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1 Basic

1.1 default code

```

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 int main() {
19     return 0;
20 }
```

1.2 .vimrc

```

1 color torte
2 syn on
3 set guifont=Consolas:h16: nu sc ai si ts=4
   sm sts=4 sw=4
4
5 map <F9> <ESC>:w<CR>:!g++ % -o %< -O2 -Wall
   -Wno-unused-result -std=c++0x<CR>
6 map <S-F9> <ESC>:w<CR>:!g++ % -o %< -O2 -
   Wall -Wno-unused-result -D_DEBUG_ -std=c
   ++0x<CR>
7 map <F5> <ESC>:!./%<<CR>
8 map <F6> <ESC>:w<CR>ggVG"+y
9 map <S-F5> <ESC>:!./%< < %<.in<CR>
10 imap <Home> <ESC>^i
11 com INPUT sp %<.in
```

2 math

2.1 ext gcd

```

1 // find one solution (x,y) of ax+by=gcd(
   a,b)
2 void ext_gcd(int a,int b,int &g,int &x,int
   &y)
3 {
4     if(!b){ g=a; x=1; y=0; }
5     else{ ext_gcd(b, a%b, g, y, x); y -= x*(a
   /b); }
6 }
```

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]*Wn;
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 }
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<n;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 }

```

2.3 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 111*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);

```

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),
34                 d%2?a:1, n);
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-->0) {
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,
55                 9780504, 1795265022};
56     for(int i=0; i<7; i++)
57         if(miller_rabin(n, as[i]) == COMPOSITE)
58             return COMPOSITE;
59     return PRIME;
60 }

```

2.5 Guass

```

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

```

```

11         for(int k = 0; k < 8; k++)
12             mat[j][k] = mat[j][k] - ratio * mat
13                 [i][k];
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 ,
22                                     // maxflow=c
23         eg[ei]=E(b,c);
24         e[a].PB(eg[ei]);
25         ei++;
26         eg[ei]=E(a,0);
27         e[b].PB(eg[ei]);
28         ei++;
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]
57             ].co==0)
58             continue;
59         if((temp=go(eg[u[i]].to,min(p,eg[u[i]
60             ].co)))==0)
61             continue;
62         eg[u[i]].co-=temp;
63         eg[u[i]^1].co+=temp;
64         ptr[n]=i;
65         return temp;
66     }
67     ptr[n]=SZ(u);
68     return 0;
69 }
70 int max_flow() {
71     int ans=0,temp;
72     while(BFS()) {
73         for(int i=0;i<v;i++)
74             ptr[i]=0;
75         while((temp=go(0,INF))>0)
76             ans+=temp;
77     }
78     return ans;
79 }
80 }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),
11         cost(co) {}
12 }eg[2*MAXE];
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].
47                     cost,d[v].S+1)<d[eg[id].to]) {
48                     d[eg[id].to]=MP(d[v].F+eg[id].
49                         cost,d[v].S+1);
50                     if(!inq[eg[id].to]) {
51                         que.push(eg[id].to);
52                         inq[eg[id].to]=1;
53                     }
54                 }
55             }
56         }
57         return d[n-1].F<INF;
58     }
59     PIL go(ll cb=cINF) {
60         // cost_bound
61         if(!SPFA()) return MP(0,0);
62         pe.clear();
63         int fl=INF;
64         for(int v=n-1;v!=0;) {
65             for(int id:e[v]) {
66                 int u=eg[id].to;
67                 const E& t=eg[id^1];
68                 if(t.ca>0 && MP(d[u].F+t.cost,d[u].
69                     S+1)==d[v]) {
70                     fl=min(fl, t.ca);
71                     v=u;
72                     pe.PB(id^1);
73                     break;
74                 }
75             }
76         }
77         if(d[n-1].F>0) fl=min(1ll*fl, cb/d[n-1].F);
78         for(int id:pe) {
79             eg[id].ca-=fl;
80             eg[id^1].ca+=fl;
81         }
82         return MP(fl, 1ll*fl*d[n-1].F);
83     }
84     PIL max_flow() {
85         PIL ans=MP(0,0),temp;
86         while((temp=go()).F>0) {
87             ans.F+=temp.F;
88             ans.S+=temp.S;
89         }
90         return ans;
91     }
92 } 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,
13     const char *T) {
14     VI ans;
15     int p=-1;
16     for(int i=0;T[i];i++) {
17         while(p!=-1 && S[p+1]!=T[i])
18             p=F[p];
19         if(S[p+1]==T[i])
20             p++;
21         if(!S[p+1]) {
22             ans.pb(i-p);
23             p=F[p];
24         }
25     }
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($O(N\log N)$)

```

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]
50             -1]+i<tR[SA[j]+i])
51             num++;
52         R[SA[j]]=num;
53         maxR=max(maxR,R[SA[j]]);
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 <stdio>
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'
18         +26;
19 }
20
21 void insert(char *s,int num) {
22     Trie *at=root;
23     while(*s) {
24         if(!at->ch[c_i(*s)])
25             at->ch[c_i(*s)]=new (na++) Trie();
26         at=at->ch[c_i(*s)],s++;
27     }
28     str[num]=at;
29 }
30
31 Trie *q[1000100];
32 int ql,qr;
33
34 void init() {
35     ql=qr=-1;
36     q[++qr]=root;
37     root->fail=NULL;
38     while(ql<qr) {
39         Trie *n=q[++ql],*f;
40         for(int i=0;i<52;i++) {
41             if(!n->ch[i])
42                 continue;
43             f=n->fail;
44             while(f && !f->ch[i])
45                 f=f->fail;
46             n->ch[i]->fail=f?f->ch[i]:root;
47             q[++qr]=n->ch[i];
48         }
49     }
50 }
51
52 void go(char *s) {
53     Trie*p=root;
54     while(*s) {
55         while(p && !p->ch[c_i(*s)])
56             p=p->fail;
57         p=p->ch[c_i(*s)];
58         p->fi=1;
59         s++;
60     }
61 }
62
63 void AC() {
64     for(int i=qr;i>0;i--)
65         q[i]->fail->c+=q[i]->c;
66 }
67
68 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(1);
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=f1[p];
54             for(;tmp&&nx[tmp][i]==0;) tmp=f1[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=f1[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],
9   cnt[MAXN];
10 int edp[MAXN];
11 int nid=1;
12 int new_node(int len_) {
13     len[nid]=len_;
14     return nid++;
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
28             [cur]+2);
29             int tmp=fail[cur];
30             while(tmp && s[i-len[tmp]-1]!=s[i])
31                 tmp=fail[tmp];
32             if(tmp==0) fail[nt]=even_root;
33             else {
34                 assert(ch[tmp][s[i]-'a']);
35                 fail[nt]=ch[tmp][s[i]-'a'];
36             }
37             edp[nt]=i;
38         }
39         cur=ch[cur][s[i]-'a'];
40         cnt[cur]++;
41     }
42     for(int i=nid-1;i>even_root;i--) {
43         cnt[fail[i]]+=cnt[i];
44         pal.PB( MP( MP(edp[i]-len[i]+1, len[i])
45             , cnt[i]) ));
46     }
47 }

```

4.8 Suffix Automaton(bcw)

```

1 // par : fail link

```

```

2 // val : a topological order ( useful for
3 // DP )
4 // go[x] : automata edge ( x is integer in
5 // [0,26) )
6
7 struct SAM{
8     struct State{
9         int par, go[26], val;
10         State () : par(0), val(0){ FZ(go); }
11         State (int _val) : par(0), val(_val){
12             FZ(go); }
13     };
14     vector<State> vec;
15     int root, tail;
16
17     void init(int arr[], int len){
18         vec.resize(2);
19         vec[0] = vec[1] = State(0);
20         root = tail = 1;
21         for (int i=0; i<len; i++)
22             extend(arr[i]);
23     }
24     void extend(int w){
25         int p = tail, np = vec.size();
26         vec.PB(State(vec[p].val+1));
27         for ( ; p && vec[p].go[w]==0; p=vec[p].
28             par)
29             vec[p].go[w] = np;
30         if (p == 0){
31             vec[np].par = root;
32         } else {
33             if (vec[vec[p].go[w]].val == vec[p].
34                 val+1){
35                 vec[np].par = vec[p].go[w];
36             } else {
37                 int q = vec[p].go[w], r = vec.size
38                     ();
39                 vec.PB(vec[q]);
40                 vec[r].val = vec[p].val+1;
41                 vec[q].par = vec[np].par = r;
42                 for ( ; p && vec[p].go[w] == q; p=
43                     vec[p].par)
44                     vec[p].go[w] = r;
45             }
46         }
47         tail = np;
48     }
49 }

```

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
41             (match[u])))
42         {
43             match[u]=x;
44             match[x]=u;
45             return 1;
46         }
47     }
48     return 0;
49 }
50
51 int main()
52 {
53     int N;
54     while(scanf("%d",&N)==1)
55     {
56         odd.clear();
57         even.clear();
58         for(int i=0;i<N;i++)
59             e[i].clear();
60         for(int i=0;i<N;i++)
61         {
62             scanf("%d",in+i);
63             if(in[i]%2==0)
64                 even.pb(i);
65             else
66                 odd.pb(i);
67         }
68         for(int i:even)
69             for(int j:odd)
70                 if(is(1ll*in[i]*in[i]+1ll*in[j]*in[j]) && __gcd(in[i],in[j])==1)
71                     e[i].pb(j), e[j].pb(i);
72         int ans=0;
73         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
4 // set of vertex
5 int N; // two set: each set have exactly N
6 // vertex
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])
12            continue;
13        vis[N+i]=1;
14        if(match[N+i]==-1 || (!vis[match[N+i]]
15            &&DFS(match[N+i]))) {
16            match[N+i]=x;
17            match[x]=N+i;
18            return 1;
19        }
20    }
21    return 0;
22 }
23
24 int KM() {
25     fill(weight, weight+N*N, 0);
26     for(int i=0;i<N;i++) {
27         for(int j=0;j<N;j++)
28             weight[i]=max(weight[i], a[i][j]);
29     }
30     fill(match, match+N*N, -1);
31     for(int u=0;u<N;u++) {
32         fill(vis, vis+N*N, 0);
33         while(!DFS(u)) {
34             int d=INF;
35             for(int i=0;i<N;i++) {
36                 if(!vis[i]) continue;
37                 for(int j=0;j<N;j++)
38                     if(!vis[N+j])
39                         d=min(d, weight[i]+weight[N+j]-
40                             a[i][j]);
41             }
42             for(int i=0;i<N;i++)
43                 if(vis[i])
44                     weight[i]-=d;
45             for(int i=N;i<N+N;i++)
46                 if(vis[i])
47                     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])
76                    && (pr[u] != v)) {
77                    if((v == st) || ((pr[v] > 0) &&
78                        bk[pr[v]] > 0))
79                        blo(u,v);
80                    else if(bk[v] == 0) {
81                        bk[v] = u;
82                        if(pr[v] > 0) {
83                            if(!inq[pr[v]]) qe.push(pr[v]);
84                        } else {
85                            ed = v;
86                            return;
87                        }
88                    }
89                }
90        }
91    void aug() {
92        int u,v,w;
93        u = ed;
94        while(u > 0) {
95            v = bk[u];
96            w = pr[v];
97            pr[v] = u;
98            pr[u] = v;
99            u = w;
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
43                    0;
44                int lb = a&(-a), lg = 0;
45                a ^= lb;
46                while(lb!=1) {
47                    lb = (unsigned int)(lb)
48                        >> 1;
49                    lg ++;
50                }
51                int u = i*32 + lg;
52                if(k + dp[u] <= ans) return
53                    0;
54                if(dfs(u, k+1)) {
55                    sol.push_back(v);
56                    return 1;
57                }
58            }
59        }
60        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]=1;
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]==1) {
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     }
64     fill(vis,vis+N,0);
65     while(bccnt)
66         BCC[--bccnt].clear();
67     DFS(0,-1,0);
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()),
21         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,
68     Treap *&b) {
69     if(!t) a = b = NULL;
70     else if(sz(t->l) < k) {
71         a = t;
72         push(a);
73         split(t->r, k - sz(t->l) - 1, a->r, b);
74         pull(a);
75     }
76     else {
77         b = t;
78         push(b);
79         split(t->l, k, a, b->l);
80         pull(b);
81     }
82 }
83
84 int main() {
85     srand(105105);

```

```

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

```

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) {}
20 };
21 Treap* make(Treap* t) {
22     return new Treap(*t);
23 }
24

```

```

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;
67 }
68
69 void pull(Treap* t) {
70     t->sz = sz(t->l) + sz(t->r) + 1;
71 }
72
73 Treap* merge(Treap* a, Treap* b) {
74     if(!a || !b) {
75         Treap* t = a ? make(a) : make(b);
76         t->refs = 0;
77         takeRef(t->l);
78         takeRef(t->r);
79         return t;
80     }
81
82     Treap* t;
83     if( rnd(a->sz+b->sz) < a->sz) {
84         t = make(a);
85         t->refs = 0;
86         t->r = merge(a->r, b);
87         takeRef(t->l);
88         takeRef(t->r);
89     }
90 }

```

```

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;
154
155         split(t, l, a, b);
156         dropRef(a);
157         split(b, r-l, c, d);
158         dropRef(b);
159         dropRef(d);
160         split(t, x, a, b);
161         dropRef(t);
162         Treap* t2 = merge(c, b);
163         dropRef(b);
164         dropRef(c);
165         t = merge(a, t2);
166         dropRef(a);
167         dropRef(t2);
168
169         if(t->sz > m) {
170             Treap* t2 = NULL;
171             split(t, m, t2, a);
172             dropRef(a);
173             dropRef(t);
174             t = t2;
175         }
176
177         print(t);
178         putchar('\n');
179
180     }
181     return 0;
182 }

```

6.3 copy on write segment tree

```

121 void print_inorder(Treap* t) {
122     if(!t) return;
123     putchar(t->val);
124     print_inorder(t->l);
125     print_inorder(t->r);
126 }
127
128 char s[N];
129
130 int main() {
131     int m;
132     scanf("%d", &m);
133     scanf("%s", s);
134     int n = strlen(s);
135     int q;
136     scanf("%d", &q);
137
138     Treap* t = NULL;
139     for(int i = 0; i < n; i++) {
140         Treap *a = t, *b = make(s[i]);
141         t = merge(a, b);
142         dropRef(a);
143         dropRef(b);
144     }
145
146     while(q--) {
147         int l, r, x;
148         scanf("%d%d%d", &l, &r, &x);
149         r++;
150
151         Treap *a, *b, *c, *d;
152         a = b = c = d = NULL;
153
154         split(t, l, a, b);
155         dropRef(a);
156         split(b, r-l, c, d);
157         dropRef(b);
158         dropRef(d);
159         split(t, x, a, b);
160         dropRef(t);
161         Treap* t2 = merge(c, b);
162         dropRef(b);
163         dropRef(c);
164         t = merge(a, t2);
165         dropRef(a);
166         dropRef(t2);
167
168         if(t->sz > m) {
169             Treap* t2 = NULL;
170             split(t, m, t2, a);
171             dropRef(a);
172             dropRef(t);
173             t = t2;
174         }
175
176         print(t);
177         putchar('\n');
178
179         return 0;
180     }
181 }

```

```

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->t1 = t1->add(k, l, m);
39 else _t->tr = tr->add(k, m+1, r);
40
41 _t->val = _t->t1->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,
47     int r) {
48     if(l == r) return l;
49
50     int m = (l+r)/2;
51
52     int a = ta->t1->val;
53     int b = tb->t1->val;
54     if(b-a >= k) return query(ta->t1, tb->t1,
55         k, l, m);
56     else return query(ta->tr, tb->tr, k,
57         -(b-a), m+1, r);
58 };
59
60 struct Query {
61     int op, l, r, k, c, v;
62
63     bool operator<(const Query b) const {
64         return c < b.c;
65     }
66 } qs[Q];
67 int arr[N];
68 Seg *t[N];
69 vector<int> vec2;
70
71 int main() {
72     int T;
73     scanf("%d", &T);
74
75     while(T--) {
76         int n, q;
77         scanf("%d%d", &n, &q);
78
79         for(int i = 1; i <= n; i++) {
80             scanf("%d", arr+i);
81             vec2.push_back(arr[i]);
82         }
83         for(int i = 0; i < q; i++) {
84             scanf("%d", &qs[i].op);
85             if(qs[i].op == 1) scanf("%d%d%d", &qs[i].l, &qs[i].r, &qs[i].k);
86             else scanf("%d%d", &qs[i].c, &qs[i].v);
87
88             if(qs[i].op == 2) vec2.push_back(qs[i].v);
89         }
90         sort(vec2.begin(), vec2.end());
91         vec2.resize(unique(vec2.begin(), vec2.end())-vec2.begin());
92         for(int i = 1; i <= n; i++) arr[i] = lower_bound(vec2.begin(), vec2.end(),
93             arr[i]) - vec2.begin();
94         int mn = 0, mx = vec2.size()-1;
95
96         for(int i = 0; i <= n; i++) t[i] = NULL;
97         t[0] = new (Seg::pmem++) Seg();
98         t[0] = t[0]->init(mn, mx);
99         int ptr = 0;
100         for(int i = 1; i <= n; i++) {
101             t[i] = t[i-1]->add(arr[i], mn, mx);
102         }
103
104         for(int i = 0; i < q; i++) {
105             int op = qs[i].op;
106             if(op == 1) {
107                 int l = qs[i].l, r = qs[i].r, k = qs[i].k;
108                 printf("%d\n", vec2[query(t[l-1], t[r], k, mn, mx)]);
109             }
110             if(op == 2) {
111                 continue;
112             }
113             if(op == 3) puts("7122");
114         }
115
116         vec2.clear();
117         Seg::pmem = Seg::mem;
118     }
119     return 0;
120 }

```

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,
12         rsum, mx_sum;
13     Treap *l, *r;
14
15     Treap() {}
16     Treap(int _val) :
17         pri(rand()), sz(1), val(_val), chg(
18             INF), rev(0), sum(_val), lsum(
19                 _val), rsum(_val), mx_sum(_val),
20                 l(NULL), r(NULL) {}
21
22     int sz(Treap* t) {return t ? t->sz : 0;}
23     int sum(Treap* t) {
24         if(!t) return 0;
25         if(t->chg == INF) return t->sum;
26         else return t->chg*t->sz;
27     }

```

```

25 int lsum(Treap* t) {
26     if(!t) return -INF;
27     if(t->chg != INF) return max(t->chg,
28         (t->chg)*(t->sz));
29     if(t->rev) return t->rsum;
30     return t->lsum;
31 }
32 int rsum(Treap* t) {
33     if(!t) return -INF;
34     if(t->chg != INF) return max(t->chg,
35         (t->chg)*(t->sz));
36     if(t->rev) return t->lsum;
37     return t->rsum;
38 }
39 int mx_sum(Treap* t) {
40     if(!t) return -INF;
41     if(t->chg != INF) return max(t->chg,
42         (t->chg)*(t->sz));
43     return t->mx_sum;
44 }
45 void push(Treap* t) {
46     if(t->chg != INF) {
47         t->val = t->chg;
48         t->sum = (t->sz) * (t->chg);
49         t->lsum = t->rsum = t->mx_sum = max
50             (t->sum, t->val);
51         if(t->l) t->l->chg = t->chg;
52         if(t->r) t->r->chg = t->chg;
53         t->chg = INF;
54     }
55     if(t->rev) {
56         swap(t->l, t->r);
57         if(t->l) t->l->rev ^= 1;
58         if(t->r) t->r->rev ^= 1;
59         t->rev = 0;
60     }
61 }
62 void pull(Treap* t) {
63     t->sz = sz(t->l)+sz(t->r)+1;
64     t->sum = sum(t->l)+sum(t->r)+t->val;
65     t->lsum = max(lsum(t->l), sum(t->l)+max
66         (0, lsum(t->r))+t->val);
67     t->rsum = max(rsum(t->r), sum(t->r)+max
68         (0, rsum(t->l))+t->val);
69     t->mx_sum = max(max(mx_sum(t->l),
70         mx_sum(t->r)), max(0, rsum(t->l))+
71         max(0, lsum(t->r))+t->val);
72 }
73 Treap* merge(Treap* a, Treap* b) {
74     if(!a || !b) return a ? a : b;
75     if(a->pri > b->pri) {
76         push(a);
77         a->r = merge(a->r, b);
78         pull(a);
79         return a;
80     }
81     else {
82         push(b);
83         b->l = merge(a, b->l);
84         pull(b);
85         return b;
86     }
87 }
88 void split(Treap* t, int k, Treap* &a,
89     Treap* &b) {
90     if(!t) {
91         a = b = NULL;
92         return ;
93     }
94     push(t);
95     if(sz(t->l) < k) {
96         a = t;
97         push(a);
98         split(t->r, k-sz(t->l)-1, a->r, b);
99         pull(a);
100     }
101     else {
102         b = t;
103         push(b);
104         split(t->l, k, a, b->l);
105         pull(b);
106     }
107 }
108 void del(Treap* t) {
109     if(!t) return;
110     del(t->l);
111     del(t->r);
112     delete t;
113 }
114 int main() {
115     srand(7122);
116
117     int n, m;
118     scanf("%d%d", &n, &m);
119
120     Treap* t = NULL;
121     for(int i = 0; i < n; i++) {
122         int x;
123         scanf("%d", &x);
124         t = merge(t, new Treap(x));
125     }
126
127     while(m--) {
128         char s[15];
129         scanf("%s", s);
130
131         Treap *t1 = NULL, *tr = NULL, *t2 =
132             NULL;
133
134         if(!strcmp(s, "INSERT")) {
135             int p, k;
136             scanf("%d%d", &p, &k);
137             for(int i = 0; i < k; i++) {
138                 int x;
139                 scanf("%d", &x);
140                 t2 = merge(t2, new Treap(x)
141                     );
142             }
143             split(t, p, t1, tr);
144             t = merge(t1, merge(t2, tr));
145         }
146
147         if(!strcmp(s, "DELETE")) {
148             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[
32         node[x].pa].ch[1]!=x;
33 }

```

```

34 inline void pull(int x) {
35     node[x].mx = max(node[x].val, max(node[
36         node[x].ch[0]].mx, node[node[x].ch
37         [1]].mx));
38 }
39
40 inline void push(int x) {
41     if(node[x].rev) {
42         node[node[x].ch[0]].rev ^= 1;
43         node[node[x].ch[1]].rev ^= 1;
44         swap(node[x].ch[0], node[x].ch[1]);
45         node[x].rev ^= 1;
46     }
47 }
48
49 void push_all(int x) {
50     if(!isroot(x)) push_all(node[x].pa);
51     push(x);
52 }
53
54 inline void rotate(int x) {
55     int y = node[x].pa, z = node[y].pa, d =
56         node[y].ch[1]==x;
57     node[x].pa = z;
58     if(!isroot(y)) node[z].ch[node[z].ch
59         [1]==y] = x;
60     node[y].ch[d] = node[x].ch[d^1];
61     node[node[x].ch[d^1]].pa = y;
62     node[x].ch[!d] = y;
63     node[y].pa = x;
64     pull(y);
65     pull(x);
66 }
67
68 void splay(int x) {
69     push_all(x);
70     while(!isroot(x)) {
71         int y = node[x].pa;
72         if(!isroot(y)) {
73             int z = node[y].pa;
74             if((node[z].ch[1]==y) ^ (node[y].ch
75                 [1]==x)) rotate(y);
76             else rotate(x);
77         }
78         rotate(x);
79     }
80 }
81
82 inline int access(int x) {
83     int last = 0;
84     while(x) {
85         splay(x);
86         node[x].ch[1] = last;
87         pull(x);
88         last = x;
89         x = node[x].pa;
90     }
91     return last;
92 }
93
94 inline void make_root(int x) {
95     node[access(x)].rev ^= 1;
96     splay(x);
97 }

```

```

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
134     chain (u->v)
135     sum: total weight of the subtree
136     data: weight of the vertex */
137     access(u);
138     int lca=access(v);
139     splay(u);
140     if(u==lca){
141         return node[lca].data+node[node[lca].ch
            [1]].sum;
142     }else{
143         return node[lca].data+node[node[lca].ch
            [1]].sum+node[u].sum;
144     }
145 }
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```

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
72         ], 1, cnt));
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
81         r) {
82         if(a <= l && r <= b) es.PB(e);
83         else if(b < l || r < a) return;
84         else {
85             int m = (l+r) / 2;
86             tl->add(a, b, e, l, m);
87             tr->add(a, b, e, m+1, r);
88         }
89     }
90
91     void solve(int l, int r) {
92         djs.save();
93         for(auto p : es) djs.uni(p.F, p.S);
94
95         if(l == r) {
96             if(q[l]) printf("%d\n", djs.gps);
97         }
98         else {
99             int m = (l+r) / 2;
100             tl->solve(l, m);
101             tr->solve(m+1, r);
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
8         (-1), _y(-1) {}
9     ll query1D(int x1, int x2, int y1, int y2
10         , int l, int r) {
11         /*
12         if no Brian improvement, dont need to
13         pass x1 and x2
14         if(tmp >= 0) {
15             if(x1<=_x&&_x<=x2 && y1<=_y&&_y<=y2)
16                 return tmp;
17             else return 0;
18         }
19         */
20         if(y1 <= 1 && r <= y2) return val;
21         else if(r < y1 || y2 < 1) return 0;
22         else {
23             int m = (l+r)/2;
24             ll a = tl ? tl->query1D(x1, x2, y1,
25                 y2, l, m) : 0,

```

```

26             b = tr ? tr->query1D(x1, x2, y1,
27                 y2, m+1, r) : 0;
28             return gcd(a, b);
29         }
30     }
31 void update1D(int x, int y, ll num, int l
32     , int r) {
33     if(l == r) {
34         val = num;
35         return ;
36     }
37     /*
38     if(tmp < 0 && !tl && !tr) {
39         tmp = val = num;
40         _x = x;
41         _y = y;
42         return ;
43     }
44     else if(tmp >= 0) {
45         int m = (l+r)/2;
46         if(_y <= m) {
47             if(!tl) tl = new Seg1D();
48             tl->update1D(_x, _y, tmp, l, m);
49         }
50         else {
51             if(!tr) tr = new Seg1D();
52             tr->update1D(_x, _y, tmp, m+1, r);
53         }
54         tmp = _x = _y = -1;
55     }*/
56     int m = (l+r)/2;
57     if(y <= m) {
58         if(!tl) tl = new Seg1D();
59         tl->update1D(x, y, num, l, m);
60     }
61     else {
62         if(!tr) tr = new Seg1D();
63         tr->update1D(x, y, num, m+1, r);
64     }
65     ll a = tl ? tl->val : 0;
66     ll b = tr ? tr->val : 0;
67     val = gcd(a, b);
68 }
69 struct Seg2D {
70     Seg2D *tl, *tr;
71     Seg1D *t2;
72     Seg2D() :
73         tl(NULL), tr(NULL), t2(NULL) {}
74     ll query2D(int x1, int x2, int y1, int y2
75         , int l, int r) {
76         if(x1 <= 1 && r <= x2) {
77             if(!t2) t2 = new Seg1D();
78             return t2->query1D(x1, x2, y1, y2, 0,
79                 C-1);
80         }
81         else if(x2 < 1 || r < x1) return 0;
82         else {
83             int m = (l+r)/2;
84             ll a = tl ? tl->query2D(x1, x2, y1,
85                 y2, l, m) : 0,
86             b = tr ? tr->query2D(x1, x2, y1,
87                 y2, m+1, r) : 0;
88             return gcd(a, b);
89         }
90     }

```



```

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(!t1) t1 = new Seg2D();
90         t1->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(!t1) t1 = new Seg2D();
97     if(!tr) tr = new Seg2D();
98     ll a = t1->t2 ? t1->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         ;
52     return p1 + v1*k;
53 }
54 void CircleInter(PDD o1, db r1, PDD o2, db
    r2) {
55     if(r2>r1)
56         swap(r1, r2), swap(o1, o2);
57     db d = abs(o2-o1);
58     PDD v = o2-o1;
59     v = v / abs(v);
60     PDD t = MP(v.S, -v.F);
61
62     db area;
63     vector<PDD> pts;
64     if(d > r1+r2+EPS)
65         area = 0;
66     else if(d < r1-r2)
67         area = r2*r2*PI;
68     else if(r2*r2+d*d > r1*r1){
69         db x = (r1*r1 - r2*r2 + d*d) / (2*d);
70         db th1 = 2*acos(x/r1), th2 = 2*acos((d-x)/r2);
71         area = (r1*r1*(th1 - sin(th1)) + r2*r2
            *(th2 - sin(th2))) / 2;
72         db y = sqrt(r1*r1 - x*x);
73         pts.PB(o1 + v*x + t*y), pts.PB(o1 + v*x
            - t*y);
74     } else {
75         db x = (r1*r1 - r2*r2 - d*d) / (2*d);
76         db th1 = acos((d+x)/r1), th2 = acos(x/
            r2);
77         area = r1*r1*th1 - r1*d*sin(th1) + r2*
            r2*(PI-th2);
78         db y = sqrt(r2*r2 - x*x);
79         pts.PB(o2 + v*x + t*y), pts.PB(o2 + v*x
            - t*y);
80     }
81     //Area: area
82     //Intersections: pts
83 }
84 int main() {
85     return 0;

```

86 | }

7.2 Smallest 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     printf("%.3f\n", r);
90 }
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 }
21 Frac operator - (Frac x) {
22     relax();
23     x.relax();
24     Frac t=x;
25     t.a*=-1;
26     return *this+t;
27 }
28 Frac operator * (Frac x) {
29     relax();
30     x.relax();
31     return Frac(a*x.a,b*x.b);
32 }
33 Frac operator / (Frac x) {
34     relax();
35     x.relax();
36     Frac t=Frac(x.b,x.a);
37     return (*this)*t;
38 };
```