree[M].x1 = min(tree[M].x1, tree[M].R->x1);
            tree[M].x2 = max(tree[M].x2, tree[M].R->x2);
            tree[M].y1 = min(tree[M].y1, tree[M].R->y1);
            tree[M].y2 = max(tree[M].y2, tree[M].R->y2);
        }
        return tree+M;
    }
    int touch(Node* r, int x, int y, LL d2){
        LL dis = sqrt(d2)+1;
        if (x<r->x1-dis || x>r->x2+dis ||
            y<r->y1-dis || y>r->y2+dis)
            return 0;
        return 1;
    }
    void nearest(Node* r, int x, int y,
        int &mID, LL &md2){
        if (!r || !touch(r, x, y, md2)) return;
        LL d2 = dis2(r->x, r->y, x, y);
        if (d2 < md2 || (d2 == md2 && mID < r->id)) {
            mID = r->id;
            md2 = d2;
        }
        // search order depends on split dim
        if ((r->f == 0 && x < r->x) ||
            (r->f == 1 && y < r->y)) {
            nearest(r->L, x, y, mID, md2);
            nearest(r->R, x, y, mID, md2);
        } else {
            nearest(r->R, x, y, mID, md2);
            nearest(r->L, x, y, mID, md2);
        }
    }
    int query(int x, int y) {
        int id = 1029384756;
        LL d2 = 102938475612345678LL;
    }
}

```

```

    nearest(root, x, y, id, d2);
    return id;
}
}tree;

```

## 6 Stringology

### 6.1 Hash

```

class Hash{
private:
    static const int N = 1000000;
    const int p = 127, q = 1208220623;
    int sz, prefix[N], power[N];
    inline int add(int x, int y){return x+y>=q?x+y-q:x+y;}
    inline int sub(int x, int y){return x-y<0?x-y+q:x-y;}
    inline int mul(int x, int y){return 1LL*x*y%q;}
public:
    void init(const std::string &x){
        sz = x.size();
        prefix[0]=0;
        for(int i=1;i<=sz;i++) prefix[i]=add(mul(prefix[i-1], p), x[i-1]);
        power[0]=1;
        for(int i=1;i<=sz;i++) power[i]=mul(power[i-1], p);
    }
    int query(int l, int r){
        // 1-base (l, r)
        return sub(prefix[r], mul(prefix[l], power[r-l]));
    }
};

```

### 6.2 Suffix Array

```

//help by http://www.geeksforgeeks.org/suffix-array-set-2-a-nlognlogn-algorithm/
struct sfx{
    int index;
    int r,nr;
};
char str[N + 10];
int len;
vector<sfx> srs[N + 10];
int mapping[N + 10];
sfx sa[N + 10];
bool cmp(sfx a,sfx b){
    if(a.r==b.r){
        return a.nr<b.nr;
    }else{
        return a.r<b.r;
    }
}
void SA(){
    len = strlen(str);
    for(int i=0;i<len;i++){
        sa[i].index = i;
        sa[i].r=str[i];
        sa[i].nr=(i+1>=len)?0:str[i+1];
    }
    //sort(sa,sa+len,cmp);
    radixSort();
    for(int j=2;j<=len;j*=2){
        int cnt=1;
        int rr = sa[0].r;
        sa[0].r=cnt;
        mapping[sa[0].index]=0;
        for(int i=1;i<len;i++){
            if(sa[i].r == rr && sa[i].nr == sa[i-1].nr){
                rr=sa[i].r;
                sa[i].r=cnt;
            }else{
                rr=sa[i].r;
                sa[i].r=++cnt;
            }
            mapping[sa[i].index]=i;
        }
        for(int i=0;i<len;i++){
            int nn = sa[i].index+j;
            sa[i].nr = (nn>=len)?0:sa[mapping[nn]].r;
        }
    }
}

```

```

    }
    //sort(sa, sa+len, cmp);
    radixSort();
}
}
void radixSort(){
    int m = 0;
    for(int i=0;i<len;i++){
        srs[sa[i].nr].PB(sa[i]);
        m=max(m,sa[i].nr);
    }
    int cnt=0;
    for(int i=0;i<=m;i++){
        if(srs[i].empty())continue;
        for(auto j:srs[i]){
            sa[cnt++] = j;
        }
        srs[i].clear();
    }
    m = 0;
    for(int i=0;i<len;i++){
        srs[sa[i].r].PB(sa[i]);
        m=max(m,sa[i].r);
    }
    cnt=0;
    for(int i=0;i<=m;i++){
        if(srs[i].empty())continue;
        for(auto j:srs[i]){
            sa[cnt++] = j;
        }
        srs[i].clear();
    }
}
}

```

### 6.3 Aho-Corasick Algorithm

```

class AhoCorasick{
private:
    static constexpr int Z = 26;
    struct node{
        node *nxt[ Z ], *fail;
        vector< int > data;
        node(): fail( nullptr ) {
            memset( nxt, 0, sizeof( nxt ) );
            data.clear();
        }
    } *rt;
    inline int Idx( char c ) { return c - 'a'; }
public:
    void init() { rt = new node(); }
    void add( const string& s, int d ) {
        node* cur = rt;
        for ( auto c : s ) {
            if ( not cur->nxt[ Idx( c ) ] )
                cur->nxt[ Idx( c ) ] = new node();
            cur = cur->nxt[ Idx( c ) ];
        }
        cur->data.push_back( d );
    }
    void compile() {
        vector< node* > bfs;
        size_t ptr = 0;
        for ( int i = 0 ; i < Z ; ++ i ) {
            if ( not rt->nxt[ i ] )
                continue;
            rt->nxt[ i ]->fail = rt;
            bfs.push_back( rt->nxt[ i ] );
        }
        while ( ptr < bfs.size() ) {
            node* u = bfs[ ptr ++ ];
            for ( int i = 0 ; i < Z ; ++ i ) {
                if ( not u->nxt[ i ] )
                    continue;
                node* u_f = u->fail;
                while ( u_f ) {
                    if ( not u_f->nxt[ i ] ) {
                        u_f = u_f->fail;
                        continue;
                    }
                    u->nxt[ i ]->fail = u_f->nxt[ i ];
                    break;
                }
            }
            if ( not u_f ) u->nxt[ i ]->fail = rt;
            bfs.push_back( u->nxt[ i ] );
        }
    }
}

```

```

    }
}
}
void match( const string& s, vector< int >& ret ) {
    node* u = rt;
    for ( auto c : s ) {
        while ( u != rt and not u->nxt[ Idx( c ) ] )
            u = u->fail;
        u = u->nxt[ Idx( c ) ];
        if ( not u ) u = rt;
        node* tmp = u;
        while ( tmp != rt ) {
            for ( auto d : tmp->data )
                ret.push_back( d );
            tmp = tmp->fail;
        }
    }
}
} ac;

```

## 6.4 KMP

```

int F[N<<1];
void KMP(char s1[], char s2[], int n, int m){
    // make F[] for s1+'\0'+s2;
    char ss[N<<1];
    int len = n+m+1;
    for(int i=0;i<n;i++) ss[i] = s1[i];
    ss[n] = '\0';
    for(int i=0;i<m;i++) ss[i+1+n] = s2[i];
    F[0] = F[1] = 0;
    for(int i=1;i<len;i++){
        int j = F[i];
        while(j > 0 and ss[i]!=ss[j]) j = F[j];
        F[i+1] = (ss[i]==ss[j]?j+1:0);
    }
    // just find (F[len2+i] == len2)
    // i from 1 to len+1 for matching
}
/*
[0, i]是個循環字串，且循環節為i-f[i]：
if(f[i]>0 and i%(i-f[i])==0)
cout << i << " " << i/(i-f[i]) << '\n';
*/

```

## 6.5 Z value

```

char s[MAXN];
int len,z[MAXN];
void Z_value() {
    int i,j,left,right;
    left=right=0; z[0]=len;
    for(i=1;i<len;i++) {
        j=max(min(z[i-left],right-i),0);
        for(;i+j<len&&s[i+j]==s[j];j++);
        z[i]=j;
        if(i+z[i]>right) {
            right=i+z[i];
            left=i;
        }
    }
}

```

## 6.6 Lexicographically Smallest Rotation

```

string mcp(string s){
    int n = s.length();
    s += s;
    int i=0, j=1;
    while (i<n && j<n){
        int k = 0;
        while (k < n && s[i+k] == s[j+k]) k++;
        if (s[i+k] <= s[j+k]) j += k+1;
        else i += k+1;
        if (i == j) j++;
    }
    int ans = i < n ? i : j;
    return s.substr(ans, n);
}

```

## 6.7 BWT

```

struct BurrowsWheeler{
#define SIGMA 26
#define BASE 'a'
    vector<int> v[ SIGMA ];
    void BWT(char* ori, char* res){
        // make ori -> ori + ori
        // then build suffix array
    }
    void iBWT(char* ori, char* res){
        for( int i = 0 ; i < SIGMA ; i ++ )
            v[ i ].clear();
        int len = strlen( ori );
        for( int i = 0 ; i < len ; i ++ )
            v[ ori[i] - BASE ].push_back( i );
        vector<int> a;
        for( int i = 0 , ptr = 0 ; i < SIGMA ; i ++ )
            for( auto j : v[ i ] ){
                a.push_back( j );
                ori[ ptr ++ ] = BASE + i;
            }
        for( int i = 0 , ptr = 0 ; i < len ; i ++ ){
            res[ i ] = ori[ a[ ptr ] ];
            ptr = a[ ptr ];
        }
        res[ len ] = 0;
    }
} bwt;

```

## 7 Misc

### 7.1 Degree Sequence Validity

#### 7.1.1 Erdős–Gallai Theorem

$d_1 \geq \dots \geq d_n$  is a valid degree sequence iff

$$\sum_{k=1}^n d_k \equiv 0 \pmod{2}$$

$$\wedge$$

$$\forall 1 \leq k \leq n, \sum_{i=1}^k d_i \leq k(k-1) + \sum_{i=k+1}^n \min(d_i, k)$$

### 7.2 Havel–Hakimi algorithm

find the vertex who has greatest degree unused, connect it with other greatest vertex.

### 7.3 MaximumEmptyRect

```

int max_empty_rect(int n, int m, bool blocked[N][N]){
    static int mxu[2][N], me=0, he=1, ans=0;
    for(int i=0;i<m;i++) mxu[he][i]=0;
    for(int i=0;i<n;i++){
        stack<PII> stk;
        for(int j=0;j<m;j++){
            if(blocked[i][j]) mxu[me][j]=0;
            else mxu[me][j]=mxu[he][j]+1;
            int la = j;
            while(!stk.empty() && stk.top().FF>mxu[me][j]){
                int x1 = i - stk.top().FF, x2 = i;
                int y1 = stk.top().SS, y2 = j;
                la = stk.top().SS; stk.pop();
                ans=max(ans, (x2-x1)*(y2-y1));
            }
            if(stk.empty() || stk.top().FF<mxu[me][j])
                stk.push({mxu[me][j], la});
        }
        while(!stk.empty()){
            int x1 = i - stk.top().FF, x2 = i;
            int y1 = stk.top().SS-1, y2 = m-1;
            stk.pop();
            ans=max(ans, (x2-x1)*(y2-y1));
        }
        swap(me, he);
    }
    return ans;
}

```



## 7.4 DP-opt Condition

### 7.4.1 totally monotone (concave/convex)

$$\forall i < i', j < j', B[i][j] \leq B[i'][j] \implies B[i][j'] \leq B[i'][j']$$

$$\forall i < i', j < j', B[i][j] \geq B[i'][j] \implies B[i][j'] \geq B[i'][j']$$

### 7.4.2 monge condition (concave/convex)

$$\forall i < i', j < j', B[i][j] + B[i'][j'] \geq B[i][j'] + B[i'][j]$$

$$\forall i < i', j < j', B[i][j] + B[i'][j'] \leq B[i][j'] + B[i'][j]$$

## 7.5 Convex 1D/1D DP

```

struct segment {
    int i, l, r;
    segment() {}
    segment(int a, int b, int c): i(a), l(b), r(c) {}
};

inline long long f(int l, int r) {
    return dp[l] + w(l + 1, r);
}

void solve() {
    dp[0] = 0ll;
    deque<segment> deq; deq.push_back(segment(0, 1, n));
    for (int i = 1; i <= n; ++i) {
        dp[i] = f(deq.front().i, i);
        while (deq.size() && deq.front().r < i + 1) deq.
            pop_front();
        deq.front().l = i + 1;
        segment seg = segment(i, i + 1, n);
        while (deq.size() && f(i, deq.back().l) < f(deq.
            back().i, deq.back().l)) deq.pop_back();
        if (deq.size()) {
            int d = 1048576, c = deq.back().l;
            while (d >>= 1) if (c + d <= deq.back().r) {
                if (f(i, c + d) > f(deq.back().i, c + d)) c +=
                    d;
            }
            deq.back().r = c; seg.l = c + 1;
        }
        if (seg.l <= n) deq.push_back(seg);
    }
}

```