Contents

1 Basic

1.1 default code

```cpp
#include <bits/stdc++.h>
#define PB push_back
#define MP make_pair
#define F first
#define S second
#define SZ(x) ((int)(x).size())
#define ALL(x) (x).begin(),(x).end()
#ifdef _DEBUG_
  #define debug(...) printf(__VA_ARGS__)
#else
  #define debug(...) (void)0
#endif
using namespace std;
typedef long long ll;
typedef pair<int,int> PII;
typedef vector<int> VI;

int main() {
  return 0;
}
```

1.2 .vimrc

```
color torte
syn on
set guifont=Consolas:h16: nu sc ai si ts=4 sm sts=4 sw=4

map <F9> <ESC>:w<CR>:!g++ % -o %< -O2 -Wall -Wno-unused-result -Wshadow -std=c++0x<CR>
map <S-F9> <ESC>:w<CR>:!g++ % -o %< -O2 -Wall -Wno-unused-result -Wshadow -D_DEBUG_ -std=c++0x<CR>
map <S-F10> <ESC>:w<CR>:!g++ % -o %< -O2 -Wall -Wno-unused-result -Wshadow -D_DEBUG_ -std=c++0x -fsanitize=undefined -fsanitize=address<CR>
map <F5> <ESC>:!./%<<CR>
map <F6> <ESC>:w<CR>ggVG"+y
map <S-F5> <ESC>:!./%< < %<.in<CR>
imap <Home> <ESC>^i
com INPUT sp %<.in
```

2 math

2.1 ext gcd

```cpp
// find one solution (x,y) of ax+by=gcd(a,b)
void ext_gcd(int a,int b,int &g,int &x,int &y)
{
  if(!b){ g=a; x=1; y=0; }
```

```
  else{ ext_gcd(b, a%b, g, y, x); y -= x*(a/b); }
}
```

2.2 FFT

```
typedef complex<double> CD;

const double PI=acos(-1.0);
inline CD ang(double t) { return CD(cos(t), sin(t)); }

int rev_int(int x,int lgn) {
  int re=0;
  for(int i=0;i<lgn;i++) {
    re=(re<<1)+(x&1);
    x>>=1;
  }
  return re;
}
void fft(CD* A, int lgn, bool inv=false) {
  int n=1<<lgn;
  for(int i=0;i<n;i++)
    if(i<rev_int(i, lgn)) swap(A[i], A[rev_int(i, lgn)]);
  for(int i=1;i<n;i*=2) {
    CD W(1.0, 0.0), Wn;
    if(inv) Wn=ang(-PI/i);
    else Wn=ang(PI/i);
    for(int j=0;j<n;j++) {
      if(j&i) {
        W=CD(1.0, 0.0);
        continue;
      }
      CD x=A[j], y=A[j+i]*W;
      A[j]=x+y;
      A[j+i]=x-y;
      W*=Wn;
    }
  }
  if(inv)
    for(int i=0;i<n;i++)
      A[i]/=n;
}
```

2.3 NTT

```
//    MOD     Wn_       LGN
//    5767169    177147 19
//    7340033      2187 20
// 2013265921 440564289 27
const int MOD=786433;
const int Wn_=5; // 25 625
const int LGN=18;// 17  16
inline int add(int x,int y) { return (x+y)%MOD; }
inline int mul(int x,int y) { return 1ll*x*y%MOD; }
inline int sub(int x,int y) { return (x-y+MOD)%MOD; }

int pW[MOD]; // power of Wn
int divN;
int inv(int a) {
  int re=1, k=MOD-2, t=a;
  while(k) {
    if(k%2) re=mul(re, t);
    k/=2;
    t=mul(t, t);
  }
  return re;
}
void NTTinit(int lgn) { // call every time using new lgn !
  int Wn=Wn_;
  for(int i=lgn;i<LGN;i++) Wn=mul(Wn,Wn);
  divN=inv(1<<lgn);
  pW[0]=1;
  for(int i=1;;i++) {
    pW[i]=mul(pW[i-1], Wn);
    if(pW[i]==1) break;
  }
}

int rev_int(int x,int lgn) {
  int re=0;
  for(int i=0;i<lgn;i++) {
    re=(re<<1)+(x&1);
    x>>=1;
  }
  return re;
}
void ntt(int *A,int lgn,bool inv=false) {
  int n=1<<lgn;
  for(int i=0;i<n;i++)
    if(i<rev_int(i,lgn))
      swap(A[i], A[rev_int(i,lgn)]);
  for(int i=1;i<n;i*=2) {
    int W=1, Wn;
    if(inv) Wn=pW[n-(n/2/i)];
    else Wn=pW[n/2/i];
    for(int j=0;j<n;j++) {
      if(j&i) {
        W=1;
        continue;
      }
      int x=A[j], y=mul(A[j+i],W);
      A[j]=add(x,y);
      A[j+i]=sub(x,y);
      W=mul(W,Wn);
    }
  }
  if(inv)
    for(int i=0;i<n;i++)
      A[i]=mul(A[i],divN);
}
```

2.4 MillerRabin other

```
/* Miller Rabin code from ioicamp */
ll mul(ll a, ll b, ll n) {
  ll r = 0;
  a %= n, b %= n;
  while(b) {
```

```
    if(b&1) r = (a+r>=n ? a+r-n : a+r);
    a = (a+a>=n ? a+a-n : a+a);
    b >>= 1;
  }
  return r;
}

ll bigmod(ll a, ll d, ll n) {
  if(d==0)  return 1LL;
  if(d==1) return a % n;
  return mul(bigmod(mul(a, a, n), d/2, n),
      d%2?a:1, n);
}

const bool PRIME = 1, COMPOSITE = 0;
bool miller_rabin(ll n, ll a) {
  if(__gcd(a, n) == n)  return PRIME;
  if(__gcd(a, n) != 1)  return COMPOSITE;
  ll d = n-1, r = 0, res;
  while(d%2==0) { ++r; d/=2; }
  res = bigmod(a, d, n);
  if(res == 1 || res == n-1)  return PRIME;
  while(r--) {
    res = mul(res, res, n);
    if(res == n-1)  return PRIME;
  }
  return COMPOSITE;
}

bool isprime(ll n) {
  if(n==1)
    return COMPOSITE;
  ll as[7] = {2, 325, 9375, 28178, 450775,
      9780504, 1795265022};
  for(int i=0; i<7; i++)
    if(miller_rabin(n, as[i]) == COMPOSITE)
        return COMPOSITE;
  return PRIME;
}
```

2.5 Guass

```
// be care of the magic number 7 & 8
void guass() {
  for(int i = 0; i < 7; i++) {
    Frac tmp = mat[i][i]; // Frac -> the
       type of data
    for(int j = 0; j < 8; j++)
      mat[i][j] = mat[i][j] / tmp;
    for(int j = 0; j < 7; j++) {
      if(i == j)
        continue;
      Frac ratio = mat[j][i]; // Frac ->
         the type of data
      for(int k = 0; k < 8; k++)
        mat[j][k] = mat[j][k] - ratio * mat
           [i][k];
    }
  }
}
```

2.6 xorFFT

```
//      1   1
// H =  1  -1
//      /sqrt(2)
vector<ll> FWHT(vector<ll> P, bool inverse)
    {
  for(int len = 1; 2 * len <= SZ(P); len
      <<= 1) {
    for(int i = 0; i < SZ(P); i += 2 * len)
        {
      for(int j = 0; j < len; j++) {
        ll u = P[i + j];
        ll v = P[i + len + j];
        P[i + j] = u + v;
        P[i + len + j] = u - v;
      }
    }
  }
  if (inverse) {
    for (int i = 0; i < SZ(P); i++)
      P[i] = P[i] / SZ(P);
  }
  return P;
}
```

2.7 orFFT

```
//      1   1
// T =  1   0
//      0   1
//T-1=  1  -1
vector<ll> transform(vector<ll> P, bool
    inverse) {
  for(int len = 1; 2 * len <= SZ(P); len
      <<= 1) {
    for(int i = 0; i < SZ(P); i += 2 * len)
        {
      for(int j = 0; j < len; j++) {
        ll u = P[i + j];
        ll v = P[i + len + j];
        if (!inverse) {
          P[i + j] = u + v;
          P[i + len + j] = u;
        } else {
          P[i + j] = v;
          P[i + len + j] = u - v;
        }
      }
    }
  }
  return P;
}
```

2.8 andFFT

```
//      0   1
// T =  1   1
//     -1   1
//T-1=  1   0
```

```
vector<ll> transform(vector<ll> P, bool inverse) {
  for(int len = 1; 2 * len <= SZ(P); len <<= 1) {
    for(int i = 0; i < SZ(P); i += 2 * len) {
      for(int j = 0; j < len; j++) {
        ll u = P[i + j];
        ll v = P[i + len + j];
        if (!inverse) {
          P[i + j] = v;
          P[i + len + j] = u + v;
        } else {
          P[i + j] = -u + v;
          P[i + len + j] = u;
        }
      }
    }
  }
  return P;
}
```

2.9 Them.

Catalan number: $C_0 = 1$, $C_{n+1} = \frac{2(2n+1)}{n+2} C_n$

3 flow

3.1 dinic

```
const int MAXV=300;
const int MAXE=10000;
const int INF=(int)1e9+10;
// ^ config those things

struct E {
  int to,co;//capacity
  E(int t=0,int c=0):to(t),co(c) {}
}eg[2*MAXE];

// source:0  sink:n-1
struct Flow {
  VI e[MAXV];
  int ei,v;
  void init(int n) {
    v=n;
    ei=0;
    for(int i=0;i<n;i++)
      e[i]=VI();
  }
  void add(int a,int b,int c) { //a to b , maxflow=c
    eg[ei]=E(b,c);
    e[a].PB(ei);
    ei++;
    eg[ei]=E(a,0);
    e[b].PB(ei);
    ei++;
  }

  int d[MAXV],qu[MAXV],ql,qr;
  bool BFS() {
    memset(d,-1,v*sizeof(int));
    ql=qr=0;
    qu[qr++]=0;
    d[0]=0;
    while(ql<qr && d[v-1]==-1) {
      int n=qu[ql++];
      VI &v=e[n];
      for(int i=SZ(v)-1;i>=0;i--) {
        int u=v[i];
        if(d[eg[u].to]==-1 && eg[u].co>0) {
          d[eg[u].to]=d[n]+1;
          qu[qr++]=eg[u].to;
        }
      }
    }
    return d[v-1]!=-1;
  }
  int ptr[MAXV];
  int go(int n,int p) {
    if(n==v-1)
      return p;
    VI &u=e[n];
    int temp;
    for(int i=ptr[n];i<SZ(u);i++) {
      if(d[n]+1!=d[eg[u[i]].to] || eg[u[i]].co==0)
        continue;
      if((temp=go(eg[u[i]].to,min(p,eg[u[i]].co)))==0)
        continue;
      eg[u[i]].co-=temp;
      eg[u[i]^1].co+=temp;
      ptr[n]=i;
      return temp;
    }
    ptr[n]=SZ(u);
    return 0;
  }
  int max_flow() {
    int ans=0,temp;
    while(BFS()) {
      for(int i=0;i<v;i++)
        ptr[i]=0;
      while((temp=go(0,INF))>0)
        ans+=temp;
    }
    return ans;
  }
}flow;
```

3.2 min-cost-max-flow

```
typedef pair<int,ll> PIL;
const int MAXV=60;
const int MAXE=6000;
const int INF=(int)1e9+10;
const ll cINF=(ll)1e18+10;
// ^ config those things

struct E {
  int to,ca,cost;//capacity, cost
```

```
  E(int t=0,int c=0,int co=0):to(t),ca(c),
      cost(co) {}
}eg[2*MAXE];

// source:0  sink:n-1
struct Flow {
  VI e[MAXV];
  int ei,n;
  void init(int n_) {
    n=n_;
    ei=0;
    for(int i=0;i<n;i++)
      e[i]=VI();
  }
  void add(int a,int b,int c,int d) {
    //a to b ,maxflow=c, cost=d
    eg[ei]=E(b,c,d);
    e[a].PB(ei);
    ei++;
    eg[ei]=E(a,0,-d);
    e[b].PB(ei);
    ei++;
  }

  PII d[MAXV]={};
  bool inq[MAXV]={};
  queue<int> que;
  VI pe;
  bool SPFA() {
    fill(d, d+n, MP(INF,INF));
    d[0]=MP(0,0);
    que.push(0);
    inq[0]=1;
    while(!que.empty()) {
      int v=que.front(); que.pop();
      inq[v]=0;
      for(int id:e[v]) {
        if(eg[id].ca>0 && MP(d[v].F+eg[id].
            cost,d[v].S+1)<d[eg[id].to]) {
          d[eg[id].to]=MP(d[v].F+eg[id].
              cost,d[v].S+1);
          if(!inq[eg[id].to]) {
            que.push(eg[id].to);
            inq[eg[id].to]=1;
          }
        }
      }
    }
    return d[n-1].F<INF;
  }
  PIL go(ll cb=cINF) {
    // cost_bound
    if(!SPFA()) return MP(0,0);
    pe.clear();
    int fl=INF;
    for(int v=n-1;v!=0;) {
      for(int id:e[v]) {
        int u=eg[id].to;
        const E& t=eg[id^1];
        if(t.ca>0 && MP(d[u].F+t.cost,d[u].
            S+1)==d[v]) {
          fl=min(fl, t.ca);
          v=u;
          pe.PB(id^1);
          break;
        }
      }
    }
    if(d[n-1].F>0) fl=min(1ll*fl, cb/d[n
        -1].F);
    for(int id:pe) {
      eg[id].ca-=fl;
      eg[id^1].ca+=fl;
    }
    return MP(fl, 1ll*fl*d[n-1].F);
  }
  PIL max_flow() {
    PIL ans=MP(0,0),temp;
    while((temp=go()).F>0) {
      ans.F+=temp.F;
      ans.S+=temp.S;
    }
    return ans;
  }
} flow;
```

4 string

4.1 KMP

```
void KMP_build(const char *S,int *F) {
  int p=F[0]=-1;
  for(int i=1;S[i];i++) {
    while(p!=-1 && S[p+1]!=S[i])
      p=F[p];
    if(S[p+1]==S[i])
      p++;
    F[i]=p;
  }
}

VI KMP_match(const char *S,const int *F,
    const char *T) {
  VI ans;
  int p=-1;
  for(int i=0;T[i];i++) {
    while(p!=-1 && S[p+1]!=T[i])
      p=F[p];
    if(S[p+1]==T[i])
      p++;
    if(!S[p+1]) {
      ans.PB(i-p);
      p=F[p];
    }
  }
  return ans;
}
```

4.2 Z-value

```
void Z_build(const char *S,int *Z) {
  Z[0]=0;
  int bst=0;
  for(int i=1;S[i];i++) {
    if(Z[bst]+bst<i) Z[i]=0;
```

```
    else Z[i]=min(Z[bst]+bst-i,Z[i-bst]);
    while(S[Z[i]]==S[i+Z[i]]) Z[i]++;
    if(Z[i]+i>Z[bst]+bst) bst=i;
  }
}
```

4.3 Z-value-palindrome

```
// AC code of NTUJ1871
char in[100100];
char s[200100];
int z[200100];

int main() {
  while(gets(in)) {
    int len=1;
    for(int i=0;in[i];i++) {
      s[len++]='*';
      s[len++]=in[i];
    }
    s[len]=0;
    z[0]=0;
    z[1]=0;
    int bst=1;
    for(int i=1;i<len;i++) {
      z[i]=min(bst+z[bst]-i,z[bst+bst-i]);
      while(s[i+z[i]+1]==s[i-z[i]-1])
        z[i]++;
      if(z[i]+i>bst+z[bst])
        bst=i;
    }
    bool yes=0;
    for(int i=3;i<len;i+=2)
      if(z[(i+1)/2]==i/2 && z[(i+len)/2]==(
          len-i-1)/2)
        yes=1;
    if(yes)
      puts("www");
    else
      puts("vvvvvv");
  }
  return 0;
}
```

4.4 Suffix Array($O(NlogN)$)

```
const int SASIZE=100020;  // >= (max length
    of string + 20)
struct SA{
  char S[SASIZE]; // put target string into
      S[0:(len-1)]
  // you can change the type of S into int
     if required
  // if the string is in int, please avoid
     number < 0
  int R[SASIZE*2],SA[SASIZE];
  int tR[SASIZE*2],tSA[SASIZE];
  int cnt[SASIZE],len;      // set len
     before calling build()
  int H[SASIZE];

  void build_SA() {
    int maxR=0;
    for(int i=0;i<len;i++)
      R[i]=S[i];
    for(int i=0;i<=len;i++)
      R[len+i]=-1;
    memset(cnt,0,sizeof(cnt));
    for(int i=0;i<len;i++)
      maxR=max(maxR,R[i]);
    for(int i=0;i<len;i++)
      cnt[R[i]+1]++;
    for(int i=1;i<=maxR;i++)
      cnt[i]+=cnt[i-1];
    for(int i=0;i<len;i++)
      SA[cnt[R[i]]++]=i;
    for(int i=1;i<len;i*=2)
    {
      memset(cnt,0,sizeof(int)*(maxR+10));
      memcpy(tSA,SA,sizeof(int)*(len+10));
      memcpy(tR,R,sizeof(int)*(len+i+10));
      for(int j=0;j<len;j++)
        cnt[R[j]+1]++;
      for(int j=1;j<=maxR;j++)
        cnt[j]+=cnt[j-1];
      for(int j=len-i;j<len;j++)
        SA[cnt[R[j]]++]=j;
      for(int j=0;j<len;j++)
      {
        int k=tSA[j]-i;
        if(k<0)
          continue;
        SA[cnt[R[k]]++]=k;
      }
      int num=0;
      maxR=0;
      R[SA[0]]=num;
      for(int j=1;j<len;j++)
      {
        if(tR[SA[j-1]]<tR[SA[j]] || tR[SA[j
            -1]+i]<tR[SA[j]+i])
          num++;
        R[SA[j]]=num;
        maxR=max(maxR,R[SA[j]]);
      }
    }
    if (len == 1)
      SA[0] = R[0] = 0;
  }
  void build_H() {
    memset(H,0,sizeof(int)*(len+10));
    for(int i=0;i<len;i++)
    {
      if(R[i]==0)
        continue;
      int &t=H[R[i]];
      if(i>0)
        t=max(0,H[R[i-1]]-1);
      while(S[i+t]==S[SA[R[i]-1]+t]) t++;
    }
  }
}sa;
```

4.5 Suffix Array(SAIS, twt)

```
struct SA{
#define REP(i,n) for ( int i=0; i<int(n); i ++ )
#define REP1(i,a,b) for ( int i=(a); i<=int (b); i++ )
  static const int MXN = 300010;
  bool _t[MXN*2];
  int _s[MXN*2], _sa[MXN*2], _c[MXN*2], x[MXN], _p[MXN], _q[MXN*2], hei[MXN], r[MXN];
  int operator [] (int i){ return _sa[i]; }
  void build(int *s, int n, int m){
    memcpy(_s, s, sizeof(int) * n);
    sais(_s, _sa, _p, _q, _t, _c, n, m);
    mkhei(n);
  }
  void mkhei(int n){
    REP(i,n) r[_sa[i]] = i;
    hei[0] = 0;
    REP(i,n) if(r[i]) {
      int ans = i>0 ? max(hei[r[i-1]] - 1, 0) : 0;
      while(_s[i+ans] == _s[_sa[r[i]-1]+ans]) ans++;
      hei[r[i]] = ans;
    }
  }
  void sais(int *s, int *sa, int *p, int *q, bool *t, int *c, int n, int z){
    bool uniq = t[n-1] = true, neq;
    int nn = 0, nmxz = -1, *nsa = sa + n, *ns = s + n, lst = -1;
#define MS0(x,n) memset((x),0,n*sizeof(*(x)))
#define MAGIC(XD) MS0(sa, n); \
    memcpy(x, c, sizeof(int) * z); \
    XD; \
    memcpy(x + 1, c, sizeof(int) * (z - 1)); \
    REP(i,n) if(sa[i] && !t[sa[i]-1]) sa[x[s[sa[i]-1]]++] = sa[i]-1; \
    memcpy(x, c, sizeof(int) * z); \
    for(int i = n - 1; i >= 0; i--) if(sa[i] && t[sa[i]-1]) sa[--x[s[sa[i]-1]]] = sa[i]-1;
    MS0(c, z);
    REP(i,n) uniq &= ++c[s[i]] < 2;
    REP(i,z-1) c[i+1] += c[i];
    if (uniq) { REP(i,n) sa[--c[s[i]]] = i; return; }
    for(int i = n - 2; i >= 0; i--) t[i] = (s[i]==s[i+1] ? t[i+1] : s[i]<s[i+1]);
    MAGIC(REP1(i,1,n-1) if(t[i] && !t[i-1]) sa[--x[s[i]]]=p[q[i]=nn++]=i);
    REP(i, n) if (sa[i] && t[sa[i]] && !t[sa[i]-1]) {
      neq=lst<0||memcmp(s+sa[i],s+lst,(p[q[sa[i]]+1]-sa[i])*sizeof(int));
      ns[q[lst=sa[i]]]=nmxz+=neq;
    }
    sais(ns, nsa, p + nn, q + n, t + n, c + z, nn, nmxz + 1);
    MAGIC(for(int i = nn - 1; i >= 0; i--) sa[--x[s[p[nsa[i]]]]] = p[nsa[i]]);
  }
}sa;

void suffix_array(int* ip, int len) {
  // should padding a zero in the back
  // s is int array, n is array length
  // s[0..n-1] != 0, and s[n] = 0
  // resulting SA will be length n+1
  ip[len++] = 0;
  sa.build(ip, len, 128);
  // original 1-base
  for (int i=0; i<l; i++) {
    hei[i] = sa.hei[i + 1];
    sa[i] = sa._sa[i + 1];
  }
}
```

4.6 Aho-Corasick-2016ioicamp

```
// AC code of 2016ioicamp 54
const int MAXNM=100010;
int pp[MAXNM];

const int sizz=100010;
int nx[sizz][26],spt;
int fl[sizz],efl[sizz],ed[sizz];
int len[sizz];
int newnode(int len_=0) {
  for(int i=0;i<26;i++)nx[spt][i]=0;
  ed[spt]=0;
  len[spt]=len_;
  return spt++;
}
int add(char *s,int p) {
  int l=1;
  for(int i=0;s[i];i++) {
    int a=s[i]-'a';
    if(nx[p][a]==0) nx[p][a]=newnode(l);
    p=nx[p][a];
    l++;
  }
  ed[p]=1;
  return p;
}
int q[sizz],qs,qe;
void make_fl(int root) {
  fl[root]=efl[root]=0;
  qs=qe=0;
  q[qe++]=root;
  for(;qs!=qe;) {
    int p=q[qs++];
    for(int i=0;i<26;i++) {
      int t=nx[p][i];
      if(t==0) continue;
      int tmp=fl[p];
      for(;tmp&&nx[tmp][i]==0;) tmp=fl[tmp];
      fl[t]=tmp?nx[tmp][i]:root;
      efl[t]=ed[fl[t]]?fl[t]:efl[fl[t]];
```

```
      q[qe++]=t;
    }
  }
}
char s[MAXNM];
char a[MAXNM];

int dp[MAXNM][4];

void mmax(int &a,int b) {
  a=max(a,b);
}

void match(int root) {
  int p=root;
  for(int i=1;s[i];i++) {
    int a=s[i]-'a';
    for(;p&&nx[p][a]==0;p=fl[p]);
    p=p?nx[p][a]:root;
    for(int j=1;j<=3;j++)
      dp[i][j]=dp[i-1][j];
    for(int t=p;t;t=efl[t]) {
      if(!ed[t])
        continue;
      for(int j=1;j<=3;j++)
        mmax(dp[i][j],dp[i-len[t]][j-1]+(pp
            [i]-pp[i-len[t]]));
    }
  }
}

int main() {
  int T;
  scanf("%d",&T);
  while(T--) {
    int n,m;
    scanf("%d%d",&n,&m);
    scanf("%s",s+1);
    for(int i=1;i<=n;i++)
      scanf("%d",pp+i);
    for(int i=1;i<=n;i++)
      pp[i]+=pp[i-1];
    spt=1;
    int root=newnode();
    for(int i=0;i<m;i++) {
      scanf("%s",a);
      add(a,root);
    }
    make_fl(root);
    for(int i=1;i<=n;i++)
      dp[i][1]=dp[i][2]=dp[i][3]=0;
    match(root);
    printf("%d\n",dp[n][3]);
  }
  return 0;
}
```

4.7 Palindrome Automaton

```
const int MAXN=100050;
char s[MAXN];
int n; // n: string length

typedef pair<PII,int> PD;
vector<PD> pal;

int ch[MAXN][26], fail[MAXN], len[MAXN],
    cnt[MAXN];
int edp[MAXN];
int nid=1;
int new_node(int len_) {
  len[nid]=len_;
  return nid++;
}

void build_pa() {
  int odd_root=new_node(-1);
  int even_root=new_node(0);
  fail[even_root]=odd_root;
  int cur=even_root;
  for(int i=1;i<=n;i++) {
    while(1) {
      if(s[i-len[cur]-1] == s[i]) break;
      cur=fail[cur];
    }
    if(ch[cur][s[i]-'a']==0) {
      int nt=ch[cur][s[i]-'a']=new_node(len
          [cur]+2);
      int tmp=fail[cur];
      while(tmp && s[i-len[tmp]-1]!=s[i])
          tmp=fail[tmp];
      if(tmp==0) fail[nt]=even_root;
      else {
        assert(ch[tmp][s[i]-'a']);
        fail[nt]=ch[tmp][s[i]-'a'];
      }
      edp[nt]=i;
    }
    cur=ch[cur][s[i]-'a'];
    cnt[cur]++;
  }
  for(int i=nid-1;i>even_root;i--) {
    cnt[fail[i]]+=cnt[i];
    pal.PB( MP( MP(edp[i]-len[i]+1, len[i])
        , cnt[i]) );
  }
}
```

4.8 Suffix Automaton(bcw)

```
// par : fail link
// val : a topological order ( useful for
    DP )
// go[x] : automata edge ( x is integer in
    [0,26) )

struct SAM{
  struct State{
    int par, go[26], val;
    State () : par(0), val(0){ FZ(go); }
    State (int _val) : par(0), val(_val){
        FZ(go); }
  };
  vector<State> vec;
  int root, tail;

```

```
  void init(int arr[], int len){
    vec.resize(2);
    vec[0] = vec[1] = State(0);
    root = tail = 1;
    for (int i=0; i<len; i++)
      extend(arr[i]);
  }
  void extend(int w){
    int p = tail, np = vec.size();
    vec.PB(State(vec[p].val+1));
    for ( ; p && vec[p].go[w]==0; p=vec[p].
        par)
      vec[p].go[w] = np;
    if (p == 0){
      vec[np].par = root;
    } else {
      if (vec[vec[p].go[w]].val == vec[p].
          val+1){
        vec[np].par = vec[p].go[w];
      } else {
        int q = vec[p].go[w], r = vec.size
            ();
        vec.PB(vec[q]);
        vec[r].val = vec[p].val+1;
        vec[q].par = vec[np].par = r;
        for ( ; p && vec[p].go[w] == q; p=
            vec[p].par)
          vec[p].go[w] = r;
      }
    }
    tail = np;
  }
};
```

5 graph

5.1 Bipartite matching($O(N^3)$)

```
// NTUJ1263
bool is(ll x) {
  ll l=1,r=2000000,m;
  while(l<=r) {
    m=(l+r)/2;
    if(m*m==x)
      return 1;
    if(m*m<x)
      l=m+1;
    else
      r=m-1;
  }
  return 0;
}

VI odd,even;
int in[300];
VI e[300];
int match[300];
bool vis[300];

bool DFS(int x) {
  vis[x]=1;
  for(int u:e[x]) {
    if(match[u]==-1 || (!vis[match[u]]&&DFS
        (match[u]))) {
      match[u]=x;
      match[x]=u;
      return 1;
    }
  }
  return 0;
}

int main() {
  int N;
  while(scanf("%d",&N)==1) {
    odd.clear();
    even.clear();
    for(int i=0;i<N;i++)
      e[i].clear();
    for(int i=0;i<N;i++) {
      scanf("%d",in+i);
      if(in[i]%2==0)
        even.pb(i);
      else
        odd.pb(i);
    }
    for(int i:even)
      for(int j:odd)
        if(is(1ll*in[i]*in[i]+1ll*in[j]*in[
            j]) && __gcd(in[i],in[j])==1)
          e[i].pb(j), e[j].pb(i);
    int ans=0;
    fill(match,match+N,-1);
    for(int i=0;i<N;i++)
      if(match[i]==-1) {
        fill(vis,vis+N,0);
        if(DFS(i))
          ans++;
      }
    printf("%d\n",ans);
  }
  return 0;
}
```

5.2 KM($O(N^4)$)

```
const int INF=1016; //> max(a[i][j])
const int MAXN=650;
int a[MAXN][MAXN]; // weight [x][y] , two
    set of vertex
int N; // two set: each set have exactly N
    vertex
int match[MAXN*2], weight[MAXN*2];
bool vis[MAXN*2];

bool DFS(int x) {
  vis[x]=1;
  for(int i=0;i<N;i++) {
    if(weight[x]+weight[N+i]!=a[x][i])
      continue;
    vis[N+i]=1;
    if(match[N+i]==-1 || (!vis[match[N+i
        ]]&&DFS(match[N+i]))) {
      match[N+i]=x;
      match[x]=N+i;
```

```
      return 1;
    }
  }
  return 0;
}

int KM() {
  fill(weight, weight+N+N, 0);
  for(int i=0;i<N;i++) {
    for(int j=0;j<N;j++)
      weight[i]=max(weight[i], a[i][j]);
  }
  fill(match, match+N+N, -1);
  for(int u=0;u<N;u++) {
    fill(vis, vis+N+N, 0);
    while(!DFS(u)) {
      int d=INF;
      for(int i=0;i<N;i++) {
        if(!vis[i]) continue;
        for(int j=0;j<N;j++)
          if(!vis[N+j])
            d=min(d, weight[i]+weight[N+j]-
                a[i][j]);
      }
      for(int i=0;i<N;i++)
        if(vis[i])
          weight[i]-=d;
      for(int i=N;i<N+N;i++)
        if(vis[i])
          weight[i]+=d;
      fill(vis, vis+N+N, 0);
    }
  }
  int ans=0;
  for(int i=0;i<N+N;i++) ans+=weight[i];
  return ans;
}
```

5.3 general graph matching(bcw)

```
#define FZ(x) memset(x,0,sizeof(x))
struct GenMatch { // 1-base
  static const int MAXN = 250;
  int V;
  bool el[MAXN][MAXN];
  int pr[MAXN];
  bool inq[MAXN],inp[MAXN],inb[MAXN];
  queue<int> qe;
  int st,ed;
  int nb;
  int bk[MAXN],djs[MAXN];
  int ans;
  void init(int _V) {
    V = _V;
    FZ(el); FZ(pr);
    FZ(inq); FZ(inp); FZ(inb);
    FZ(bk); FZ(djs);
    ans = 0;
  }
  void add_edge(int u, int v) {
    el[u][v] = el[v][u] = 1;
  }
  int lca(int u,int v) {
    memset(inp,0,sizeof(inp));
    while(1) {
      u = djs[u];
      inp[u] = true;
      if(u == st) break;
      u = bk[pr[u]];
    }
    while(1) {
      v = djs[v];
      if(inp[v]) return v;
      v = bk[pr[v]];
    }
    return v;
  }
  void upd(int u) {
    int v;
    while(djs[u] != nb) {
      v = pr[u];
      inb[djs[u]] = inb[djs[v]] = true;
      u = bk[v];
      if(djs[u] != nb) bk[u] = v;
    }
  }
  void blo(int u,int v) {
    nb = lca(u,v);
    memset(inb,0,sizeof(inb));
    upd(u); upd(v);
    if(djs[u] != nb) bk[u] = v;
    if(djs[v] != nb) bk[v] = u;
    for(int tu = 1; tu <= V; tu++)
      if(inb[djs[tu]]) {
        djs[tu] = nb;
        if(!inq[tu]){
          qe.push(tu);
          inq[tu] = 1;
        }
      }
  }
  void flow() {
    memset(inq,false,sizeof(inq));
    memset(bk,0,sizeof(bk));
    for(int i = 1; i <= V;i++)
      djs[i] = i;

    while(qe.size()) qe.pop();
    qe.push(st);
    inq[st] = 1;
    ed = 0;
    while(qe.size()) {
      int u = qe.front(); qe.pop();
      for(int v = 1; v <= V; v++)
        if(el[u][v] && (djs[u] != djs[v])
            && (pr[u] != v)) {
          if((v == st) || ((pr[v] > 0) &&
              bk[pr[v]] > 0))
            blo(u,v);
          else if(bk[v] == 0) {
            bk[v] = u;
            if(pr[v] > 0) {
              if(!inq[pr[v]]) qe.push(pr[v
                  ]);
            } else {
              ed = v;
              return;
            }
```

```
          }
        }
    }
  }
  void aug() {
    int u,v,w;
    u = ed;
    while(u > 0) {
      v = bk[u];
      w = pr[v];
      pr[v] = u;
      pr[u] = v;
      u = w;
    }
  }
  int solve() {
    memset(pr,0,sizeof(pr));
    for(int u = 1; u <= V; u++)
      if(pr[u] == 0) {
        st = u;
        flow();
        if(ed > 0) {
          aug();
          ans ++;
        }
      }
    return ans;
  }
} gm;
```

5.4 Max clique(bcw)

```
class MaxClique {
public:
  static const int MV = 210;

  int V;
  int el[MV][MV/30+1];
  int dp[MV];
  int ans;
  int s[MV][MV/30+1];
  vector<int> sol;

  void init(int v) {
    V = v; ans = 0;
    FZ(el); FZ(dp);
  }

  /* Zero Base */
  void addEdge(int u, int v) {
    if(u > v) swap(u, v);
    if(u == v) return;
    el[u][v/32] |= (1<<(v%32));
  }

  bool dfs(int v, int k) {
    int c = 0, d = 0;
    for(int i=0; i<(V+31)/32; i++) {
      s[k][i] = el[v][i];
      if(k != 1) s[k][i] &= s[k-1][i];
      c += __builtin_popcount(s[k][i]);
    }
    if(c == 0) {
      if(k > ans) {
        ans = k;
        sol.clear();
        sol.push_back(v);
        return 1;
      }
      return 0;
    }
    for(int i=0; i<(V+31)/32; i++) {
      for(int a = s[k][i]; a ; d++) {
        if(k + (c-d) <= ans) return 0;
        int lb = a&(-a), lg = 0;
        a ^= lb;
        while(lb!=1) {
          lb = (unsigned int)(lb) >> 1;
          lg ++;
        }
        int u = i*32 + lg;
        if(k + dp[u] <= ans) return 0;
        if(dfs(u, k+1)) {
          sol.push_back(v);
          return 1;
        }
      }
    }
    return 0;
  }

  int solve() {
    for(int i=V-1; i>=0; i--) {
      dfs(i, 1);
      dp[i] = ans;
    }
    return ans;
  }
};
```

5.5 EdgeBCC

```
const int MAXN=1010;
const int MAXM=5010;
VI e[MAXN];
int low[MAXN],lvl[MAXN],bel[MAXN];
bool vis[MAXN];
int cnt;
VI st;
void DFS(int x,int l,int p) {
  st.PB(x);
  vis[x]=1;
  low[x]=lvl[x]=l;
  bool top=0;
  for(int u:e[x]) {
    if(u==p && !top) {
      top=1;
      continue;
    }
    if(!vis[u]) {
      DFS(u,l+1,x);
    }
    low[x]=min(low[x],low[u]);
  }
  if(x==1 || low[x]==l) {
    while(st.back()!=x) {
```

```
      bel[st.back()]=cnt;
      st.pop_back();
    }
    bel[st.back()]=cnt;
    st.pop_back();
    cnt++;
  }
}
int main() {
  int T;
  scanf("%d",&T);
  while(T--) {
    int N,M,a,b;
    scanf("%d%d",&N,&M);
    fill(vis,vis+N+1,0);
    for(int i=1;i<=N;i++)
      e[i].clear();
    while(M--) {
      scanf("%d%d",&a,&b);
      e[a].PB(b);
      e[b].PB(a);
    }
    cnt=0;
    DFS(1,0,-1);
    /*****/
  }
  return 0;
}
```

5.6 VerticeBCC

```
const int MAXN=10000;
const int MAXE=100000;

VI e[MAXN+10];
vector<PII> BCC[MAXE];
int bccnt;
vector<PII> st;
bool vis[MAXN+10];
int low[MAXN+10],level[MAXN+10];

void DFS(int x,int p,int l) {
  vis[x]=1;
  level[x]=low[x]=l;
  for(int u:e[x]) {
    if(u==p)
      continue;
    if(vis[u]) {
      if(level[u]<l) {
        st.PB(MP(x,u));
        low[x]=min(low[x],level[u]);
      }
    }
    else {
      st.PB(MP(x,u));
      DFS(u,x,l+1);
      if(low[u]>=l) {
        PII t=st.back();
        st.pop_back();
        while(t!=MP(x,u)) {
          BCC[bccnt].PB(t);
          t=st.back();
          st.pop_back();
        }
        BCC[bccnt].PB(t);
        bccnt++;
      }
      low[x]=min(low[x],low[u]);
    }
  }
}

int main() {
  int T,N,M;
  scanf("%d",&T);
  while(T--) {
    scanf("%d%d",&N,&M);
    for(int i=0;i<N;i++)
      e[i].clear();
    int cnt=0;
    while(1) {
      int x,y;
      scanf("%d%d",&x,&y);
      if(x==-1 && y==-1)
        break;
      cnt++;
      e[x].PB(y);
      e[y].PB(x);
    }
    for(int i=0;i<N;i++) { // no multi-edge
      sort(ALL(e[i]));
      e[i].erase(unique(ALL(e[i])),e[i].end
          ());
    }
    fill(vis,vis+N,0);
    while(bccnt)
      BCC[--bccnt].clear();
    DFS(0,-1,0);
    /***/
  }
  return 0;
}
```

5.7 Dominating Tree

```
const int MAXN = 200000 + 10;

VI e[MAXN], re[MAXN];
int par[MAXN], num[MAXN], t, rn[MAXN];
int sd[MAXN], id[MAXN];
PII p[MAXN];
VI sdom_at[MAXN];

void dfs(int u) {
  num[u] = ++t;
  rn[t] = u;
  for(int v : e[u]) {
    if(num[v])  continue;
    par[v] = u;
    dfs(v);
  }
}

void LINK(int x, int y) {
  p[x].F = y;
  if(sd[y] < sd[p[x].S])  p[x].S = y;
```

```
}

int EVAL(int x) {
  if(p[p[x].F].F != p[x].F) {
    int w = EVAL(p[x].F);
    if(sd[w] < sd[p[x].S])  p[x].S = w;
    p[x].F = p[ p[x].F ].F;
  }
  return p[x].S;
}

void DominatingTree(int n) {
  // 1-indexed
  par[1] = 1;
  fill(num, num+n+1, 0);
  fill(rn, rn+n+1, 0);
  t = 0;
  dfs(1);

  for(int i=1; i<=n; i++) {
    p[i] = MP(i, i);
  }
  for(int i=1; i<=n; i++) {
    sd[i] = (num[i] ? num[i] : MAXN+10);
    id[i] = i;
  }
  for(int i=n; i>1; i--) {
    int v = rn[i];
    if(!v)  continue;
    for(int u : re[v]) {
      int w = EVAL(u);
      sd[v] = min(sd[v], sd[w]);
    }
    sdom_at[rn[sd[v]]].PB(v);
    LINK(v, par[v]);

    for(int w : sdom_at[par[v]]) {
      int u = EVAL(w);
      id[w] = (sd[u]<sd[w] ? u : par[v]);
    }
    sdom_at[par[v]].clear();
  }

  for(int i=2; i<=n; i++) {
    int v = rn[i];
    if(!v)  break;
    if(id[v] != rn[sd[v]])  id[v] = id[id[v
        ]];
  }
}
```

5.8 Min Cut

```
const int MAXN = 500 + 50;
int w[MAXN][MAXN];
ll cost[MAXN];
bool out[MAXN];

int N, M;
ll go(int V) {
  fill(cost, cost + N, 0);
  cost[0] = -1;
  int nxt = 0, lst = 0;
  for(int i = 0; i < N; i++) {
    if(out[i]) continue;
    cost[i] += w[0][i];
    if(cost[i] > cost[nxt]) nxt = i;
  }
  while(V > 2) {
    int u = nxt;
    if(cost[u] <= 0) return 0;
    cost[u] = -1;
    for(int i = 0; i < N; i++) {
      if(cost[i] == -1 || out[i]) continue;
      cost[i] += w[u][i];
      if(cost[i] > cost[nxt]) nxt = i;
    }
    V--;
    lst = u;
  }
  if(cost[nxt] <= 0) return 0;
  out[nxt] = true;
  for(int i = 0; i < N; i++)
    w[i][lst] = w[lst][i] = (w[lst][i] + w[
        nxt][i]);
  return cost[nxt];
}

ll min_cut() {
  fill(out, out + N, false);
  ll res = go(N);
  for(int v = N - 1; v > 1; v--) {
    res = min(go(v), res);
    if(res == 0) return res;
  }
  return res;
}
```

5.9 DMST with sol(bcw)

```
const int INF = 1029384756;

struct edge_t{
  int u,v,w;
  set< pair<int,int> > add, sub;
  edge_t() : u(-1), v(-1), w(0) {}
  edge_t(int _u, int _v, int _w) {
    u = _u; v = _v; w = _w;
    add.insert({u, v});
  }
  edge_t& operator += (const edge_t& obj) {
    w += obj.w;
    FOR (it, obj.add) {
      if (!sub.count(*it)) add.insert(*it);
      else sub.erase(*it);
    }
    FOR (it, obj.sub) {
      if (!add.count(*it)) sub.insert(*it);
      else add.erase(*it);
    }
    return *this;
  }
  edge_t& operator -= (const edge_t& obj) {
    w -= obj.w;
    FOR (it, obj.sub) {
      if (!sub.count(*it)) add.insert(*it);
```

```
      else sub.erase(*it);
    }
    for (auto it : obj.add) {
      if (!add.count(it)) sub.insert(it);
      else add.erase(it);
    }
    return *this;
  }
}eg[MXN*MXN],prv[MXN],EDGE_INF(-1,-1,INF);
int N,M;
int cid,incyc[MXN],contracted[MXN];
vector<int> E[MXN];

edge_t dmst(int rt){
  edge_t cost;
  for (int i=0; i<N; i++){
    contracted[i] = incyc[i] = 0;
    prv[i] = EDGE_INF;
  }
  cid = 0;
  int u,v;
  while (true){
    for (v=0; v<N; v++){
      if (v != rt && !contracted[v] && prv[
          v].w == INF) break;
    }
    if (v >= N) break; // end
    for (int i=0; i<M; i++){
      if (eg[i].v == v && eg[i].w < prv[v].
          w)
        prv[v] = eg[i];
    }
    if (prv[v].w == INF) // not connected
      return EDGE_INF;
    cost += prv[v];
    for (u=prv[v].u; u!=v && u!=-1; u=prv[u
        ].u);
    if (u == -1) continue;
    incyc[v] = ++cid;
    for (u=prv[v].u; u!=v; u=prv[u].u){
      contracted[u] = 1;
      incyc[u] = cid;
    }
    for (int i=0; i<M; i++){
      if (incyc[eg[i].u] != cid && incyc[eg
          [i].v] == cid){
        eg[i] -= prv[eg[i].v];
      }
    }
    for (int i=0; i<M; i++){
      if (incyc[eg[i].u] == cid) eg[i].u =
          v;
      if (incyc[eg[i].v] == cid) eg[i].v =
          v;
      if (eg[i].u == eg[i].v) eg[i--] = eg
          [--M];
    }
    for (int i=0; i<N; i++){
      if (contracted[i]) continue;
      if (prv[i].u>=0 && incyc[prv[i].u] ==
           cid)
        prv[i].u = v;
    }
    prv[v] = EDGE_INF;
  }
  return cost;
}

void solve(){
  edge_t cost = dmst(0);
  for (auto it : cost.add){ // find a
      solution
    E[it.F].PB(it.S);
    prv[it.S] = edge_t(it.F,it.S,0);
  }
}
```

5.10 Them.

1. Max (vertex) independent set = Max clique on Complement graph
2. Min vertex cover = |V| - Max independent set
3. On bipartite: Min vertex cover = Max Matching(edge independent)
4. Any graph with no isolated vertices: Min edge cover + Max Matching = |V|

6 data structure

6.1 Treap

```
const int N = ;
struct Treap {
  static Treap mem[N], *pmem;
  int sz, pri;
  ll val, sum, add;
  Treap *l, *r;
  Treap() {}
  Treap(ll _val):
    l(NULL), r(NULL), sz(1), pri(rand()),
        val(_val), sum(_val), add(0) {}
} Treap::mem[N], *Treap::pmem = Treap::mem;
Treap* make(ll val) {
  return new (Treap::pmem++) Treap(val);
}
inline int sz(Treap *t) {
  return t ? t->sz : 0;
}
inline ll sum(Treap *t) {
  return t ? t->sum + t->add * sz(t) : 0;
}
inline void add(Treap *t, ll x) {
  t->add += x;
}
void push(Treap *t) {
  t->val += t->add;
  if(t->l)  t->l->add += t->add;
  if(t->r)  t->r->add += t->add;
  t->add = 0;
}
void pull(Treap *t) {
  t->sum = sum(t->l) + sum(t->r) + t->val;
  t->sz = sz(t->l) + sz(t->r) + 1;
}
```

```
Treap* merge(Treap *a, Treap *b) {
  if(!a || !b)  return a ? a : b;
  else if(a->pri > b->pri) {
    push(a);
    a->r = merge(a->r, b);
    pull(a);
    return a;
  }
  else {
    push(b);
    b->l = merge(a, b->l);
    pull(b);
    return b;
  }
}
void split(Treap* t, int k, Treap *&a,
    Treap *&b) {
  if(!t)  a = b = NULL;
  else if(sz(t->l) < k) {
    a = t;
    push(a);
    split(t->r, k - sz(t->l) - 1, a->r, b);
    pull(a);
  }
  else {
    b = t;
    push(b);
    split(t->l, k, a, b->l);
    pull(b);
  }
}
```

6.2 copy on write treap

```
#include <cstdlib>
#include <cstdio>
#include <algorithm>
#include <climits>
#include <cstring>

using namespace std;

const int N = 1000000 + 10;

struct Treap {
    char val;
    int sz, refs;
    Treap *l, *r;

    Treap() {}
    Treap(char _val):
        val(_val), sz(1), refs(0), l(NULL),
            r(NULL) {}
};

Treap* make(Treap* t) {
    return new Treap(*t);
}

Treap* make(char _val) {
    return new Treap(_val);
}

void print_ref(Treap* t) {
    if(!t)  return ;
    print_ref(t->l);
    printf("%d ", t->refs);
    print_ref(t->r);
}

void print(Treap* t) {
    if(!t)  return ;
    print(t->l);
    putchar(t->val);
    print(t->r);
}

void takeRef(Treap* t) {
    if(t)   t->refs++;
}

void dropRef(Treap* t) {
    if(t) {
        char c = t->val;
        t->refs--;
        if(t->refs <= 0) {
            dropRef(t->l);
            dropRef(t->r);
            delete t;
        }
    }
}

int sz(Treap* t) {
    return t ? t->sz : 0;
}

int rnd(int m) {
    static int x = 851025;
    return (x = (x*0xdefaced+1) & INT_MAX)
       % m;
}

void pull(Treap* t) {
    t->sz = sz(t->l) + sz(t->r) + 1;
}

Treap* merge(Treap* a, Treap* b) {
    if(!a || !b) {
        Treap* t = a ? make(a) : make(b);
        t->refs = 0;
        takeRef(t->l);
        takeRef(t->r);
        return t;
    }

    Treap* t;
    if( rnd(a->sz+b->sz) < a->sz) {
        t = make(a);
        t->refs = 0;
        t->r = merge(a->r, b);
        takeRef(t->l);
        takeRef(t->r);
    }
    else {
        t = make(b);
        t->refs = 0;
        t->l = merge(a, b->l);
```

```
        takeRef(t->l);
        takeRef(t->r);
    }

    pull(t);
    return t;
}

void split(Treap* t, int k, Treap* &a, Treap* &b) {
    if(!t)  a = b = NULL;
    else if(sz(t->l) < k) {
        a = make(t);
        a->refs = 0;
        split(a->r, k-sz(t->l)-1, a->r, b);
        takeRef(a->l);
        takeRef(a->r);
        pull(a);
    }
    else {
        b = make(t);
        b->refs = 0;
        split(b->l, k, a, b->l);
        takeRef(b->l);
        takeRef(b->r);
        pull(b);
    }
}

void print_inorder(Treap* t) {
    if(!t)  return ;
    putchar(t->val);
    print_inorder(t->l);
    print_inorder(t->r);
}

char s[N];

int main() {
    int m;
    scanf("%d", &m);
    scanf("%s", s);
    int n = strlen(s);
    int q;
    scanf("%d", &q);

    Treap* t = NULL;
    for(int i = 0; i < n; i++) {
        Treap *a = t, *b = make(s[i]);
        t = merge(a, b);
        dropRef(a);
        dropRef(b);
    }

    while(q--) {
        int l, r, x;
        scanf("%d%d%d", &l, &r, &x);
        r++;

        Treap *a, *b, *c, *d;
        a = b = c = d = NULL;
        split(t, l, a, b);    dropRef(a);
        split(b, r-l, c, d);  dropRef(b);
            dropRef(d);
        split(t, x, a, b);    dropRef(t);

        Treap* t2 = merge(c, b);  dropRef(b); dropRef(c);

    t = merge(a, t2); dropRef(a); dropRef(t2);
        if(t->sz > m) {
            Treap* t2 = NULL;
            split(t, m, t2, a);   dropRef(a); dropRef(t);
            t = t2;
        }
    }

    print(t);
    putchar('\n');

    return 0;
}
```

6.3 copy on write segment tree

```
const int N = ;
const int Q = ;
struct Seg {
  static Seg mem[N*80], *pmem;
  int val;
  Seg *tl, *tr;
  Seg() :
    tl(NULL), tr(NULL), val(0) {}
  Seg* init(int l, int r) {
    Seg* t = new (pmem++) Seg();
    if(l != r) {
      int m = (l+r)/2;
      t->tl = init(l, m);
      t->tr = init(m+1, r);
    }
    return t;
  }
  Seg* add(int k, int l, int r) {
    Seg* _t = new (pmem++) Seg(*this);
    if(l==r) {
      _t->val++;
      return _t;
    }
    int m = (l+r)/2;
    if(k <= m)  _t->tl = tl->add(k, l, m);
    else    _t->tr = tr->add(k, m+1, r);
    _t->val = _t->tl->val + _t->tr->val;
    return _t;
  }
} Seg::mem[N*80], *Seg::pmem = mem;

int query(Seg* ta, Seg* tb, int k, int l, int r) {
  if(l == r)  return l;
  int m = (l+r)/2;
  int a = ta->tl->val;
  int b = tb->tl->val;
  if(b-a >= k)  return query(ta->tl, tb->tl, k, l, m);
  else      return query(ta->tr, tb->tr, k-(b-a), m+1, r);
```

```
};
```

6.4 Treap+(HOJ 92)

```
const int INF = 103456789;
struct Treap {
    int pri, sz, val, chg, rev, sum, lsum, rsum, mx_sum;
    Treap *l, *r;

    Treap() {}
    Treap(int _val) :
        pri(rand()), sz(1), val(_val), chg(INF), rev(0), sum(_val), lsum(_val), rsum(_val), mx_sum(_val), l(NULL), r(NULL) {}
};
int sz(Treap* t) {return t ? t->sz : 0;}
int sum(Treap* t) {
    if(!t)  return 0;
    if(t->chg == INF)   return t->sum;
    else    return t->chg*t->sz;
}
int lsum(Treap* t) {
    if(!t)  return -INF;
    if(t->chg != INF)   return max(t->chg, (t->chg)*(t->sz));
    if(t->rev)  return t->rsum;
    return t->lsum;
}
int rsum(Treap* t) {
    if(!t)  return -INF;
    if(t->chg != INF)   return max(t->chg, (t->chg)*(t->sz));
    if(t->rev)  return t->lsum;
    return t->rsum;
}
int mx_sum(Treap* t) {
    if(!t)  return -INF;
    if(t->chg != INF)   return max(t->chg, (t->chg)*(t->sz));
    return t->mx_sum;
}
void push(Treap* t) {
    if(t->chg != INF) {
        t->val = t->chg;
        t->sum = (t->sz) * (t->chg);
        t->lsum = t->rsum = t->mx_sum = max(t->sum, t->val);
        if(t->l)    t->l->chg = t->chg;
        if(t->r)    t->r->chg = t->chg;
        t->chg = INF;
    }
    if(t->rev) {
        swap(t->l, t->r);
        if(t->l)    t->l->rev ^= 1;
        if(t->r)    t->r->rev ^= 1;
        t->rev = 0;
    }
}
void pull(Treap* t) {
    t->sz = sz(t->l)+sz(t->r)+1;
    t->sum = sum(t->l)+sum(t->r)+t->val;
    t->lsum = max(lsum(t->l), sum(t->l)+max(0, lsum(t->r))+t->val);
    t->rsum = max(rsum(t->r), sum(t->r)+max(0, rsum(t->l))+t->val);
    t->mx_sum = max(max(mx_sum(t->l), mx_sum(t->r)), max(0, rsum(t->l))+max(0, lsum(t->r))+t->val);
}
Treap* merge(Treap* a, Treap* b) {
    if(!a || !b)    return a ? a : b;
    if(a->pri > b->pri) {
        push(a);
        a->r = merge(a->r, b);
        pull(a);
        return a;
    }
    else {
        push(b);
        b->l = merge(a, b->l);
        pull(b);
        return b;
    }
}
void split(Treap* t, int k, Treap* &a, Treap* &b) {
    if(!t) {
        a = b = NULL;
        return ;
    }
    push(t);
    if(sz(t->l) < k) {
        a = t;
        push(a);
        split(t->r, k-sz(t->l)-1, a->r, b);
        pull(a);
    }
    else {
        b = t;
        push(b);
        split(t->l, k, a, b->l);
        pull(b);
    }
}
void del(Treap* t) {
    if(!t)  return;
    del(t->l);
    del(t->r);
    delete t;
}
```

6.5 Leftist Tree

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

struct Left {
  Left *l,*r;
  int v,h;
  Left(int v_) : v(v_), h(1), l(0), r(0) {}
};

int height(Left *p) { return p ? p -> h : 0 ; }
```

```

Left* combine(Left *a,Left *b) {
  if(!a || !b) return a ? a : b ;
  Left *p ;
  if( a->v > b->v) {
    p = a;
    p -> r = combine( p -> r , b );
  }
  else {
    p = b;
    p -> r = combine( p -> r , a );
  }
  if( height( p->l ) < height( p->r ) )
    swap( p->l , p->r );
  p->h = min( height( p->l ) , height( p->r ) ) + 1;
  return p;
}
Left *root;

void push(int v) {
  Left *p = new Left(v);
  root = combine( root , p );
}
int top() { return root? root->v : -1; }
void pop() {
  if(!root) return;
  Left *a = root->l , *b = root->r ;
  delete root;
  root = combine( a , b );
}
void clear(Left* &p) {
  if(!p)
    return;
  if(p->l) clear(p->l);
  if(p->r) clear(p->r);
  delete p;
  p = 0 ;
}

int main() {
  while (T--) {
    clear(root);
    /** do something **/
  }
  return 0;
}
```

6.6 Link Cut Tree

```
const int MAXN = ;
struct SplayTree {
  int val, mx, ch[2], pa;
  bool rev;
  void init() {
    val = mx = -1;
    rev = false;
    pa = ch[0] = ch[1] = 0;
  }
} node[MAXN*2];
inline bool isroot(int x) {
  return node[node[x].pa].ch[0]!=x && node[node[x].pa].ch[1]!=x;
}
inline void pull(int x) {
  node[x].mx = max(node[x].val, max(node[node[x].ch[0]].mx, node[node[x].ch[1]].mx));
}
inline void push(int x) {
  if(node[x].rev) {
    node[node[x].ch[0]].rev ^= 1;
    node[node[x].ch[1]].rev ^= 1;
    swap(node[x].ch[0], node[x].ch[1]);
    node[x].rev ^= 1;
  }
}
void push_all(int x) {
  if(!isroot(x))  push_all(node[x].pa);
  push(x);
}
inline void rotate(int x) {
  int y = node[x].pa, z = node[y].pa, d = node[y].ch[1]==x;
  node[x].pa = z;
  if(!isroot(y))  node[z].ch[node[z].ch[1]==y] = x;
  node[y].ch[d] = node[x].ch[d^1];
  node[node[x].ch[d^1]].pa = y;
  node[x].ch[!d] = y;
  node[y].pa = x;
  pull(y);
  pull(x);
}
void splay(int x) {
  push_all(x);
  while(!isroot(x)) {
    int y = node[x].pa;
    if(!isroot(y)) {
      int z = node[y].pa;
      if((node[z].ch[1]==y) ^ (node[y].ch[1]==x)) rotate(y);
      else  rotate(x);
    }
    rotate(x);
  }
}
inline int access(int x) {
  int last = 0;
  while(x) {
    splay(x);
    node[x].ch[1] = last;
    pull(x);
    last = x;
    x = node[x].pa;
  }
  return last;
}
inline void make_root(int x) {
  node[access(x)].rev ^= 1;
  splay(x);
}
inline void link(int x, int y) {
  make_root(x);
  node[x].pa = y;
}
inline void cut(int x, int y) {
  make_root(x);
```

```
  access(y);
  splay(y);
  node[y].ch[0] = 0;
  node[x].pa = 0;
}
inline void cut_parent(int x) {
  x = access(x);
  splay(x);
  node[node[x].ch[0]].pa = 0;
  node[x].ch[0] = 0;
  pull(x);
}
inline int find_root(int x) {
  x = access(x);
  while(node[x].ch[0])  x = node[x].ch[0];
  splay(x);
  return x;
}
int find_mx(int x) {
  if(node[x].val == node[x].mx) return x;
  return node[node[x].ch[0]].mx==node[x].mx
      ? find_mx(node[x].ch[0]) : find_mx(
     node[x].ch[1]);
}
inline void change(int x,int b){
    splay(x);
    node[x].data=b;
    up(x);
}
inline int query_lca(int u,int v){
/*retrun: sum of weight of vertices on the
   chain (u->v)
sum: total weight of the subtree
data: weight of the vertex */
  access(u);
  int lca=access(v);
  splay(u);
  if(u==lca){
    return node[lca].data+node[node[lca].ch
       [1]].sum;
  }else{
    return node[lca].data+node[node[lca].ch
       [1]].sum+node[u].sum;
  }
}
```

6.7 Heavy Light Decomposition

```
const int MAXN = 10000 + 10;
vector<PII> e[MAXN];
int val[MAXN];
int sz[MAXN], max_son[MAXN], p[MAXN], dep[
   MAXN];
int link[MAXN], link_top[MAXN], cnt;
void find_max_son(int u) {
  sz[u] = 1;
  max_son[u] = -1;
  for(int i=0; i<SZ(e[u]); i++) {
    PII tmp = e[u][i];
    int v = tmp.F;
    if(v == p[u]) continue;

    p[v] = u;
    dep[v] = dep[u]+1;
    val[v] = tmp.S;
    find_max_son(v);
    if(max_son[u]<0 || sz[v]>sz[ max_son[u]
       ])  max_son[u] = v;
    sz[u] += sz[v];
  }
}
void build_link(int u, int top) {
  link[u] = ++cnt;
  link_top[u] = top;
  if(max_son[u] > 0)  build_link(max_son[u
     ], top);
  for(int i=0; i<SZ(e[u]); i++) {
    PII tmp = e[u][i];
    int v = tmp.F;
    if(v==p[u] || v==max_son[u])  continue;
    build_link(v, v);
  }
}
int query(int a, int b) {
  int res = -1;
  int ta = link_top[a], tb = link_top[b];
  while(ta != tb) {
    if(dep[ta] < dep[tb]) {
      swap(a, b);
      swap(ta, tb);
    }
    res = max(res, seg->qry(link[ta], link[
       a], 1, cnt));
    ta = link_top[a=p[ta]];
  }
  if(a != b) {
    if(dep[a] > dep[b]) swap(a, b);
    a = max_son[a];
    res = max(res, seg->qry(link[a], link[b
       ], 1, cnt));
  }
  return res;
}
```

6.8 Disjoint Sets + offline skill

```
const int MAXN = ;
bool q[MAXN];
struct DisJointSet {
  int p[MAXN], sz[MAXN], gps;
  vector<pair<int*, int> > h;
  VI sf;
  void init(int n) {
    for(int i=1; i<=n; i++) {
      p[i] = i;
      sz[i] = 1;
    }
    gps = n;
  }
  void assign(int *k, int v) {
    h.PB(MP(k, *k));
    *k = v;
  }
  void save() {
    sf.PB(SZ(h));
  }
```

```
  void load() {
    int last = sf.back(); sf.pop_back();
    while(SZ(h) != last) {
      auto x = h.back();  h.pop_back();
      *x.F = x.S;
    }
  }
  int find(int x) {
    return x==p[x] ? x : find(p[x]);
  }
  void uni(int x, int y) {
    x = find(x), y = find(y);
    if(x == y)  return ;
    if(sz[x] < sz[y]) swap(x, y);
    assign(&sz[x], sz[x]+sz[y]);
    assign(&p[y], x);
    assign(&gps, gps-1);
  }
} djs;
struct Seg {
  vector<PII> es;
  Seg *tl, *tr;
  Seg() {}
  Seg(int l, int r) {
    if(l == r)  tl = tr = NULL;
    else {
      int m = (l+r) / 2;
      tl = new Seg(l, m);
      tr = new Seg(m+1, r);
    }
  }
  // add an edge e from time a to time b
  void add(int a, int b, PII e, int l, int
      r) {
    if(a <= l && r <= b)  es.PB(e);
    else if(b < l || r < a) return ;
    else {
      int m = (l+r) / 2;
      tl->add(a, b, e, l, m);
      tr->add(a, b, e, m+1, r);
    }
  }
  void solve(int l, int r) {
    djs.save();
    for(auto p : es)  djs.uni(p.F, p.S);
    if(l == r) {
      if(q[l]); // answer the query here
    }
    else {
      int m = (l+r) / 2;
      tl->solve(l, m);
      tr->solve(m+1, r);
    }
    djs.load();
  }
};
```

6.9 2D Segment Tree

```
struct Seg1D {
  Seg1D *tl, *tr;
  ll val;
  // ll tmp;
  //int _x, _y;
  Seg1D() :
    tl(NULL), tr(NULL), val(0), tmp(-1), _x
        (-1), _y(-1) {}
  ll query1D(int x1, int x2, int y1, int y2
      , int l, int r) {
    /*
    if no Brian improvement, dont need to
       pass x1 and x2
    if(tmp >= 0) {
      if(x1<=_x&&_x<=x2 && y1<=_y&&_y<=y2)
          return tmp;
      else  return 0;
    }
    */
    if(y1 <= l && r <= y2)  return val;
    else if(r < y1 || y2 < l) return 0;
    else {
      int m = (l+r)/2;
      ll a = tl ? tl->query1D(x1, x2, y1,
          y2, l, m) : 0,
         b = tr ? tr->query1D(x1, x2, y1,
            y2, m+1, r) : 0;
      return gcd(a, b);
    }
  }
  void update1D(int x, int y, ll num, int l
      , int r) {
    if(l == r) {
      val = num;
      return ;
    }
    /*
    if(tmp < 0 && !tl && !tr) {
      tmp = val = num;
      _x = x;
      _y = y;
      return ;
    }
    else if(tmp >= 0) {
      int m = (l+r)/2;
      if(_y <= m) {
        if(!tl) tl = new Seg1D();
        tl->update1D(_x, _y, tmp, l, m);
      }
      else {
        if(!tr) tr = new Seg1D();
        tr->update1D(_x, _y, tmp, m+1, r);
      }
      tmp = _x = _y = -1;
    }*/
    int m = (l+r)/2;
    if(y <= m) {
      if(!tl) tl = new Seg1D();
      tl->update1D(x, y, num, l, m);
    }
    else {
      if(!tr) tr = new Seg1D();
      tr->update1D(x, y, num, m+1, r);
    }
    ll a = tl ? tl->val : 0;
    ll b = tr ? tr->val : 0;
    val = gcd(a, b);
  }
};
```

```
struct Seg2D {
  Seg2D *tl, *tr;
  Seg1D *t2;
  Seg2D() :
    tl(NULL), tr(NULL), t2(NULL) {}
  ll query2D(int x1, int x2, int y1, int y2
      , int l, int r) {
    if(x1 <= l && r <= x2) {
      if(!t2) t2 = new Seg1D();
      return t2->query1D(x1, x2, y1, y2, 0,
          C-1);
    }
    else if(x2 < l || r < x1) return 0;
    else {
      int m = (l+r)/2;
      ll a = tl ? tl->query2D(x1, x2, y1,
          y2, l, m) : 0,
         b = tr ? tr->query2D(x1, x2, y1,
             y2, m+1, r) : 0;
      return gcd(a, b);
    }
  }
  void update2D(int x, int y, ll num, int l
      , int r) {
    int m = (l+r)/2;
    if(l == r) {
      if(!t2) t2 = new Seg1D();
      t2->update1D(x, y, num, 0, C-1);
      return ;
    }
    if(x <= m) {
      if(!tl) tl = new Seg2D();
      tl->update2D(x, y, num, l, m);
    }
    else {
      if(!tr) tr = new Seg2D();
      tr->update2D(x, y, num, m+1, r);
    }
    if(!tl) tl = new Seg2D();
    if(!tr) tr = new Seg2D();
    ll a = tl->t2 ? tl->t2->query1D(l, m, y
        , y, 0, C-1) : 0,
       b = tr->t2 ? tr->t2->query1D(m+1, r,
           y, y, 0, C-1) : 0;
    if(!t2) t2 = new Seg1D();
    t2->update1D(x, y, gcd(a, b), 0, C-1);
  }
};
```

7 geometry

7.1 Basic

```
typedef double tp;
typedef double db;

const db PI = acos(-1.0);
const tp INF = 1e18;
const tp EPS = 1e-9;

bool eq(tp a, tp b) { return a-b<=EPS && b-
    a<=EPS; }
bool lt(tp a, tp b) { return a < b-EPS; }
bool le(tp a, tp b) { return !lt(b, a); }
bool gt(tp a, tp b) { return lt(b, a); }
bool ge(tp a, tp b) { return !lt(a, b); }

struct coor {
  tp x, y, z;
  coor(tp _x=0, tp _y=0, tp _z=0): x(_x), y
      (_y), z(_z) {}
  coor operator+(const coor p) const {
      return coor(x+p.x, y+p.y, z+p.z); }
  coor operator-(const coor p) const {
      return coor(x-p.x, y-p.y, z-p.z); }
  coor operator*(const tp a) const { return
       coor(x*a, y*a, z*a); }
  coor operator/(const tp a) const { return
       coor(x/a, y/a, z/a); }
  tp operator*(const coor p) const { return
       x*p.x + y*p.y + z*p.z; }
  db atan() const {
    db ret = atan2(y, x);
    if(ret<0) ret += 2*PI;
    return ret;
  }
  bool operator==(const coor p) const {
      return eq(x, p.x) && eq(y, p.y) && eq(
      z, p.z); }
  void input() { cin >> x >> y; }
  // 2D only
  tp operator%(const coor p) const { return
       x*p.y - y*p.x; }
  bool operator<(const coor p) const {
    if(x != p.x)  return x<p.x;
    if(y != p.y)  return y<p.y;
    return z<p.z;
  }
};
tp abs2(const coor a) { return a.x*a.x+a.y*
    a.y+a.z*a.z; }
db abs(const coor a) { return sqrt(abs2(a))
    ; }
coor perp(const coor p) { return coor(-p.y,
     p.x); } // +0.5pi

bool polar(const coor a, const coor b) {
  // integral
  if(a.y*b.y<0)     return a.y>0;
  if(b.y==0 and b.x>0)  return false;
  if(a.y==0 and a.x>0)  return true;
  return a%b>0;
  //floating
  return a.atan() < b.atan();
}
```

7.2 CircleCover

```
#define N 1021

struct Circ {
  coor O;
  db R;
  Circ(coor _o=0, db _r=0): O(_o), R(_r) {}
};
```

```
8
9  struct CircleCover{
10   int C; Circ c[ N ];
11   bool g[ N ][ N ], overlap[ N ][ N ];
12   // Area[i] : area covered by at least i
       circles
13   db Area[ N ];
14   void init( int _C ){ C = _C; }
15   bool CCinter( Circ& a , Circ& b , coor&
       p1 , coor& p2 ){
16     coor o1 = a.O , o2 = b.O;
17     db r1 = a.R , r2 = b.R;
18     tp d2 = abs2(o1-o2);
19     db d = abs(o1-o2);
20     if( d > r1 + r2 ) return false;
21     if( d < max(r1, r2) - min(r1, r2) )
         return false;
22     //if( d > r1 + r2 ) return false;
23     coor u=(o1+o2)*0.5 + (o1-o2)*((r2*r2-r1
         *r1)/(2*d2));
24     db A=sqrt((r1+r2+d)*(r1-r2+d)*(r1+r2-d)
         *(-r1+r2+d));
25     coor v=coor( o1.y-o2.y , -o1.x + o2.x )
          * A / (2*d2);
26     p1 = u + v; p2 = u - v;
27     return true;
28   }
29   struct Teve {
30     coor p; db ang; int add;
31     Teve() {}
32     Teve(coor _a, db _b, int _c):p(_a), ang
         (_b), add(_c){}
33     bool operator<(const Teve &a)const
34     {return ang < a.ang;}
35   }eve[ N * 2 ];
36   int sign(db x) {
37     return x < 0 ? -1 : x > 0;
38   }
39   // strict: x = 0, otherwise x = -1
40   bool disjuct( Circ& a, Circ &b, int x )
41   {return sign( abs( a.O - b.O ) - a.R - b.
       R ) > x;}
42   bool contain( Circ& a, Circ &b, int x )
43   {return sign( a.R - b.R - abs( a.O - b.O
       ) ) > x;}
44   bool contain(int i, int j){
45     /* c[j] is non-strictly in c[i]. */
46     return (sign(c[i].R - c[j].R) > 0 ||
47         (sign(c[i].R - c[j].R) == 0 && i <
            j) ) && contain(c[i], c[j], -1);
48   }
49   void solve(){
50     for( int i = 0 ; i <= C + 1 ; i ++ )
51       Area[ i ] = 0;
52     for( int i = 0 ; i < C ; i ++ )
53       for( int j = 0 ; j < C ; j ++ )
54         overlap[i][j] = contain(i, j);
55     for( int i = 0 ; i < C ; i ++ )
56       for( int j = 0 ; j < C ; j ++ )
57         g[i][j] = !(overlap[i][j] ||
              overlap[j][i] ||
58             disjuct(c[i], c[j], -1));
59     for( int i = 0 ; i < C ; i ++ ){
60       int E = 0, cnt = 1;
61       for( int j = 0 ; j < C ; j ++ )
62         if( j != i && overlap[j][i] )
63           cnt ++;
64       for( int j = 0 ; j < C ; j ++ )
65         if( i != j && g[i][j] ){
66           coor aa, bb;
67           CCinter(c[i], c[j], aa, bb);
68           db A=atan2(aa.y - c[i].O.y, aa.x
               - c[i].O.x);
69           db B=atan2(bb.y - c[i].O.y, bb.x
               - c[i].O.x);
70           eve[E ++] = Teve(bb, B, 1);
71           eve[E ++] = Teve(aa, A, -1);
72           if(B > A) cnt ++;
73         }
74       if( E == 0 ) Area[ cnt ] += PI * c[i
           ].R * c[i].R;
75       else{
76         sort( eve , eve + E );
77         eve[E] = eve[0];
78         for( int j = 0 ; j < E ; j ++ ){
79           cnt += eve[j].add;
80           Area[cnt] += (eve[j].p % eve[j +
               1].p) * .5;
81           db theta = eve[j + 1].ang - eve[j
               ].ang;
82           if (theta < 0) theta += 2. * PI;
83           Area[cnt] +=
84             (theta - sin(theta)) * c[i].R*c
                 [i].R * .5;
85         }
86       }
87     }
88   }
89 } oracle;
```

7.3 ConvexHull

```
1  typedef vector<coor> VP;
2
3  // Convex Hull
4  // keep redundant points or not
5  VP CH(VP arr, bool keep=false) {
6    sort(ALL(arr));
7    VP upper, lower;
8    for(int i=0; i<SZ(arr); i++) {
9      if(i>0 and arr[i] == arr[i-1])
10       continue;
11     coor c = arr[i];
12     while(SZ(upper)>=2) {
13       int last = SZ(upper)-1;
14       coor a = upper[last-1], b=upper[last
           ];
15       if(lt((c-a)%(b-a), 0) or (!keep and
           le((c-a)%(b-a), 0)))
16         upper.pop_back();
17       else
18         break;
19     }
20     upper.PB(c);
21     while(SZ(lower)>=2) {
22       int last = SZ(lower)-1;
23       coor a = lower[last-1], b=lower[last
           ];
```

```
      if(gt((c-a)%(b-a), 0) or (!keep and
         ge((c-a)%(b-a), 0)))
        lower.pop_back();
      else
        break;
    }
    lower.PB(c);
  }
  for(int i=SZ(upper)-2; i>0; i--)
    lower.PB(upper[i]);
  return lower;
}
```

7.4 HalfPlaneNSquare

```
typedef vector<coor> poly;
void cut(poly &tar, const coor vec, const
    db c) {
  poly tmp;
  coor st = tar[0];
  tar.PB(st);
  for(int k = 1; k < SZ(tar); k++) {
    coor ed = tar[k];
    db a = st*vec, b = ed*vec;
    coor v2 = st * ((b-c)/(b-a)) + ed * ((c
        -a)/(b-a));

    if(le(a, c))
      tmp.PB(st);
    if((lt(a, c) and gt(b, c)) || (gt(a, c)
        and lt(b, c)))
      tmp.PB(v2);
    st = ed;
  }
  tar.clear();
  for(int i=0; i<SZ(tmp); i++)
    tar.PB(tmp[i]);
}

void polyIntersect(poly &P, const poly &Q)
    {
  for(int i=0; i<SZ(Q); i++) {
    coor v = perp(Q[(i+1)%SZ(Q)]-Q[i])*(-1)
        ;
    v = v/abs(v);
    cut(P, v, v*Q[i]);
  }
}
```

7.5 LineIntersection

```
coor line_inter(const coor p1, const coor
    v1, const coor p2, const coor v2) {
  if(eq(v1%v2, 0.0))
    return coor(INF, INF);
  db k = ((p2-p1)%v2) / (v1%v2);
  return p1 + v1*k;
}
```

7.6 OldCircleInter

```
void CircleInter(coor o1, db r1, coor o2,
    db r2) {
  if(r2>r1)
    swap(r1, r2), swap(o1, o2);
  db d = (o2-o1).abs();
  coor v = o2-o1;
  v = v / v.abs();
  coor t = coor(v.y, -v.x);

  db area;
  vector<coor> pts;
  if(d > r1+r2+EPS)
    area = 0;
  else if(d < r1-r2)
    area = r2*r2*PI;
  else if(r2*r2+d*d > r1*r1){
    db x = (r1*r1 - r2*r2 + d*d) / (2*d);
    db th1 = 2*acos(x/r1), th2 = 2*acos((d-
        x)/r2);
    area = (r1*r1*(th1 - sin(th1)) + r2*r2
        *(th2 - sin(th2))) / 2;
    db y = sqrt(r1*r1 - x*x);
    pts.PB(o1 + v*x + t*y), pts.PB(o1 + v*x
        - t*y);
  } else {
    db x = (r1*r1 - r2*r2 - d*d) / (2*d);
    db th1 = acos((d+x)/r1), th2 = acos(x/
        r2);
    area = r1*r1*th1 - r1*d*sin(th1) + r2*
        r2*(PI-th2);
    db y = sqrt(r2*r2 - x*x);
    pts.PB(o2 + v*x + t*y), pts.PB(o2 + v*x
        - t*y);
  }
  //Area: area
  //Intersections: pts
}
```

7.7 PolyCircleIntersect

```
// Divides into multiple triangle, and sum
    up
// oriented area
int sign(db x) { return x < 0 ? -1 : x > 0;
    }
db area2(coor pa, coor pb, db r){
  if( abs(pa) < abs(pb) ) swap(pa, pb);
  if( abs(pb) < EPS ) return 0;
  db S, h, theta;
  db a = abs( pb ), b = abs( pa ), c = abs(
      pb - pa);
  db cosB = (pb * (pb - pa)) / a / c, B =
      acos(cosB);
  db cosC = (pa * pb) / a / b, C = acos(
      cosC);
  if(a > r){
    S = (C/2)*r*r;
    h = a*b*sin(C)/c;
    if (h < r && B < PI/2) S -= (acos(h/r)*
        r*r - h*sqrt(r*r-h*h));
  }else if(b > r){
```

```
    theta = PI - B - asin(sin(B)/r*a);
    S = .5*a*r*sin(theta) + (C-theta)/2*r*r;
  }else S = .5*sin(C)*a*b;
  return S;
}
db area(coor ori, db r, const poly &P) {
  db S = 0;
  int n = SZ(P);
  for(int i = 0; i < n; ++i) {
    coor v1=P[i]-ori, v2=P[(i+1)%n]-ori;
    S += area2(v1, v2, r) * sign(v1%v2);
  }
  return fabs(S);
}
```

7.8 SegmentIntersection

```
int ori(const coor o, const coor a, const coor b) {
  tp val = (a-o)%(b-o);
  return gt(val, 0) - lt(val, 0);
}
bool SegmentIntersect(const coor p1, const coor p2, const coor q1, const coor q2) {
  if( eq((p2-p1)%(q2-q1), 0) ) {
    if( ori(p1, p2, q1) ) return false;
    return le( ( p1 - q1 ) * ( p2 - q1 ), 0) ||
           le( ( p1 - q2 ) * ( p2 - q2 ), 0) ||
           le( ( q1 - p1 ) * ( q2 - p1 ), 0) ||
           le( ( q1 - p2 ) * ( q2 - p2 ), 0);
  }
  return (ori( p1, p2, q1 ) * ori( p1, p2, q2 ) <= 0) &&
         (ori( q1, q2, p1 ) * ori( q1, q2, p2 ) <= 0);
}
```

7.9 Triangulation

```
typedef vector<coor> poly;
const int N = 105;

bool inside(const coor pnt, const poly &P) {
  int n = SZ(P);
  for(int i=0; i<n; i++) {
    coor p1=P[i], p2=P[(i+1)%n];
    if(lt((p1-pnt) % (p2-pnt), 0))
      return false;
  }
  return true;
}

int prv[N], nxt[N];
bool isear(int x, const poly &P) {
  int n = SZ(P);
  int x1 = nxt[x], x2=prv[x];
  coor v=P[x], v1=P[x1], v2=P[x2];
  if(le((v1-v)%(v2-v), 0))  return false;
  poly cand;
  cand.PB(v), cand.PB(v1), cand.PB(v2);
  for(int j=0; j<n; j++) {
    if(j==x or j==x1 or j==x2)  continue;
    if(inside(P[j], cand))
      return false;
  }
  return true;
}

vector<poly> triangulation(const poly &P) {
  bool used[N]={}, ear[N]={};
  int n = SZ(P);
  for(int i=0; i<n; i++)  prv[i] = (i-1+n)%n, nxt[i] = (i+1)%n;
  queue<int> que;
  for(int i=0; i<n; i++) {
    ear[i] = isear(i, P);
    if(ear[i])  que.push(i);
  }
  vector<poly> ret;
  while(true) {
    assert(!que.empty());
    int head=que.front();
    que.pop();
    if(used[head] or !ear[head])  continue;
    poly trian;
    int x1 = nxt[head], x2 = prv[head];
    trian.PB(P[head]), trian.PB(P[x1]), trian.PB(P[x2]);
    ret.PB(trian);
    used[head]=true;
    nxt[x2] = x1, prv[x1] = x2;
    if(prv[x2] == x1) break;

    ear[x1] = isear(x1, P), ear[x2] = isear(x2, P);
    if(ear[x1]) que.push(x1);
    if(ear[x2]) que.push(x2);
  }
  return ret;
}
```

7.10 Smallest circle problem

```
const int MAXN = ;
struct PT {
  double x, y;
  PT() {}
  PT(double x, double y):
    x(x), y(y) {}
  PT operator+(const PT &b) const {
    return (PT) {x+b.x, y+b.y};
  }
  PT operator-(const PT &b) const {
    return (PT) {x-b.x, y-b.y};
  }
  PT operator*(const double b) const {
    return (PT) {x*b, y*b};
  }
  PT operator/(const double b) const {
```

```
    return (PT) {x/b, y/b};
  }
  double operator%(const PT &b) const {
    return x*b.y - y*b.x;
  }
  double len() const {
    return sqrt(x*x + y*y);
  }
  PT T() const {
    return (PT) {-y, x};
  }
} p[MAXN];
void update(PT a, PT b, PT c, PT &o, double
    &r) {
  if(c.x < 0.0) o = (a+b) / 2.0;
  else {
    PT p1 = (a+b)/2.0, p2 = p1 + (b-a).T();
    PT p3 = (a+c)/2.0, p4 = p3 + (c-a).T();
    double a123 = (p2-p1)%(p3-p1), a124 = (
        p2-p1)%(p4-p1);
    if(a123 * a124 > 0.0) a123 = -a123;
    else  a123 = abs(a123), a124 = abs(a124
        );
    o = (p4*a123 + p3*a124) / (a123 + a124)
        ;
  }
  r = (a-o).len();
}
void solve(PT &o, double &r) {
  random_shuffle(p, p+n);
  PT a = p[0], b = p[1], c(-1.0, -1.0);
  o = (a+b) / 2.0;
  double r = (a-o).len();
  for(int i = 2; i < n; i++) {
    if((p[i]-o).len() <= r) continue;
    a = p[i], b = p[0], c = (PT) {-1.0,
        -1.0};
    update(a, b, c, o, r);
    for(int j = 1; j < i; j++) {
      if((p[j]-o).len() <= r) continue;
      b = p[j], c = (PT) {-1.0, -1.0};
      update(a, b, c, o, r);
      for(int k = 0; k < j; k++) {
        if((p[k]-o).len() <= r) continue;
        c = p[k];
        update(a, b, c, o, r);
      }
    }
  }
}
```

8 Others

8.1 Random

```
const int seed=1;

mt19937 rng(seed);
int randint(int lb,int ub) { // [lb, ub]
  return uniform_int_distribution<int>(lb,
      ub)(rng);
}
```

8.2 Fraction

```
struct Frac {
  ll a,b; //  a/b
  void relax() {
    ll g=__gcd(a,b);
    if(g!=0 && g!=1)
      a/=g, b/=g;
    if(b<0)
      a*=-1, b*=-1;
  }
  Frac(ll a_=0,ll b_=1): a(a_), b(b_) {
    relax();
  }
  Frac operator + (Frac x) {
    relax();
    x.relax();
    ll g=__gcd(b,x.b);
    ll lcm=b/g*x.b;
    return Frac(a*(lcm/b)+x.a*(lcm/x.b),lcm
        );
  }
  Frac operator - (Frac x) {
    relax();
    x.relax();
    Frac t=x;
    t.a*=-1;
    return *this+t;
  }
  Frac operator * (Frac x) {
    relax();
    x.relax();
    return Frac(a*x.a,b*x.b);
  }
  Frac operator / (Frac x) {
    relax();
    x.relax();
    Frac t=Frac(x.b,x.a);
    return (*this)*t;
  }
  bool operator < (Frac x) {
    ll lcm=b/__gcd(b,x.b)*x.b;
    return ( (lcm/b)*a < (lcm/x.b)*x.a );
  }
};
```

8.3 Slope Optimization

```
bool bye(PLL p1, PLL p2, PLL p3) {
    ll a1 = p1.F, b1 = p1.S;
    ll a2 = p2.F, b2 = p2.S;
    ll a3 = p3.F, b3 = p3.S;

    return (a1-a3)*(b2-b1) >= (b3-b1)*(a1-
        a2);
}
/* slope is decreasing */
while(SZ(ch)>=2 && bye(ch[SZ(ch)-2], ch.
    back(), v[i]))  ch.pop_back();
```