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 -std=c++0x<CR>
map <S-F9> <ESC>:w<CR>:!g++ % -o %< -O2 -
    Wall -Wno-unused-result -D_DEBUG_ -std=c
    ++0x<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

```
 1 typedef complex<double> CD;
 2
 3 const double PI=acos(-1.0);
 4 inline CD ang(double t) { return CD(cos(t),
     sin(t)); }
 5
 6 int rev_int(int x,int lgn) {
 7   int re=0;
 8   for(int i=0;i<lgn;i++) {
 9     re=(re<<1)+(x&1);
10     x>>=1;
11   }
12   return re;
13 }
14 void fft(CD* A, int lgn, bool inv=false) {
15   int n=1<<lgn;
16   for(int i=0;i<n;i++)
17     if(i<rev_int(i, lgn)) swap(A[i], A[
        rev_int(i, lgn)]);
18   for(int i=1;i<n;i*=2) {
19     CD W(1.0, 0.0), Wn;
20     if(inv) Wn=ang(-PI/i);
21     else Wn=ang(PI/i);
22     for(int j=0;j<n;j++) {
23       if(j&i) {
24         W=CD(1.0, 0.0);
25         continue;
26       }
27       CD x=A[j], y=A[j+i]*W;
28       A[j]=x+y;
29       A[j+i]=x-y;
30       W*=Wn;
31     }
32   }
33   if(inv)
34     for(int i=0;i<n;i++)
35       A[i]/=n;
36 }
```

2.3 NTT

```
 1 //     MOD      Wn_       LGN
 2 //    5767169    177147 19
 3 //    7340033      2187 20
 4 // 2013265921 440564289 27
 5 const int MOD=786433;
 6 const int Wn_=5; // 25 625
 7 const int LGN=18;// 17  16
 8 inline int add(int x,int y) { return (x+y)%
     MOD; }
 9 inline int mul(int x,int y) { return 1ll*x*
     y%MOD; }
10 inline int sub(int x,int y) { return (x-y+
     MOD)%MOD; }
11
12 int pW[MOD]; // power of Wn
13 int divN;
14 int inv(int a) {
15   int re=1, k=MOD-2, t=a;
16   while(k) {
17     if(k%2) re=mul(re, t);
18     k/=2;
19     t=mul(t, t);
```

```
20   }
21   return re;
22 }
23 void NTTinit(int lgn) { // call every time
     using new lgn !
24   int Wn=Wn_;
25   for(int i=lgn;i<LGN;i++) Wn=mul(Wn,Wn);
26   divN=inv(1<<lgn);
27   pW[0]=1;
28   for(int i=1;;i++) {
29     pW[i]=mul(pW[i-1], Wn);
30     if(pW[i]==1) break;
31   }
32 }
33
34 int rev_int(int x,int lgn) {
35   int re=0;
36   for(int i=0;i<lgn;i++) {
37     re=(re<<1)+(x&1);
38     x>>=1;
39   }
40   return re;
41 }
42 void ntt(int *A,int lgn,bool inv=false) {
43   int n=1<<lgn;
44   for(int i=0;i<n;i++)
45     if(i<rev_int(i,lgn))
46       swap(A[i], A[rev_int(i,lgn)]);
47   for(int i=1;i<n;i*=2) {
48     int W=1, Wn;
49     if(inv) Wn=pW[n-(n/2/i)];
50     else Wn=pW[n/2/i];
51     for(int j=0;j<n;j++) {
52       if(j&i) {
53         W=1;
54         continue;
55       }
56       int x=A[j], y=mul(A[j+i],W);
57       A[j]=add(x,y);
58       A[j+i]=sub(x,y);
59       W=mul(W,Wn);
60     }
61   }
62   if(inv)
63     for(int i=0;i<n;i++)
64       A[i]=mul(A[i],divN);
65 }
```

2.4 MillerRabin other

```
 1 /* Miller Rabin code from ioicamp */
 2 #include <bits/stdc++.h>
 3 #define PB push_back
 4 #define MP make_pair
 5 #define F first
 6 #define S second
 7 #define SZ(x) ((int)(x).size())
 8 #define ALL(x) (x).begin(),(x).end()
 9 #ifdef _DEBUG_
10   #define debug(...) printf(__VA_ARGS__)
11 #else
12   #define debug(...) 0
13 #endif
```

```
14 using namespace std;
15 typedef long long ll;
16 typedef pair<int,int> PII;
17 typedef vector<int> VI;
18
19 ll mul(ll a, ll b, ll n) {
20   ll r = 0;
21   a %= n, b %= n;
22   while(b) {
23     if(b&1) r = (a+r>=n ? a+r-n : a+r);
24     a = (a+a>=n ? a+a-n : a+a);
25     b >>= 1;
26   }
27   return r;
28 }
29
30 ll bigmod(ll a, ll d, ll n) {
31   if(d==0)  return 1LL;
32   if(d==1) return a % n;
33   return mul(bigmod(mul(a, a, n), d/2, n),
         d%2?a:1, n);
34 }
35
36 const bool PRIME = 1, COMPOSITE = 0;
37 bool miller_rabin(ll n, ll a) {
38   if(__gcd(a, n) == n)  return PRIME;
39   if(__gcd(a, n) != 1)  return COMPOSITE;
40   ll d = n-1, r = 0, res;
41   while(d%2==0) { ++r; d/=2; }
42   res = bigmod(a, d, n);
43   if(res == 1 || res == n-1)  return PRIME;
44   while(r--) {
45     res = mul(res, res, n);
46     if(res == n-1)  return PRIME;
47   }
48   return COMPOSITE;
49 }
50
51 bool isprime(ll n) {
52   if(n==1)
53     return COMPOSITE;
54   ll as[7] = {2, 325, 9375, 28178, 450775,
         9780504, 1795265022};
55   for(int i=0; i<7; i++)
56     if(miller_rabin(n, as[i]) == COMPOSITE)
           return COMPOSITE;
57   return PRIME;
58 }
```

2.5 Guass

```
1 // be care of the magic number 7 & 8
2 void guass() {
3   for(int i = 0; i < 7; i++) {
4     Frac tmp = mat[i][i]; // Frac -> the
         type of data
5     for(int j = 0; j < 8; j++)
6       mat[i][j] = mat[i][j] / tmp;
7     for(int j = 0; j < 7; j++) {
8       if(i == j)
9         continue;
10       Frac ratio = mat[j][i]; // Frac ->
           the type of data
11       for(int k = 0; k < 8; k++)
12         mat[j][k] = mat[j][k] - ratio * mat
             [i][k];
13     }
14   }
15 }
```

3 flow

3.1 dinic

```
1 const int MAXV=300;
2 const int MAXE=10000;
3 const int INF=(int)1e9+10;
4 // ^ config those things
5
6 struct E {
7   int to,co;//capacity
8   E(int t=0,int c=0):to(t),co(c) {}
9 }eg[2*MAXE];
10
11 // source:0  sink:n-1
12 struct Flow {
13   VI e[MAXV];
14   int ei,v;
15   void init(int n) {
16     v=n;
17     ei=0;
18     for(int i=0;i<n;i++)
19       e[i]=VI();
20   }
21   void add(int a,int b,int c) { //a to b ,
       maxflow=c
22     eg[ei]=E(b,c);
23     e[a].PB(ei);
24     ei++;
25     eg[ei]=E(a,0);
26     e[b].PB(ei);
27     ei++;
28   }
29
30   int d[MAXV],qu[MAXV],ql,qr;
31   bool BFS() {
32     memset(d,-1,v*sizeof(int));
33     ql=qr=0;
34     qu[qr++]=0;
35     d[0]=0;
36     while(ql<qr && d[v-1]==-1) {
37       int n=qu[ql++];
38       VI &v=e[n];
39       for(int i=SZ(v)-1;i>=0;i--) {
40         int u=v[i];
41         if(d[eg[u].to]==-1 && eg[u].co>0) {
42           d[eg[u].to]=d[n]+1;
43           qu[qr++]=eg[u].to;
44         }
45       }
46     }
47     return d[v-1]!=-1;
48   }
49   int ptr[MAXV];
50   int go(int n,int p) {
```

```
51      if(n==v-1)
52        return p;
53      VI &u=e[n];
54      int temp;
55      for(int i=ptr[n];i<SZ(u);i++) {
56        if(d[n]+1!=d[eg[u[i]].to] || eg[u[i
              ]].co==0)
57          continue;
58        if((temp=go(eg[u[i]].to,min(p,eg[u[i
              ]].co)))==0)
59          continue;
60        eg[u[i]].co-=temp;
61        eg[u[i]^1].co+=temp;
62        ptr[n]=i;
63        return temp;
64      }
65      ptr[n]=SZ(u);
66      return 0;
67    }
68    int max_flow() {
69      int ans=0,temp;
70      while(BFS()) {
71        for(int i=0;i<v;i++)
72          ptr[i]=0;
73        while((temp=go(0,INF))>0)
74          ans+=temp;
75      }
76      return ans;
77    }
78 }flow;
```

3.2 min-cost-max-flow

```
1  typedef pair<int,ll> PIL;
2  const int MAXV=60;
3  const int MAXE=6000;
4  const int INF=(int)1e9+10;
5  const ll cINF=(ll)1e18+10;
6  // ^ config those things
7
8  struct E {
9    int to,ca,cost;//capacity, cost
10   E(int t=0,int c=0,int co=0):to(t),ca(c),
        cost(co) {}
11 }eg[2*MAXE];
12
13 // source:0  sink:n-1
14 struct Flow {
15   VI e[MAXV];
16   int ei,n;
17   void init(int n_) {
18     n=n_;
19     ei=0;
20     for(int i=0;i<n;i++)
21       e[i]=VI();
22   }
23   void add(int a,int b,int c,int d) {
24     //a to b ,maxflow=c, cost=d
25     eg[ei]=E(b,c,d);
26     e[a].PB(ei);
27     ei++;
28     eg[ei]=E(a,0,-d);
29     e[b].PB(ei);
30     ei++;
31   }
32
33   PII d[MAXV]={};
34   bool inq[MAXV]={};
35   queue<int> que;
36   VI pe;
37   bool SPFA() {
38     fill(d, d+n, MP(INF,INF));
39     d[0]=MP(0,0);
40     que.push(0);
41     inq[0]=1;
42     while(!que.empty()) {
43       int v=que.front(); que.pop();
44       inq[v]=0;
45       for(int id:e[v]) {
46         if(eg[id].ca>0 && MP(d[v].F+eg[id].
              cost,d[v].S+1)<d[eg[id].to]) {
47           d[eg[id].to]=MP(d[v].F+eg[id].
                cost,d[v].S+1);
48           if(!inq[eg[id].to]) {
49             que.push(eg[id].to);
50             inq[eg[id].to]=1;
51           }
52         }
53       }
54     }
55     return d[n-1].F<INF;
56   }
57   PIL go(ll cb=cINF) {
58     // cost_bound
59     if(!SPFA()) return MP(0,0);
60     pe.clear();
61     int fl=INF;
62     for(int v=n-1;v!=0;) {
63       for(int id:e[v]) {
64         int u=eg[id].to;
65         const E& t=eg[id^1];
66         if(t.ca>0 && MP(d[u].F+t.cost,d[u].
              S+1)==d[v]) {
67           fl=min(fl, t.ca);
68           v=u;
69           pe.PB(id^1);
70           break;
71         }
72       }
73     }
74     if(d[n-1].F>0) fl=min(1ll*fl, cb/d[n
          -1].F);
75     for(int id:pe) {
76       eg[id].ca-=fl;
77       eg[id^1].ca+=fl;
78     }
79     return MP(fl, 1ll*fl*d[n-1].F);
80   }
81   PIL max_flow() {
82     PIL ans=MP(0,0),temp;
83     while((temp=go()).F>0) {
84       ans.F+=temp.F;
85       ans.S+=temp.S;
86     }
87     return ans;
88   }
89 } flow;
```

4 string

4.1 KMP

```
1  void KMP_build(const char *S,int *F) {
2    int p=F[0]=-1;
3    for(int i=1;S[i];i++) {
4      while(p!=-1 && S[p+1]!=S[i])
5        p=F[p];
6      if(S[p+1]==S[i])
7        p++;
8      F[i]=p;
9    }
10 }
11
12 VI KMP_match(const char *S,const int *F,
     const char *T) {
13   VI ans;
14   int p=-1;
15   for(int i=0;T[i];i++) {
16     while(p!=-1 && S[p+1]!=T[i])
17       p=F[p];
18     if(S[p+1]==T[i])
19       p++;
20     if(!S[p+1]) {
21       ans.PB(i-p);
22       p=F[p];
23     }
24   }
25   return ans;
26 }
```

4.2 Z-value

```
1  void Z_build(const char *S,int *Z) {
2    Z[0]=0;
3    int bst=0;
4    for(int i=1;S[i];i++) {
5      if(Z[bst]+bst<i) Z[i]=0;
6      else Z[i]=min(Z[bst]+bst-i,Z[i-bst]);
7      while(S[Z[i]]==S[i+Z[i]]) Z[i]++;
8      if(Z[i]+i>Z[bst]+bst) bst=i;
9    }
10 }
```

4.3 Z-value-palindrome

```
1  // AC code of NTUJ1871
2  #include <bits/stdc++.h>
3  #define pb push_back
4  #define F first
5  #define S second
6  #define SZ(x) ((int)(x).size())
7  #define MP make_pair
8  using namespace std;
9  typedef long long ll;
10 typedef pair<int,int> PII;
11 typedef vector<int> VI;
12
13 char in[100100];
14 char s[200100];
15 int z[200100];
16
17 int main()
18 {
19   while(gets(in))
20   {
21     int len=1;
22     for(int i=0;in[i];i++)
23     {
24       s[len++]='*';
25       s[len++]=in[i];
26     }
27     s[len]=0;
28     z[0]=0;
29     z[1]=0;
30     int bst=1;
31     for(int i=1;i<len;i++)
32     {
33       z[i]=min(bst+z[bst]-i,z[bst+bst
           -i]);
34       while(s[i+z[i]+1]==s[i-z[i]-1])
35         z[i]++;
36       if(z[i]+i>bst+z[bst])
37         bst=i;
38     }
39     /*for(int i=1;i<len;i++)
40         putchar(s[i]);
41     puts("");
42     for(int i=1;i<len;i++)
43         printf("%d",z[i]);
44     puts("");*/
45     bool yes=0;
46     for(int i=3;i<len;i+=2)
47       if(z[(i+1)/2]==i/2 && z[(i+len)
           /2]==(len-i-1)/2)
48         yes=1;
49     if(yes)
50       puts("www");
51     else
52       puts("vvvvvv");
53   }
54   return 0;
55 }
```

4.4 Suffix Array($O(NlogN)$)

```
1  const int SASIZE=100020;  // >= (max length
       of string + 20)
2  struct SA{
3    char S[SASIZE]; // put target string into
         S[0:(len-1)]
4    // you can change the type of S into int
         if required
5    // if the string is in int, please avoid
         number < 0
6    int R[SASIZE*2],SA[SASIZE];
7    int tR[SASIZE*2],tSA[SASIZE];
8    int cnt[SASIZE],len;     // set len
         before calling build()
9    int H[SASIZE];
10
11   void build_SA() {
12     int maxR=0;
```

```
13        for(int i=0;i<len;i++)
14          R[i]=S[i];
15        for(int i=0;i<=len;i++)
16          R[len+i]=-1;
17        memset(cnt,0,sizeof(cnt));
18        for(int i=0;i<len;i++)
19          maxR=max(maxR,R[i]);
20        for(int i=0;i<len;i++)
21          cnt[R[i]+1]++;
22        for(int i=1;i<=maxR;i++)
23          cnt[i]+=cnt[i-1];
24        for(int i=0;i<len;i++)
25          SA[cnt[R[i]]++]=i;
26        for(int i=1;i<len;i*=2)
27        {
28          memset(cnt,0,sizeof(int)*(maxR+10));
29          memcpy(tSA,SA,sizeof(int)*(len+10));
30          memcpy(tR,R,sizeof(int)*(len+i+10));
31          for(int j=0;j<len;j++)
32            cnt[R[j]+1]++;
33          for(int j=1;j<=maxR;j++)
34            cnt[j]+=cnt[j-1];
35          for(int j=len-i;j<len;j++)
36            SA[cnt[R[j]]++]=j;
37          for(int j=0;j<len;j++)
38          {
39            int k=tSA[j]-i;
40            if(k<0)
41              continue;
42            SA[cnt[R[k]]++]=k;
43          }
44          int num=0;
45          maxR=0;
46          R[SA[0]]=num;
47          for(int j=1;j<len;j++)
48          {
49            if(tR[SA[j-1]]<tR[SA[j]] || tR[SA[j
                -1]+i]<tR[SA[j]+i])
50              num++;
51            R[SA[j]]=num;
52            maxR=max(maxR,R[SA[j]]);
53          }
54        }
55      }
56      void build_H() {
57        memset(H,0,sizeof(int)*(len+10));
58        for(int i=0;i<len;i++)
59        {
60          if(R[i]==0)
61            continue;
62          int &t=H[R[i]];
63          if(i>0)
64            t=max(0,H[R[i-1]]-1);
65          while(S[i+t]==S[SA[R[i]-1]+t]) t++;
66        }
67      }
68    }sa;
```

4.5 Aho-Corasick

```
1  // AC code of UVa 10679
2  #include <cstdio>
3  #include <cstring>
4  #include <new>
5
6  struct Trie {
7    int c;
8    bool fi=0;
9    Trie *fail,*ch[52];
10   Trie():c(0){memset(ch,0,sizeof(ch));}
11 }trie[1000100];
12
13 char m[1010],f[100100];
14 Trie *str[1010],*na,*root;
15
16 inline int c_i(char a) {
17   return (a>='A' && a<='Z') ? a-'A' : a-'a'
         +26;
18 }
19
20 void insert(char *s,int num) {
21   Trie *at=root;
22   while(*s) {
23     if(!at->ch[c_i(*s)])
24       at->ch[c_i(*s)]=new (na++) Trie();
25     at=at->ch[c_i(*s)],s++;
26   }
27   str[num]=at;
28 }
29
30 Trie *q[1000100];
31 int ql,qr;
32
33 void init() {
34   ql=qr=-1;
35   q[++qr]=root;
36   root->fail=NULL;
37   while(ql<qr) {
38     Trie *n=q[++ql],*f;
39     for(int i=0;i<52;i++) {
40       if(!n->ch[i])
41         continue;
42       f=n->fail;
43       while(f && !f->ch[i])
44         f=f->fail;
45       n->ch[i]->fail=f?f->ch[i]:root;
46       q[++qr]=n->ch[i];
47     }
48   }
49 }
50
51 void go(char *s) {
52   Trie*p=root;
53   while(*s) {
54     while(p && !p->ch[c_i(*s)])
55       p=p->fail;
56     p=p?p->ch[c_i(*s)]:root;
57     p->fi=1;
58     s++;
59   }
60 }
61
62 void AC() {
63   for(int i=qr;i>0;i--)
64     q[i]->fail->c+=q[i]->c;
65 }
66
67 int main() {
```

```
68    int T,q;
69    scanf("%d",&T);
70    while(T--) {
71      na=trie;
72      root=new (na++) Trie();
73      scanf("%s",f);
74      scanf("%d",&q);
75      for(int i=0;i<q;i++) {
76        scanf("%s",m);
77        insert(m,i);
78      }
79      init();
80      go(f);
81      for(int i=0;i<q;i++)
82        puts(str[i]->fi?"y":"n");
83    }
84    return 0;
85 }
```

4.6 Aho-Corasick-2016ioicamp

```
1  // AC code of 2016ioicamp 54
2  #include <bits/stdc++.h>
3  #define PB push_back
4  #define MP make_pair
5  #define F first
6  #define S second
7  #define SZ(x) ((int)(x).size())
8  #define ALL(x) (x).begin(),(x).end()
9  #ifdef _DEBUG_
10   #define debug(...) printf(__VA_ARGS__)
11 #else
12   #define debug(...) (void)0
13 #endif
14 using namespace std;
15 typedef long long ll;
16 typedef pair<int,int> PII;
17 typedef vector<int> VI;
18
19 const int MAXNM=100010;
20 int pp[MAXNM];
21
22 const int sizz=100010;
23 int nx[sizz][26],spt;
24 int fl[sizz],efl[sizz],ed[sizz];
25 int len[sizz];
26 int newnode(int len_=0) {
27   for(int i=0;i<26;i++)nx[spt][i]=0;
28   ed[spt]=0;
29   len[spt]=len_;
30   return spt++;
31 }
32 int add(char *s,int p) {
33   int l=1;
34   for(int i=0;s[i];i++) {
35     int a=s[i]-'a';
36     if(nx[p][a]==0) nx[p][a]=newnode(l);
37     p=nx[p][a];
38     l++;
39   }
40   ed[p]=1;
41   return p;
42 }
```

```
43 int q[sizz],qs,qe;
44 void make_fl(int root) {
45   fl[root]=efl[root]=0;
46   qs=qe=0;
47   q[qe++]=root;
48   for(;qs!=qe;) {
49     int p=q[qs++];
50     for(int i=0;i<26;i++) {
51       int t=nx[p][i];
52       if(t==0) continue;
53       int tmp=fl[p];
54       for(;tmp&&nx[tmp][i]==0;) tmp=fl[tmp
           ];
55       fl[t]=tmp?nx[tmp][i]:root;
56       efl[t]=ed[fl[t]]?fl[t]:efl[fl[t]];
57       q[qe++]=t;
58     }
59   }
60 }
61 char s[MAXNM];
62 char a[MAXNM];
63
64 int dp[MAXNM][4];
65
66 void mmax(int &a,int b) {
67   a=max(a,b);
68 }
69
70 void match(int root) {
71   int p=root;
72   for(int i=1;s[i];i++) {
73     int a=s[i]-'a';
74     for(;p&&nx[p][a]==0;p=fl[p]);
75     p=p?nx[p][a]:root;
76     for(int j=1;j<=3;j++)
77       dp[i][j]=dp[i-1][j];
78     for(int t=p;t;t=efl[t]) {
79       if(!ed[t])
80         continue;
81       for(int j=1;j<=3;j++)
82         mmax(dp[i][j],dp[i-len[t]][j-1]+(pp
             [i]-pp[i-len[t]]));
83     }
84   }
85 }
86
87 int main() {
88   int T;
89   scanf("%d",&T);
90   while(T--) {
91     int n,m;
92     scanf("%d%d",&n,&m);
93     scanf("%s",s+1);
94     for(int i=1;i<=n;i++)
95       scanf("%d",pp+i);
96     for(int i=1;i<=n;i++)
97       pp[i]+=pp[i-1];
98     spt=1;
99     int root=newnode();
100    for(int i=0;i<m;i++) {
101      scanf("%s",a);
102      add(a,root);
103    }
104    make_fl(root);
105    for(int i=1;i<=n;i++)
```

```
106        dp[i][1]=dp[i][2]=dp[i][3]=0;
107      match(root);
108      printf("%d\n",dp[n][3]);
109    }
110    return 0;
111  }
```

4.7 Palindrome Automaton

```
1  const int MAXN=100050;
2  char s[MAXN];
3  int n; // n: string length
4
5  typedef pair<PII,int> PD;
6  vector<PD> pal;
7
8  int ch[MAXN][26], fail[MAXN], len[MAXN],
       cnt[MAXN];
9  int edp[MAXN];
10 int nid=1;
11 int new_node(int len_) {
12   len[nid]=len_;
13   return nid++;
14 }
15
16 void build_pa() {
17   int odd_root=new_node(-1);
18   int even_root=new_node(0);
19   fail[even_root]=odd_root;
20   int cur=even_root;
21   for(int i=1;i<=n;i++) {
22     while(1) {
23       if(s[i-len[cur]-1] == s[i]) break;
24       cur=fail[cur];
25     }
26     if(ch[cur][s[i]-'a']==0) {
27       int nt=ch[cur][s[i]-'a']=new_node(len
         [cur]+2);
28       int tmp=fail[cur];
29       while(tmp && s[i-len[tmp]-1]!=s[i])
           tmp=fail[tmp];
30       if(tmp==0) fail[nt]=even_root;
31       else {
32         assert(ch[tmp][s[i]-'a']);
33         fail[nt]=ch[tmp][s[i]-'a'];
34       }
35       edp[nt]=i;
36     }
37     cur=ch[cur][s[i]-'a'];
38     cnt[cur]++;
39   }
40   for(int i=nid-1;i>even_root;i--) {
41     cnt[fail[i]]+=cnt[i];
42     pal.PB( MP( MP(edp[i]-len[i]+1, len[i])
         , cnt[i]) );
43   }
44 }
```

4.8 Suffix Automaton(bcw)

```
1  // par : fail link
```

```
2  // val : a topological order ( useful for
      DP )
3  // go[x] : automata edge ( x is integer in
      [0,26) )
4
5  struct SAM{
6    struct State{
7      int par, go[26], val;
8      State () : par(0), val(0){ FZ(go); }
9      State (int _val) : par(0), val(_val){
         FZ(go); }
10   };
11   vector<State> vec;
12   int root, tail;
13
14   void init(int arr[], int len){
15     vec.resize(2);
16     vec[0] = vec[1] = State(0);
17     root = tail = 1;
18     for (int i=0; i<len; i++)
19       extend(arr[i]);
20   }
21   void extend(int w){
22     int p = tail, np = vec.size();
23     vec.PB(State(vec[p].val+1));
24     for ( ; p && vec[p].go[w]==0; p=vec[p].
         par)
25       vec[p].go[w] = np;
26     if (p == 0){
27       vec[np].par = root;
28     } else {
29       if (vec[vec[p].go[w]].val == vec[p].
           val+1){
30         vec[np].par = vec[p].go[w];
31       } else {
32         int q = vec[p].go[w], r = vec.size
             ();
33         vec.PB(vec[q]);
34         vec[r].val = vec[p].val+1;
35         vec[q].par = vec[np].par = r;
36         for ( ; p && vec[p].go[w] == q; p=
             vec[p].par)
37           vec[p].go[w] = r;
38       }
39     }
40     tail = np;
41   }
42 };
```

5 graph

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

```
1  // NTUJ1263
2  #include <bits/stdc++.h>
3  #define pb push_back
4  #define F first
5  #define S second
6  #define SZ(x) ((int)(x).size())
7  #define MP make_pair
8  using namespace std;
9  typedef long long ll;
```

```
10  typedef pair<int,int> PII;
11  typedef vector<int> VI;
12
13  bool is(ll x)
14  {
15    ll l=1,r=2000000,m;
16    while(l<=r)
17    {
18      m=(l+r)/2;
19      if(m*m==x)
20        return 1;
21      if(m*m<x)
22        l=m+1;
23      else
24        r=m-1;
25    }
26    return 0;
27  }
28
29  VI odd,even;
30  int in[300];
31  VI e[300];
32  int match[300];
33  bool vis[300];
34
35  bool DFS(int x)
36  {
37    vis[x]=1;
38    for(int u:e[x])
39    {
40      if(match[u]==-1 || (!vis[match[u]]&&DFS
          (match[u])))
41      {
42        match[u]=x;
43        match[x]=u;
44        return 1;
45      }
46    }
47    return 0;
48  }
49
50  int main()
51  {
52    int N;
53    while(scanf("%d",&N)==1)
54    {
55      odd.clear();
56      even.clear();
57      for(int i=0;i<N;i++)
58        e[i].clear();
59      for(int i=0;i<N;i++)
60      {
61        scanf("%d",in+i);
62        if(in[i]%2==0)
63          even.pb(i);
64        else
65          odd.pb(i);
66      }
67      for(int i:even)
68        for(int j:odd)
69          if(is(1ll*in[i]*in[i]+1ll*in[j]*in[
             j]) && __gcd(in[i],in[j])==1)
70            e[i].pb(j), e[j].pb(i);
71      int ans=0;
72      fill(match,match+N,-1);
```

```
73      for(int i=0;i<N;i++)
74        if(match[i]==-1)
75        {
76          fill(vis,vis+N,0);
77          if(DFS(i))
78            ans++;
79        }
80      printf("%d\n",ans);
81    }
82    return 0;
83  }
```

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

```
1   const int INF=1016; //> max(a[i][j])
2   const int MAXN=650;
3   int a[MAXN][MAXN]; // weight [x][y] , two
        set of vertex
4   int N; // two set: each set have exactly N
        vertex
5   int match[MAXN*2], weight[MAXN*2];
6   bool vis[MAXN*2];
7
8   bool DFS(int x) {
9     vis[x]=1;
10    for(int i=0;i<N;i++) {
11      if(weight[x]+weight[N+i]!=a[x][i])
          continue;
12      vis[N+i]=1;
13      if(match[N+i]==-1 || (!vis[match[N+i
          ]]&&DFS(match[N+i]))) {
14        match[N+i]=x;
15        match[x]=N+i;
16        return 1;
17      }
18    }
19    return 0;
20  }
21
22  int KM() {
23    fill(weight, weight+N+N, 0);
24    for(int i=0;i<N;i++) {
25      for(int j=0;j<N;j++)
26        weight[i]=max(weight[i], a[i][j]);
27    }
28    fill(match, match+N+N, -1);
29    for(int u=0;u<N;u++) {
30      fill(vis, vis+N+N, 0);
31      while(!DFS(u)) {
32        int d=INF;
33        for(int i=0;i<N;i++) {
34          if(!vis[i]) continue;
35          for(int j=0;j<N;j++)
36            if(!vis[N+j])
37              d=min(d, weight[i]+weight[N+j]-
                  a[i][j]);
38        }
39        for(int i=0;i<N;i++)
40          if(vis[i])
41            weight[i]-=d;
42        for(int i=N;i<N+N;i++)
43          if(vis[i])
44            weight[i]+=d;
```

```
45        fill(vis, vis+N+N, 0);
46      }
47    }
48    int ans=0;
49    for(int i=0;i<N+N;i++) ans+=weight[i];
50    return ans;
51 }
```

5.3 general graph matching(bcw)

```
 1 #define FZ(x) memset(x,0,sizeof(x))
 2 struct GenMatch { // 1-base
 3    static const int MAXN = 250;
 4    int V;
 5    bool el[MAXN][MAXN];
 6    int pr[MAXN];
 7    bool inq[MAXN],inp[MAXN],inb[MAXN];
 8    queue<int> qe;
 9    int st,ed;
10    int nb;
11    int bk[MAXN],djs[MAXN];
12    int ans;
13    void init(int _V) {
14      V = _V;
15      FZ(el); FZ(pr);
16      FZ(inq); FZ(inp); FZ(inb);
17      FZ(bk); FZ(djs);
18      ans = 0;
19    }
20    void add_edge(int u, int v) {
21      el[u][v] = el[v][u] = 1;
22    }
23    int lca(int u,int v) {
24      memset(inp,0,sizeof(inp));
25      while(1) {
26        u = djs[u];
27        inp[u] = true;
28        if(u == st) break;
29        u = bk[pr[u]];
30      }
31      while(1) {
32        v = djs[v];
33        if(inp[v]) return v;
34        v = bk[pr[v]];
35      }
36      return v;
37    }
38    void upd(int u) {
39      int v;
40      while(djs[u] != nb) {
41        v = pr[u];
42        inb[djs[u]] = inb[djs[v]] = true;
43        u = bk[v];
44        if(djs[u] != nb) bk[u] = v;
45      }
46    }
47    void blo(int u,int v) {
48      nb = lca(u,v);
49      memset(inb,0,sizeof(inb));
50      upd(u); upd(v);
51      if(djs[u] != nb) bk[u] = v;
52      if(djs[v] != nb) bk[v] = u;
53      for(int tu = 1; tu <= V; tu++)
54        if(inb[djs[tu]]) {
55          djs[tu] = nb;
56          if(!inq[tu]){
57            qe.push(tu);
58            inq[tu] = 1;
59          }
60        }
61    }
62    void flow() {
63      memset(inq,false,sizeof(inq));
64      memset(bk,0,sizeof(bk));
65      for(int i = 1; i <= V;i++)
66        djs[i] = i;
67
68      while(qe.size()) qe.pop();
69      qe.push(st);
70      inq[st] = 1;
71      ed = 0;
72      while(qe.size()) {
73        int u = qe.front(); qe.pop();
74        for(int v = 1; v <= V; v++)
75          if(el[u][v] && (djs[u] != djs[v])
               && (pr[u] != v)) {
76            if((v == st) || ((pr[v] > 0) &&
                 bk[pr[v]] > 0))
77              blo(u,v);
78            else if(bk[v] == 0) {
79              bk[v] = u;
80              if(pr[v] > 0) {
81                if(!inq[pr[v]]) qe.push(pr[v
                     ]);
82              } else {
83                ed = v;
84                return;
85              }
86            }
87          }
88      }
89    }
90    void aug() {
91      int u,v,w;
92      u = ed;
93      while(u > 0) {
94        v = bk[u];
95        w = pr[v];
96        pr[v] = u;
97        pr[u] = v;
98        u = w;
99      }
100   }
101   int solve() {
102     memset(pr,0,sizeof(pr));
103     for(int u = 1; u <= V; u++)
104       if(pr[u] == 0) {
105         st = u;
106         flow();
107         if(ed > 0) {
108           aug();
109           ans ++;
110         }
111       }
112     return ans;
113   }
114 } gm;
```

5.4 Max clique(bcw)

```
1  class MaxClique {
2  public:
3      static const int MV = 210;
4
5      int V;
6      int el[MV][MV/30+1];
7      int dp[MV];
8      int ans;
9      int s[MV][MV/30+1];
10     vector<int> sol;
11
12     void init(int v) {
13         V = v; ans = 0;
14         FZ(el); FZ(dp);
15     }
16
17     /* Zero Base */
18     void addEdge(int u, int v) {
19         if(u > v) swap(u, v);
20         if(u == v) return;
21         el[u][v/32] |= (1<<(v%32));
22     }
23
24     bool dfs(int v, int k) {
25         int c = 0, d = 0;
26         for(int i=0; i<(V+31)/32; i++) {
27             s[k][i] = el[v][i];
28             if(k != 1) s[k][i] &= s[k-1][i
                   ];
29             c += __builtin_popcount(s[k][i
                   ]);
30         }
31         if(c == 0) {
32             if(k > ans) {
33                 ans = k;
34                 sol.clear();
35                 sol.push_back(v);
36                 return 1;
37             }
38             return 0;
39         }
40         for(int i=0; i<(V+31)/32; i++) {
41             for(int a = s[k][i]; a ; d++) {
42                 if(k + (c-d) <= ans) return
                       0;
43                 int lb = a&(-a), lg = 0;
44                 a ^= lb;
45                 while(lb!=1) {
46                     lb = (unsigned int)(lb)
                           >> 1;
47                     lg ++;
48                 }
49                 int u = i*32 + lg;
50                 if(k + dp[u] <= ans) return
                       0;
51                 if(dfs(u, k+1)) {
52                     sol.push_back(v);
53                     return 1;
54                 }
55             }
56         }
57         return 0;
58     }
59
60     int solve() {
61         for(int i=V-1; i>=0; i--) {
62             dfs(i, 1);
63             dp[i] = ans;
64         }
65         return ans;
66     }
67  };
```

5.5 EdgeBCC

```
1  const int MAXN=1010;
2  const int MAXM=5010;
3  VI e[MAXN];
4  int low[MAXN],lvl[MAXN],bel[MAXN];
5  bool vis[MAXN];
6  int cnt;
7  VI st;
8  void DFS(int x,int l,int p) {
9    st.PB(x);
10   vis[x]=1;
11   low[x]=lvl[x]=l;
12   bool top=0;
13   for(int u:e[x]) {
14     if(u==p && !top) {
15       top=1;
16       continue;
17     }
18     if(!vis[u]) {
19       DFS(u,l+1,x);
20     }
21     low[x]=min(low[x],low[u]);
22   }
23   if(x==1 || low[x]==l) {
24     while(st.back()!=x) {
25       bel[st.back()]=cnt;
26       st.pop_back();
27     }
28     bel[st.back()]=cnt;
29     st.pop_back();
30     cnt++;
31   }
32  }
33  int main() {
34    int T;
35    scanf("%d",&T);
36    while(T--) {
37      int N,M,a,b;
38      scanf("%d%d",&N,&M);
39      fill(vis,vis+N+1,0);
40      for(int i=1;i<=N;i++)
41        e[i].clear();
42      while(M--) {
43        scanf("%d%d",&a,&b);
44        e[a].PB(b);
45        e[b].PB(a);
46      }
47      cnt=0;
48      DFS(1,0,-1);
49      /*****/
50    }
```

```
51    return 0;
52 }
```

5.6 VerticeBCC

```
 1 const int MAXN=10000;
 2 const int MAXE=100000;
 3
 4 VI e[MAXN+10];
 5 vector<PII> BCC[MAXE];
 6 int bccnt;
 7 vector<PII> st;
 8 bool vis[MAXN+10];
 9 int low[MAXN+10],level[MAXN+10];
10
11 void DFS(int x,int p,int l) {
12   vis[x]=1;
13   level[x]=low[x]=l;
14   for(int u:e[x]) {
15     if(u==p)
16       continue;
17     if(vis[u]) {
18       if(level[u]<l) {
19         st.PB(MP(x,u));
20         low[x]=min(low[x],level[u]);
21       }
22     }
23     else {
24       st.PB(MP(x,u));
25       DFS(u,x,l+1);
26       if(low[u]>=l) {
27         PII t=st.back();
28         st.pop_back();
29         while(t!=MP(x,u)) {
30           BCC[bccnt].PB(t);
31           t=st.back();
32           st.pop_back();
33         }
34         BCC[bccnt].PB(t);
35         bccnt++;
36       }
37       low[x]=min(low[x],low[u]);
38     }
39   }
40 }
41
42 int main() {
43   int T,N,M;
44   scanf("%d",&T);
45   while(T--) {
46     scanf("%d%d",&N,&M);
47     for(int i=0;i<N;i++)
48       e[i].clear();
49     int cnt=0;
50     while(1) {
51       int x,y;
52       scanf("%d%d",&x,&y);
53       if(x==-1 && y==-1)
54         break;
55       cnt++;
56       e[x].PB(y);
57       e[y].PB(x);
58     }
```

```
59     for(int i=0;i<N;i++) { // no multi-edge
60       sort(ALL(e[i]));
61       e[i].erase(unique(ALL(e[i])),e[i].end
            ());
62     }
63     fill(vis,vis+N,0);
64     while(bccnt)
65       BCC[--bccnt].clear();
66     DFS(0,-1,0);
67     /***/
68   }
69   return 0;
70 }
```

5.7 Dominating Tree

```
 1 const int MAXN = 200000 + 10;
 2
 3 VI e[MAXN], re[MAXN];
 4 int par[MAXN], num[MAXN], t, rn[MAXN];
 5 int sd[MAXN], id[MAXN];
 6 PII p[MAXN];
 7 VI sdom_at[MAXN];
 8
 9 void dfs(int u) {
10   num[u] = ++t;
11   rn[t] = u;
12   for(int v : e[u]) {
13     if(num[v])  continue;
14     par[v] = u;
15     dfs(v);
16   }
17 }
18
19 void LINK(int x, int y) {
20   p[x].F = y;
21   if(sd[y] < sd[p[x].S])  p[x].S = y;
22 }
23
24 int EVAL(int x) {
25   if(p[p[x].F].F != p[x].F) {
26     int w = EVAL(p[x].F);
27     if(sd[w] < sd[p[x].S])  p[x].S = w;
28     p[x].F = p[ p[x].F ].F;
29   }
30   return p[x].S;
31 }
32
33 void DominatingTree(int n) {
34   // 1-indexed
35   par[1] = 1;
36   fill(num, num+n+1, 0);
37   fill(rn, rn+n+1, 0);
38   t = 0;
39   dfs(1);
40
41   for(int i=1; i<=n; i++) {
42     p[i] = MP(i, i);
43   }
44   for(int i=1; i<=n; i++) {
45     sd[i] = (num[i] ? num[i] : MAXN+10);
46     id[i] = i;
47   }
```

```
48    for(int i=n; i>1; i--) {
49      int v = rn[i];
50      if(!v)  continue;
51      for(int u : re[v]) {
52        int w = EVAL(u);
53        sd[v] = min(sd[v], sd[w]);
54      }
55      sdom_at[rn[sd[v]]].PB(v);
56      LINK(v, par[v]);
57
58      for(int w : sdom_at[par[v]]) {
59        int u = EVAL(w);
60        id[w] = (sd[u]<sd[w] ? u : par[v]);
61      }
62      sdom_at[par[v]].clear();
63    }
64
65    for(int i=2; i<=n; i++) {
66      int v = rn[i];
67      if(!v)  break;
68      if(id[v] != rn[sd[v]])  id[v] = id[id[v
          ]];
69    }
70 }
```

5.8 Them.

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

6 data structure

6.1 Treap

```
1  #include <cstdlib>
2  #include <cstdio>
3  #include <algorithm>
4
5  using namespace std;
6
7  typedef long long ll;
8
9  const int N = 100000 + 10;
10
11 struct Treap {
12   static Treap mem[N], *pmem;
13
14   int sz, pri;
15   ll val, sum, add;
16   Treap *l, *r;
17
18   Treap() {}
19   Treap(ll _val):
20     l(NULL), r(NULL), sz(1), pri(rand()),
         val(_val), sum(_val), add(0) {}
21 } Treap::mem[N], *Treap::pmem = Treap::mem;
22
23 Treap* make(ll val) {
24   return new (Treap::pmem++) Treap(val);
25 }
26
27 inline int sz(Treap *t) {
28   return t ? t->sz : 0;
29 }
30
31 inline ll sum(Treap *t) {
32   return t ? t->sum + t->add * sz(t) : 0;
33 }
34
35 inline void add(Treap *t, ll x) {
36   t->add += x;
37 }
38
39 void push(Treap *t) {
40   t->val += t->add;
41   if(t->l)  t->l->add += t->add;
42   if(t->r)  t->r->add += t->add;
43   t->add = 0;
44 }
45
46 void pull(Treap *t) {
47   t->sum = sum(t->l) + sum(t->r) + t->val;
48   t->sz = sz(t->l) + sz(t->r) + 1;
49 }
50
51 Treap* merge(Treap *a, Treap *b) {
52   if(!a || !b)  return a ? a : b;
53   else if(a->pri > b->pri) {
54     push(a);
55     a->r = merge(a->r, b);
56     pull(a);
57     return a;
58   }
59   else {
60     push(b);
61     b->l = merge(a, b->l);
62     pull(b);
63     return b;
64   }
65 }
66
67 void split(Treap* t, int k, Treap *&a,
     Treap *&b) {
68   if(!t)  a = b = NULL;
69   else if(sz(t->l) < k) {
70     a = t;
71     push(a);
72     split(t->r, k - sz(t->l) - 1, a->r, b);
73     pull(a);
74   }
75   else {
76     b = t;
77     push(b);
78     split(t->l, k, a, b->l);
79     pull(b);
80   }
81 }
82
83 int main() {
84   srand(105105);
```

```cpp
 85
 86   int n, q;
 87   scanf("%d%d", &n, &q);
 88
 89   Treap *t = NULL;
 90   for(int i = 0; i < n; i++) {
 91     ll tmp;
 92     scanf("%lld", &tmp);
 93     t = merge(t, make(tmp));
 94   }
 95
 96   while(q--) {
 97     char c;
 98     int l, r;
 99     scanf("\n%c %d %d", &c, &l, &r);
100
101     Treap *tl = NULL, *tr = NULL;
102     if(c == 'Q') {
103       split(t, l - 1, tl, t);
104       split(t, r - l + 1, t, tr);
105       printf("%lld\n", sum(t));
106       t = merge(tl, merge(t, tr));
107     }
108     else {
109       ll x;
110       scanf("%lld", &x);
111       split(t, l - 1, tl, t);
112       split(t, r - l + 1, t, tr);
113       add(t, x);
114       t = merge(tl, merge(t, tr));
115     }
116   }
117
118   return 0;
119 }
```

6.2 copy on write treap

```cpp
 1 #include <cstdlib>
 2 #include <cstdio>
 3 #include <algorithm>
 4 #include <climits>
 5 #include <cstring>
 6
 7 using namespace std;
 8
 9 const int N = 1000000 + 10;
10
11 struct Treap {
12     char val;
13     int sz, refs;
14     Treap *l, *r;
15
16     Treap() {}
17     Treap(char _val):
18         val(_val), sz(1), refs(0), l(NULL),
19                 r(NULL) {}
19 };
20
21 Treap* make(Treap* t) {
22     return new Treap(*t);
23 }
24
```

```cpp
25 Treap* make(char _val) {
26     return new Treap(_val);
27 }
28
29 void print_ref(Treap* t) {
30     if(!t)  return ;
31     print_ref(t->l);
32     printf("%d ", t->refs);
33     print_ref(t->r);
34 }
35
36 void print(Treap* t) {
37     if(!t)  return ;
38     print(t->l);
39     putchar(t->val);
40     print(t->r);
41 }
42
43 void takeRef(Treap* t) {
44     if(t)   t->refs++;
45 }
46
47 void dropRef(Treap* t) {
48     if(t) {
49         char c = t->val;
50         t->refs--;
51         if(t->refs <= 0) {
52             dropRef(t->l);
53             dropRef(t->r);
54             delete t;
55         }
56     }
57 }
58
59 int sz(Treap* t) {
60     return t ? t->sz : 0;
61 }
62
63 int rnd(int m) {
64     static int x = 851025;
65     return (x = (x*0xdefaced+1) & INT_MAX)
66         % m;
66 }
67
68 void pull(Treap* t) {
69     t->sz = sz(t->l) + sz(t->r) + 1;
70 }
71
72 Treap* merge(Treap* a, Treap* b) {
73     if(!a || !b) {
74         Treap* t = a ? make(a) : make(b);
75         t->refs = 0;
76         takeRef(t->l);
77         takeRef(t->r);
78         return t;
79     }
80
81     Treap* t;
82     if( rnd(a->sz+b->sz) < a->sz) {
83         t = make(a);
84         t->refs = 0;
85         t->r = merge(a->r, b);
86         takeRef(t->l);
87         takeRef(t->r);
88     }
```

```
89        else {
90            t = make(b);
91            t->refs = 0;
92            t->l = merge(a, b->l);
93            takeRef(t->l);
94            takeRef(t->r);
95        }
96
97        pull(t);
98        return t;
99  }
100
101 void split(Treap* t, int k, Treap* &a,
102     Treap* &b) {
103     if(!t)  a = b = NULL;
104     else if(sz(t->l) < k) {
105         a = make(t);
106         a->refs = 0;
107         split(a->r, k-sz(t->l)-1, a->r, b);
108         takeRef(a->l);
109         takeRef(a->r);
110         pull(a);
111     }
112     else {
113         b = make(t);
114         b->refs = 0;
115         split(b->l, k, a, b->l);
116         takeRef(b->l);
117         takeRef(b->r);
118         pull(b);
119     }
120 }
121
122 void print_inorder(Treap* t) {
123     if(!t)  return ;
124     putchar(t->val);
125     print_inorder(t->l);
126     print_inorder(t->r);
127 }
128
129 char s[N];
130
131 int main() {
132     int m;
133     scanf("%d", &m);
134     scanf("%s", s);
135     int n = strlen(s);
136     int q;
137     scanf("%d", &q);
138
139     Treap* t = NULL;
140     for(int i = 0; i < n; i++) {
141         Treap *a = t, *b = make(s[i]);
142         t = merge(a, b);
143         dropRef(a);
144         dropRef(b);
145     }
146
147     while(q--) {
148         int l, r, x;
149         scanf("%d%d%d", &l, &r, &x);
150         r++;
151
152         Treap *a, *b, *c, *d;
153         a = b = c = d = NULL;
```

```
153         split(t, l, a, b);
154         dropRef(a);
155         split(b, r-l, c, d);
156         dropRef(b);
157         dropRef(d);
158         split(t, x, a, b);
159         dropRef(t);
160         Treap* t2 = merge(c, b);
161         dropRef(b);
162         dropRef(c);
163         t = merge(a, t2);
164         dropRef(a);
165         dropRef(t2);
166
167         if(t->sz > m) {
168             Treap* t2 = NULL;
169             split(t, m, t2, a);
170             dropRef(a);
171             dropRef(t);
172             t = t2;
173         }
174     }
175
176     print(t);
177     putchar('\n');
178
179     return 0;
180 }
```

6.3 copy on write segment tree

```
1  #include <cstdlib>
2  #include <cstdio>
3  #include <algorithm>
4  #include <vector>
5
6  using namespace std;
7
8  const int N = 50000 + 10;
9  const int Q = 10000 + 10;
10
11 struct Seg {
12   static Seg mem[N*80], *pmem;
13
14   int val;
15   Seg *tl, *tr;
16
17   Seg() :
18     tl(NULL), tr(NULL), val(0) {}
19
20   Seg* init(int l, int r) {
21     Seg* t = new (pmem++) Seg();
22     if(l != r) {
23       int m = (l+r)/2;
24       t->tl = init(l, m);
25       t->tr = init(m+1, r);
26     }
27     return t;
28   }
29
30   Seg* add(int k, int l, int r) {
31     Seg* _t = new (pmem++) Seg(*this);
32     if(l==r) {
```

```
33        _t->val++;
34        return _t;
35      }
36
37      int m = (l+r)/2;
38      if(k <= m)  _t->tl = tl->add(k, l, m);
39      else     _t->tr = tr->add(k, m+1, r);
40
41      _t->val = _t->tl->val + _t->tr->val;
42      return _t;
43    }
44 } Seg::mem[N*80], *Seg::pmem = mem;
45
46 int query(Seg* ta, Seg* tb, int k, int l,
       int r) {
47   if(l == r)  return l;
48
49   int m = (l+r)/2;
50
51   int a = ta->tl->val;
52   int b = tb->tl->val;
53   if(b-a >= k)  return query(ta->tl, tb->tl
       , k, l, m);
54   else      return query(ta->tr, tb->tr, k
       -(b-a), m+1, r);
55 };
56
57 struct Query {
58   int op, l, r, k, c, v;
59
60   bool operator<(const Query b) const {
61     return c < b.c;
62   }
63 } qs[Q];
64 int arr[N];
65 Seg *t[N];
66 vector<int> vec2;
67
68 int main() {
69   int T;
70   scanf("%d", &T);
71
72   while(T--) {
73     int n, q;
74     scanf("%d%d", &n, &q);
75
76     for(int i = 1; i <= n; i++) {
77       scanf("%d", arr+i);
78       vec2.push_back(arr[i]);
79     }
80     for(int i = 0; i < q; i++) {
81       scanf("%d", &qs[i].op);
82       if(qs[i].op == 1) scanf("%d%d%d", &qs
         [i].l, &qs[i].r, &qs[i].k);
83       else  scanf("%d%d", &qs[i].c, &qs[i].
         v);
84
85       if(qs[i].op == 2) vec2.push_back(qs[i
         ].v);
86     }
87     sort(vec2.begin(), vec2.end());
88     vec2.resize(unique(vec2.begin(), vec2.
         end())-vec2.begin());
89     for(int i = 1; i <= n; i++) arr[i] =
         lower_bound(vec2.begin(), vec2.end()
```

```
         , arr[i]) - vec2.begin();
90     int mn = 0, mx = vec2.size()-1;
91
92     for(int i = 0; i <= n; i++) t[i] = NULL
         ;
93     t[0] = new (Seg::pmem++) Seg();
94     t[0] = t[0]->init(mn, mx);
95     int ptr = 0;
96     for(int i = 1; i <= n; i++) {
97       t[i] = t[i-1]->add(arr[i], mn, mx);
98     }
99
100    for(int i = 0; i < q; i++) {
101      int op = qs[i].op;
102      if(op == 1) {
103        int l = qs[i].l, r = qs[i].r, k =
             qs[i].k;
104        printf("%d\n", vec2[query(t[l-1], t
             [r], k, mn, mx)]);
105      }
106      if(op == 2) {
107        continue;
108      }
109      if(op == 3) puts("7122");
110    }
111
112    vec2.clear();
113    Seg::pmem = Seg::mem;
114  }
115
116  return 0;
117 }
```

6.4 Treap+(HOJ 92)

```
1 #include <cstdlib>
2 #include <cstdio>
3 #include <algorithm>
4 #include <cstring>
5
6 using namespace std;
7
8 const int INF = 103456789;
9
10 struct Treap {
11   int pri, sz, val, chg, rev, sum, lsum,
       rsum, mx_sum;
12   Treap *l, *r;
13
14   Treap() {}
15   Treap(int _val) :
16     pri(rand()), sz(1), val(_val), chg(
         INF), rev(0), sum(_val), lsum(
         _val), rsum(_val), mx_sum(_val),
         l(NULL), r(NULL) {}
17 };
18
19 int sz(Treap* t) {return t ? t->sz : 0;}
20 int sum(Treap* t) {
21   if(!t)  return 0;
22   if(t->chg == INF)   return t->sum;
23   else    return t->chg*t->sz;
24 }
```

```
25 int lsum(Treap* t) {
26     if(!t)   return -INF;
27     if(t->chg != INF)    return max(t->chg,
           (t->chg)*(t->sz));
28     if(t->rev)   return t->rsum;
29     return t->lsum;
30 }
31 int rsum(Treap* t) {
32     if(!t)   return -INF;
33     if(t->chg != INF)    return max(t->chg,
           (t->chg)*(t->sz));
34     if(t->rev)   return t->lsum;
35     return t->rsum;
36 }
37 int mx_sum(Treap* t) {
38     if(!t)   return -INF;
39     if(t->chg != INF)    return max(t->chg,
           (t->chg)*(t->sz));
40     return t->mx_sum;
41 }
42
43 void push(Treap* t) {
44     if(t->chg != INF) {
45         t->val = t->chg;
46         t->sum = (t->sz) * (t->chg);
47         t->lsum = t->rsum = t->mx_sum = max
             (t->sum, t->val);
48         if(t->l)    t->l->chg = t->chg;
49         if(t->r)    t->r->chg = t->chg;
50         t->chg = INF;
51     }
52     if(t->rev) {
53         swap(t->l, t->r);
54         if(t->l)    t->l->rev ^= 1;
55         if(t->r)    t->r->rev ^= 1;
56         t->rev = 0;
57     }
58 }
59
60 void pull(Treap* t) {
61     t->sz = sz(t->l)+sz(t->r)+1;
62     t->sum = sum(t->l)+sum(t->r)+t->val;
63     t->lsum = max(lsum(t->l), sum(t->l)+max
         (0, lsum(t->r))+t->val);
64     t->rsum = max(rsum(t->r), sum(t->r)+max
         (0, rsum(t->l))+t->val);
65     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);
66 }
67
68 Treap* merge(Treap* a, Treap* b) {
69     if(!a || !b)    return a ? a : b;
70     if(a->pri > b->pri) {
71         push(a);
72         a->r = merge(a->r, b);
73         pull(a);
74         return a;
75     }
76     else {
77         push(b);
78         b->l = merge(a, b->l);
79         pull(b);
80         return b;
81     }
82 }
83
84 void split(Treap* t, int k, Treap* &a,
       Treap* &b) {
85     if(!t) {
86         a = b = NULL;
87         return ;
88     }
89     push(t);
90     if(sz(t->l) < k) {
91         a = t;
92         push(a);
93         split(t->r, k-sz(t->l)-1, a->r, b);
94         pull(a);
95     }
96     else {
97         b = t;
98         push(b);
99         split(t->l, k, a, b->l);
100        pull(b);
101    }
102 }
103
104 void del(Treap* t) {
105     if(!t)   return;
106     del(t->l);
107     del(t->r);
108     delete t;
109 }
110
111 int main() {
112     srand(7122);
113
114     int n, m;
115     scanf("%d%d", &n, &m);
116
117     Treap* t = NULL;
118     for(int i = 0; i < n; i++) {
119         int x;
120         scanf("%d", &x);
121         t = merge(t, new Treap(x));
122     }
123
124     while(m--) {
125         char s[15];
126         scanf("%s", s);
127
128         Treap *tl = NULL, *tr = NULL, *t2 =
             NULL;
129
130         if(!strcmp(s, "INSERT")) {
131             int p, k;
132             scanf("%d%d", &p, &k);
133             for(int i = 0; i < k; i++) {
134                 int x;
135                 scanf("%d", &x);
136                 t2 = merge(t2, new Treap(x)
                     );
137             }
138             split(t, p, tl, tr);
139             t = merge(tl, merge(t2, tr));
140         }
141
142         if(!strcmp(s, "DELETE")) {
143             int p, k;
```

```
144            scanf("%d%d", &p, &k);
145            split(t, p-1, tl, t);
146            split(t, k, t, tr);
147            del(t);
148            t = merge(tl, tr);
149        }
150
151        if(!strcmp(s, "MAKE-SAME")) {
152            int p, k, l;
153            scanf("%d%d%d", &p, &k, &l);
154            split(t, p-1, tl, t);
155            split(t, k, t, tr);
156            if(t)   t->chg = l;
157            t = merge(tl, merge(t, tr));
158        }
159
160        if(!strcmp(s, "REVERSE")) {
161            int p, k;
162            scanf("%d%d", &p, &k);
163            split(t, p-1, tl, t);
164            split(t, k, t, tr);
165            if(t)   t->rev ^= 1;
166            t = merge(tl, merge(t, tr));
167        }
168
169        if(!strcmp(s, "GET-SUM")) {
170            int p, k;
171            scanf("%d%d", &p, &k);
172            split(t, p-1, tl, t);
173            split(t, k, t, tr);
174            printf("%d\n", sum(t));
175            t = merge(tl, merge(t, tr));
176        }
177
178        if(!strcmp(s, "MAX-SUM")) {
179            printf("%d\n", mx_sum(t));
180        }
181    }
182
183    return 0;
184 }
```

6.5 Leftist Tree

```
 1 #include <bits/stdc++.h>
 2 using namespace std;
 3
 4 struct Left {
 5   Left *l,*r;
 6   int v,h;
 7   Left(int v_) : v(v_), h(1), l(0), r(0) {}
 8 };
 9
10 int height(Left *p) { return p ? p -> h : 0
      ; }
11
12 Left* combine(Left *a,Left *b) {
13   if(!a || !b) return a ? a : b ;
14   Left *p ;
15   if( a->v > b->v) {
16     p = a;
17     p -> r = combine( p -> r , b );
18   }
```

```
19   else {
20     p = b;
21     p -> r = combine( p -> r , a );
22   }
23   if( height( p->l ) < height( p->r ) )
24     swap( p->l , p->r );
25   p->h = min( height( p->l ) , height( p->r
        ) ) + 1;
26   return p;
27 }
28 Left *root;
29
30 void push(int v) {
31   Left *p = new Left(v);
32   root = combine( root , p );
33 }
34 int top() { return root? root->v : -1; }
35 void pop() {
36   if(!root) return;
37   Left *a = root->l , *b = root->r ;
38   delete root;
39   root = combine( a , b );
40 }
41 void clear(Left* &p) {
42   if(!p)
43     return;
44   if(p->l) clear(p->l);
45   if(p->r) clear(p->r);
46   delete p;
47   p = 0 ;
48 }
49
50 int main() {
51   int T,n,x,o,size;
52   bool bst,bqu,bpq;
53   scanf("%d",&T);
54   while(T--) {
55     bst=bqu=bpq=1;
56     stack<int> st;
57     queue<int> qu;
58     clear(root);
59     size=0;
60     scanf("%d",&n);
61     while(n--) {
62       scanf("%d%d",&o,&x);
63       if(o==1)
64         st.push(x),qu.push(x),push(x),size
              ++;
65       else if(o==2) {
66         size--;
67         if(size<0)
68           bst=bqu=bpq=0;
69         if(bst) {
70           if(st.top()!=x)
71             bst=0;
72           st.pop();
73         }
74         if(bqu) {
75           if(qu.front()!=x)
76             bqu=0;
77           qu.pop();
78         }
79         if(bpq) {
80           //  printf("(%d)\n",top());
81           if(top()!=x)
```

```
82            bpq=0;
83          pop();
84        }
85      }
86    }
87    int count=0;
88    if(bst)
89      count++;
90    if(bqu)
91      count++;
92    if(bpq)
93      count++;
94
95    if(count>1)
96      puts("not sure");
97    else if(count==0)
98      puts("impossible");
99    else if(bst)
100     puts("stack");
101   else if(bqu)
102     puts("queue");
103   else if(bpq)
104     puts("priority queue");
105  }
106  return 0;
107 }
```

6.6 Link Cut Tree

```
1 #include <bits/stdc++.h>
2 #define PB push_back
3 #define MP make_pair
4 #define F first
5 #define S second
6 #define SZ(x) ((int)(x).size())
7 #define ALL(x) (x).begin(),(x).end()
8 #ifdef _DEBUG_
9   #define debug(...) printf(__VA_ARGS__)
10 #else
11   #define debug(...) (void)0
12 #endif
13 using namespace std;
14 typedef long long ll;
15 typedef pair<int,int> PII;
16 typedef vector<int> VI;
17
18 const int MAXN = 100000 + 10;
19
20 struct SplayTree {
21   int val, mx, ch[2], pa;
22   bool rev;
23   void init() {
24     val = mx = -1;
25     rev = false;
26     pa = ch[0] = ch[1] = 0;
27   }
28 } node[MAXN*2];
29
30 inline bool isroot(int x) {
31   return node[node[x].pa].ch[0]!=x && node[
         node[x].pa].ch[1]!=x;
32 }
33
34 inline void pull(int x) {
35   node[x].mx = max(node[x].val, max(node[
         node[x].ch[0]].mx, node[node[x].ch
         [1]].mx));
36 }
37
38 inline void push(int x) {
39   if(node[x].rev) {
40     node[node[x].ch[0]].rev ^= 1;
41     node[node[x].ch[1]].rev ^= 1;
42     swap(node[x].ch[0], node[x].ch[1]);
43     node[x].rev ^= 1;
44   }
45 }
46
47 void push_all(int x) {
48   if(!isroot(x))  push_all(node[x].pa);
49   push(x);
50 }
51
52 inline void rotate(int x) {
53   int y = node[x].pa, z = node[y].pa, d =
         node[y].ch[1]==x;
54   node[x].pa = z;
55   if(!isroot(y))  node[z].ch[node[z].ch
         [1]==y] = x;
56   node[y].ch[d] = node[x].ch[d^1];
57   node[node[x].ch[d^1]].pa = y;
58   node[x].ch[!d] = y;
59   node[y].pa = x;
60   pull(y);
61   pull(x);
62 }
63
64 void splay(int x) {
65   push_all(x);
66   while(!isroot(x)) {
67     int y = node[x].pa;
68     if(!isroot(y)) {
69       int z = node[y].pa;
70       if((node[z].ch[1]==y) ^ (node[y].ch
           [1]==x)) rotate(y);
71       else  rotate(x);
72     }
73     rotate(x);
74   }
75 }
76
77 inline int access(int x) {
78   int last = 0;
79   while(x) {
80     splay(x);
81     node[x].ch[1] = last;
82     pull(x);
83     last = x;
84     x = node[x].pa;
85   }
86   return last;
87 }
88
89 inline void make_root(int x) {
90   node[access(x)].rev ^= 1;
91   splay(x);
92 }
93
```

```
 94 inline void link(int x, int y) {
 95   make_root(x);
 96   node[x].pa = y;
 97 }
 98
 99 inline void cut(int x, int y) {
100   make_root(x);
101   access(y);
102   splay(y);
103   node[y].ch[0] = 0;
104   node[x].pa = 0;
105 }
106
107 inline void cut_parent(int x) {
108   x = access(x);
109   splay(x);
110   node[node[x].ch[0]].pa = 0;
111   node[x].ch[0] = 0;
112   pull(x);
113 }
114
115 inline int find_root(int x) {
116   x = access(x);
117   while(node[x].ch[0])  x = node[x].ch[0];
118   splay(x);
119   return x;
120 }
121
122 int find_mx(int x) {
123   if(node[x].val == node[x].mx) return x;
124   return node[node[x].ch[0]].mx==node[x].mx
          ? find_mx(node[x].ch[0]) : find_mx(
          node[x].ch[1]);
125 }
126
127 inline void change(int x,int b){
128     splay(x);
129     node[x].data=b;
130     up(x);
131 }
132 inline int query_lca(int u,int v){
133 /*retrun: sum of weight of vertices on the
      chain (u->v)
134 sum: total weight of the subtree
135 data: weight of the vertex */
136   access(u);
137   int lca=access(v);
138   splay(u);
139   if(u==lca){
140     return node[lca].data+node[node[lca].ch
          [1]].sum;
141   }else{
142     return node[lca].data+node[node[lca].ch
          [1]].sum+node[u].sum;
143   }
144 }
```

6.7 Heavy Light Decomposition

```
 1 #include <bits/stdc++.h>
 2 #define PB push_back
 3 #define MP make_pair
 4 #define F first
 5 #define S second
 6 #define SZ(x) ((int)(x).size())
 7 #define ALL(x) (x).begin(),(x).end()
 8 #ifdef _DEBUG_
 9   #define debug(...) printf(__VA_ARGS__)
10 #else
11   #define debug(...) (void)0
12 #endif
13 using namespace std;
14 typedef long long ll;
15 typedef pair<int,int> PII;
16 typedef vector<int> VI;
17
18 const int MAXN = 10000 + 10;
19
20 vector<PII> e[MAXN];
21 int val[MAXN];
22 int sz[MAXN], max_son[MAXN], p[MAXN], dep[
     MAXN];
23 int link[MAXN], link_top[MAXN], cnt;
24
25 void find_max_son(int u) {
26   sz[u] = 1;
27   max_son[u] = -1;
28   for(int i=0; i<SZ(e[u]); i++) {
29     PII tmp = e[u][i];
30     int v = tmp.F;
31     if(v == p[u]) continue;
32
33     p[v] = u;
34     dep[v] = dep[u]+1;
35     val[v] = tmp.S;
36     find_max_son(v);
37     if(max_son[u]<0 || sz[v]>sz[ max_son[u]
          ])  max_son[u] = v;
38     sz[u] += sz[v];
39   }
40 }
41
42 void build_link(int u, int top) {
43   link[u] = ++cnt;
44   link_top[u] = top;
45   if(max_son[u] > 0)  build_link(max_son[u
        ], top);
46   for(int i=0; i<SZ(e[u]); i++) {
47     PII tmp = e[u][i];
48     int v = tmp.F;
49     if(v==p[u] || v==max_son[u])  continue;
50
51     build_link(v, v);
52   }
53 }
54
55 int query(int a, int b) {
56   int res = -1;
57   int ta = link_top[a], tb = link_top[b];
58   while(ta != tb) {
59     if(dep[ta] < dep[tb]) {
60       swap(a, b);
61       swap(ta, tb);
62     }
63
64     res = max(res, seg->qry(link[ta], link[
          a], 1, cnt));
65     ta = link_top[a=p[ta]];
```

```
66      }
67
68      if(a != b) {
69        if(dep[a] > dep[b]) swap(a, b);
70        a = max_son[a];
71        res = max(res, seg->qry(link[a], link[b
              ], 1, cnt));
72      }
73
74      return res;
75  }
```

6.8 Disjoint Sets + offline skill

```
1  #include <bits/stdc++.h>
2  #define PB push_back
3  #define MP make_pair
4  #define F first
5  #define S second
6  #define SZ(x) ((int)(x).size())
7  #define ALL(x) (x).begin(),(x).end()
8  #ifdef _DEBUG_
9    #define debug(...) printf(__VA_ARGS__)
10 #else
11   #define debug(...) (void)0
12 #endif
13 using namespace std;
14 typedef long long ll;
15 typedef pair<int,int> PII;
16 typedef vector<int> VI;
17
18 const int MAXN = 300000 + 10;
19
20 bool q[MAXN];
21
22 struct DisJointSet {
23   int p[MAXN], sz[MAXN], gps;
24   vector<pair<int*, int> > h;
25   VI sf;
26
27   void init(int n) {
28     for(int i=1; i<=n; i++) {
29       p[i] = i;
30       sz[i] = 1;
31     }
32     gps = n;
33   }
34
35   void assign(int *k, int v) {
36     h.PB(MP(k, *k));
37     *k = v;
38   }
39
40   void save() {
41     sf.PB(SZ(h));
42   }
43
44   void load() {
45     int last = sf.back(); sf.pop_back();
46     while(SZ(h) != last) {
47       auto x = h.back();  h.pop_back();
48       *x.F = x.S;
49     }
```

```
50      }
51
52      int find(int x) {
53        return x==p[x] ? x : find(p[x]);
54      }
55
56      void uni(int x, int y) {
57        x = find(x), y = find(y);
58        if(x == y)  return ;
59        if(sz[x] < sz[y]) swap(x, y);
60        assign(&sz[x], sz[x]+sz[y]);
61        assign(&p[y], x);
62        assign(&gps, gps-1);
63      }
64  } djs;
65
66  struct Seg {
67    vector<PII> es;
68    Seg *tl, *tr;
69
70    Seg() {}
71    Seg(int l, int r) {
72      if(l == r)  tl = tr = NULL;
73      else {
74        int m = (l+r) / 2;
75        tl = new Seg(l, m);
76        tr = new Seg(m+1, r);
77      }
78    }
79
80    void add(int a, int b, PII e, int l, int
         r) {
81      if(a <= l && r <= b)  es.PB(e);
82      else if(b < l || r < a) return ;
83      else {
84        int m = (l+r) / 2;
85        tl->add(a, b, e, l, m);
86        tr->add(a, b, e, m+1, r);
87      }
88    }
89
90    void solve(int l, int r) {
91      djs.save();
92      for(auto p : es)  djs.uni(p.F, p.S);
93
94      if(l == r) {
95        if(q[l])  printf("%d\n", djs.gps);
96      }
97      else {
98        int m = (l+r) / 2;
99        tl->solve(l, m);
100       tr->solve(m+1, r);
101     }
102
103     djs.load();
104   }
105 };
106
107 map<PII, int> prv;
108
109 int main() {
110   freopen("connect.in", "r", stdin);
111   freopen("connect.out", "w", stdout);
112
113   int n, k;
```

```
114    scanf("%d%d\n", &n, &k);
115    if(!k)   return 0;
116
117    Seg *seg = new Seg(1, k);
118    djs.init(n);
119    for(int i=1; i<=k; i++) {
120        char op = getchar();
121        if(op == '?') {
122            q[i] = true;
123            op = getchar();
124        }
125        else {
126            int u, v;
127            scanf("%d%d\n", &u, &v);
128            if(u > v) swap(u, v);
129            PII eg = MP(u, v);
130            int p = prv[eg];
131            if(p) {
132                seg->add(p, i, eg, 1, k);
133                prv[eg] = 0;
134            }
135            else   prv[eg] = i;
136        }
137    }
138    for(auto p : prv) {
139        if(p.S) {
140            seg->add(p.S, k, p.F, 1, k);
141        }
142    }
143
144    seg->solve(1, k);
145
146        return 0;
147 }
```

6.9 2D Segment Tree

```
1  struct Seg1D {
2    Seg1D *tl, *tr;
3    ll val;
4    // ll tmp;
5    //int _x, _y;
6    Seg1D() :
7      tl(NULL), tr(NULL), val(0), tmp(-1), _x
         (-1), _y(-1) {}
8    ll query1D(int x1, int x2, int y1, int y2
       , int l, int r) {
9      /*
10     if no Brian improvement, dont need to
          pass x1 and x2
11     if(tmp >= 0) {
12        if(x1<=_x&&_x<=x2 && y1<=_y&&_y<=y2)
               return tmp;
13        else   return 0;
14     }
15     */
16     if(y1 <= l && r <= y2)   return val;
17     else if(r < y1 || y2 < l) return 0;
18     else {
19        int m = (l+r)/2;
20        ll a = tl ? tl->query1D(x1, x2, y1,
            y2, l, m) : 0,
```

```
21           b = tr ? tr->query1D(x1, x2, y1,
                y2, m+1, r) : 0;
22        return gcd(a, b);
23     }
24   }
25   void update1D(int x, int y, ll num, int l
       , int r) {
26     if(l == r) {
27        val = num;
28        return ;
29     }
30     /*
31     if(tmp < 0 && !tl && !tr) {
32        tmp = val = num;
33        _x = x;
34        _y = y;
35        return ;
36     }
37     else if(tmp >= 0) {
38        int m = (l+r)/2;
39        if(_y <= m) {
40           if(!tl) tl = new Seg1D();
41           tl->update1D(_x, _y, tmp, l, m);
42        }
43        else {
44           if(!tr) tr = new Seg1D();
45           tr->update1D(_x, _y, tmp, m+1, r);
46        }
47        tmp = _x = _y = -1;
48     }*/
49     int m = (l+r)/2;
50     if(y <= m) {
51        if(!tl) tl = new Seg1D();
52        tl->update1D(x, y, num, l, m);
53     }
54     else {
55        if(!tr) tr = new Seg1D();
56        tr->update1D(x, y, num, m+1, r);
57     }
58     ll a = tl ? tl->val : 0;
59     ll b = tr ? tr->val : 0;
60     val = gcd(a, b);
61   }
62 };
63 struct Seg2D {
64   Seg2D *tl, *tr;
65   Seg1D *t2;
66   Seg2D() :
67     tl(NULL), tr(NULL), t2(NULL) {}
68   ll query2D(int x1, int x2, int y1, int y2
       , int l, int r) {
69     if(x1 <= l && r <= x2) {
70        if(!t2) t2 = new Seg1D();
71        return t2->query1D(x1, x2, y1, y2, 0,
            C-1);
72     }
73     else if(x2 < l || r < x1) return 0;
74     else {
75        int m = (l+r)/2;
76        ll a = tl ? tl->query2D(x1, x2, y1,
            y2, l, m) : 0,
77           b = tr ? tr->query2D(x1, x2, y1,
                y2, m+1, r) : 0;
78        return gcd(a, b);
79     }
```

```
80      }
81    void update2D(int x, int y, ll num, int l
          , int r) {
82      int m = (l+r)/2;
83      if(l == r) {
84        if(!t2) t2 = new Seg1D();
85        t2->update1D(x, y, num, 0, C-1);
86        return ;
87      }
88      if(x <= m) {
89        if(!tl) tl = new Seg2D();
90        tl->update2D(x, y, num, l, m);
91      }
92      else {
93        if(!tr) tr = new Seg2D();
94        tr->update2D(x, y, num, m+1, r);
95      }
96      if(!tl) tl = new Seg2D();
97      if(!tr) tr = new Seg2D();
98      ll a = tl->t2 ? tl->t2->query1D(l, m, y
          , y, 0, C-1) : 0,
99         b = tr->t2 ? tr->t2->query1D(m+1, r,
             y, y, 0, C-1) : 0;
100     if(!t2) t2 = new Seg1D();
101     t2->update1D(x, y, gcd(a, b), 0, C-1);
102   }
103 };
```

7 geometry

7.1 Basic

```
1 // correct code of NPSC2013 senior-final pF
2
3 #include <bits/stdc++.h>
4 #define PB push_back
5 #define F first
6 #define S second
7 #define SZ(x) ((int)(x).size())
8 #define MP make_pair
9 using namespace std;
10 typedef long long ll;
11 typedef pair<int,int> PII;
12 typedef vector<int> VI;
13
14 typedef double db;
15 typedef pair<db, db> PDD;
16
17 PDD operator+(const PDD &a, const PDD &b) {
18     return MP(a.F+b.F, a.S+b.S);
19 }
20 PDD operator-(const PDD &a, const PDD &b) {
21     return MP(a.F-b.F, a.S-b.S);
22 }
23 PDD operator*(const PDD &a, const db &b) {
24     return MP(a.F*b, a.S*b);
25 }
26 PDD operator/(const PDD &a, const db &b) {
27     return MP(a.F/b, a.S/b);
28 }
29 db dot(const PDD &a, const PDD &b) {
30     return a.F*b.F + a.S*b.S;
31 }
32 db cross(const PDD &a, const PDD &b) {
33     return a.F*b.S - a.S*b.F;
34 }
35 db abs2(const PDD &a) {
36   return dot(a, a);
37 }
38 db abs(const PDD &a) {
39     return sqrt( abs2(a) );
40 }
41
42 const db PI = acos(-1);
43 const db INF = 1e18;
44 const db EPS = 1e-8;
45
46 PDD inter(const PDD &p1, const PDD &v1,
      const PDD &p2, const PDD &v2) //
      intersection
47 {
48   if(fabs(cross(v1, v2)) < EPS)
49     return MP(INF, INF);
50   db k = cross((p2-p1), v2) / cross(v1, v2)
       ;
51   return p1 + v1*k;
52 }
53 void CircleInter(PDD o1, db r1, PDD o2, db
    r2) {
54   if(r2>r1)
55     swap(r1, r2), swap(o1, o2);
56   db d = abs(o2-o1);
57   PDD v = o2-o1;
58   v = v / abs(v);
59   PDD t = MP(v.S, -v.F);
60
61   db area;
62   vector<PDD> pts;
63   if(d > r1+r2+EPS)
64     area = 0;
65   else if(d < r1-r2)
66     area = r2*r2*PI;
67   else if(r2*r2+d*d > r1*r1){
68     db x = (r1*r1 - r2*r2 + d*d) / (2*d);
69     db th1 = 2*acos(x/r1), th2 = 2*acos((d-
         x)/r2);
70     area = (r1*r1*(th1 - sin(th1)) + r2*r2
         *(th2 - sin(th2))) / 2;
71     db y = sqrt(r1*r1 - x*x);
72     pts.PB(o1 + v*x + t*y), pts.PB(o1 + v*x
         - t*y);
73   } else {
74     db x = (r1*r1 - r2*r2 - d*d) / (2*d);
75     db th1 = acos((d+x)/r1), th2 = acos(x/
         r2);
76     area = r1*r1*th1 - r1*d*sin(th1) + r2*
         r2*(PI-th2);
77     db y = sqrt(r2*r2 - x*x);
78     pts.PB(o2 + v*x + t*y), pts.PB(o2 + v*x
         - t*y);
79   }
80   //Area: area
81   //Intersections: pts
82 }
83
84 int main() {
85   return 0;
```

```
86 }
```

7.2 Smallist circle problem

```
 1 #include <cstdlib>
 2 #include <cstdio>
 3 #include <algorithm>
 4 #include <cmath>
 5
 6 using namespace std;
 7
 8 const int N = 1000000 + 10;
 9
10 struct PT {
11   double x, y;
12
13   PT() {}
14   PT(double x, double y):
15     x(x), y(y) {}
16   PT operator+(const PT &b) const {
17     return (PT) {x+b.x, y+b.y};
18   }
19   PT operator-(const PT &b) const {
20     return (PT) {x-b.x, y-b.y};
21   }
22   PT operator*(const double b) const {
23     return (PT) {x*b, y*b};
24   }
25   PT operator/(const double b) const {
26     return (PT) {x/b, y/b};
27   }
28   double operator%(const PT &b) const {
29     return x*b.y - y*b.x;
30   }
31
32   double len() const {
33     return sqrt(x*x + y*y);
34   }
35   PT T() const {
36     return (PT) {-y, x};
37   }
38 } p[N];
39
40 void update(PT a, PT b, PT c, PT &o, double
       &r) {
41   if(c.x < 0.0) o = (a+b) / 2.0;
42   else {
43     PT p1 = (a+b)/2.0, p2 = p1 + (b-a).T();
44     PT p3 = (a+c)/2.0, p4 = p3 + (c-a).T();
45     double a123 = (p2-p1)%(p3-p1), a124 = (
         p2-p1)%(p4-p1);
46     if(a123 * a124 > 0.0) a123 = -a123;
47     else  a123 = abs(a123), a124 = abs(a124
         );
48     o = (p4*a123 + p3*a124) / (a123 + a124)
         ;
49   }
50   r = (a-o).len();
51 }
52
53 int main() {
54   srand(7122);
55
```

```
56   int m, n;
57   while(scanf("%d%d", &m, &n)) {
58     if(!n && !m)  return 0;
59
60     for(int i = 0; i < n; i++)  scanf("%lf%
         lf", &p[i].x, &p[i].y);
61
62     for(int i = 0; i < n; i++)
63       swap(p[i], p[rand() % (i+1)]);
64
65     PT a = p[0], b = p[1], c(-1.0, -1.0), o
         = (a+b) / 2.0;
66     double r = (a-o).len();
67     for(int i = 2; i < n; i++) {
68       if((p[i]-o).len() <= r) continue;
69
70       a = p[i];
71       b = p[0];
72       c = (PT) {-1.0, -1.0};
73       update(a, b, c, o, r);
74       for(int j = 1; j < i; j++) {
75         if((p[j]-o).len() <= r) continue;
76
77         b = p[j];
78         c = (PT) {-1.0, -1.0};
79         update(a, b, c, o, r);
80
81         for(int k = 0; k < j; k++) {
82           if((p[k]-o).len() <= r) continue;
83
84           c = p[k];
85           update(a, b, c, o, r);
86         }
87       }
88     }
89
90     printf("%.3f\n", r);
91   }
92 }
```

8 Others

8.1 Random

```
1 const int seed=1;
2
3 mt19937 rng(seed);
4 int randint(int lb,int ub) { // [lb, ub]
5   return uniform_int_distribution<int>(lb,
      ub)(rng);
6 }
```

8.2 Fraction

```
1 struct Frac {
2   ll a,b; //  a/b
3   void relax() {
4     ll g=__gcd(a,b);
5     if(g!=0 && g!=1)
6       a/=g, b/=g;
7     if(b<0)
```

```
 8        a*=-1, b*=-1;
 9    }
10    Frac(ll a_=0,ll b_=1): a(a_), b(b_) {
11        relax();
12    }
13    Frac operator + (Frac x) {
14        relax();
15        x.relax();
16        ll g=__gcd(b,x.b);
17        ll lcm=b/g*x.b;
18        return Frac(a*(lcm/b)+x.a*(lcm/x.b),lcm
             );
19    }
20    Frac operator - (Frac x) {
21        relax();
22        x.relax();
23        Frac t=x;
24        t.a*=-1;
25        return *this+t;
26    }
27    Frac operator * (Frac x) {
28        relax();
29        x.relax();
30        return Frac(a*x.a,b*x.b);
31    }
32    Frac operator / (Frac x) {
33        relax();
34        x.relax();
35        Frac t=Frac(x.b,x.a);
36        return (*this)*t;
37    }
38    bool operator < (Frac x) {
39        ll lcm=b/__gcd(b,x.b)*x.b;
40        return ( (lcm/b)*a < (lcm/x.b)*x.a );
41    }
42 };
```


THIS SIDE UP

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