

Code Library



Himemiyu Nanao @ Perfect Freeze

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1 Data Structure

1.1 atlantis

```
1 #include<cstdio>
2 #include<algorithm>
3 #include<map>
4
5 #define MAXX 111
6 #define inf 333
7 #define MAX inf*5
8
9 int mid[MAX],cnt[MAX];
10 double len[MAX];
11
12 int n,i,cas;
13 double x1,x2,y1,y2;
14 double ans;
15 std::map<double,int>map;
16 std::map<double,int>::iterator it;
17 double rmap[inf];
18
19 void make(int id,int l,int r)
20 {
21     mid[id]=(l+r)>>1;
22     if(l==r)
23     {
24         make(id<<1,l,mid[id]);
25         make(id<<1|1,mid[id]+1,r);
26     }
27 }
28
29 void update(int id,int ll,int rr,int l,int r,int val)
30 {
31     if(ll==l && rr==r)
32     {
33         cnt[id]+=val;
34         if(cnt[id])
35             len[id]=rmap[r]-rmap[l-1];
36         else
37             if(l!=r)
38                 len[id]=len[id<<1]+len[id<<1|1];
39             else
40                 len[id]=0;
41         return;
42     }
43     if(mid[id]>=r)
44         update(id<<1,ll,mid[id],l,r,val);
45     else
46         if(mid[id]<l)
47             update(id<<1|1,mid[id]+1,rr,l,r,val);
48         else
49         {
50             update(id<<1,ll,mid[id],l,mid[id],val);
51             update(id<<1|1,mid[id]+1,rr,mid[id]+1,r,val);
52         }
53     if(!cnt[id])
54         len[id]=len[id<<1]+len[id<<1|1];
55 }
56
57 struct node
58 {
59     double l,r,h;
60     char f;
61     inline bool operator<(const node &a)const
62     {
63         return h<a.h;
64     }
65     inline void print()
66     {
67         printf("%lf_%lf_%lf_%d\n",l,r,h,f);
68     }
69 }ln[inf];
70
71 int main()
72 {
73     make(1,1,inf);
74     while(scanf("%d",&n),n)
75     {
76         n<=<1;
77         map.clear();
78         for(i=0;i<n;++i)
79         {
80             scanf("%lf%lf%lf%lf",&x1,&y1,&x2,&y2);
81             if(x1>x2)
82                 std::swap(x1,x2);
83             if(y1>y2)
84                 std::swap(y1,y2);
85             ln[i].l=x1;
86             ln[i].r=x2;
87             ln[i].h=y1;
88             ln[i].f=1;
89             ln[++i].l=x1;
90             ln[i].r=x2;
91             ln[i].h=y2;
```

```
92             ln[i].f=-1;
93             map[x1]=1;
94             map[x2]=1;
95         }
96         i=1;
97         for(it=map.begin();it!=map.end();++it,++i)
98         {
99             it->second=i;
100             rmap[i]=it->first;
101         }
102         std::sort(ln,ln+n);
103         ans=0;
104         update(1,1,inf,map[ln[0].l]+1,map[ln[0].r],ln[0].f);
105         for(i=1;i<n;++i)
106         {
107             ans+=len[i]*(ln[i].h-ln[i-1].h);
108             update(1,1,inf,map[ln[i].l]+1,map[ln[i].r],ln[i].f);
109         }
110         printf("Test case %d\nTotal explored area: %.2lf\n\n",++cas,ans);
111     }
112     return 0;
113 }
```

1.2 binary indexed tree

```
1 int tree[MAXX];
2
3 inline int lowbit(const int &a)
4 {
5     return a&-a;
6 }
7
8 inline void update(int pos,const int &val)
9 {
10     while(pos<MAXX)
11     {
12         tree[pos]+=val;
13         pos+=lowbit(pos);
14     }
15 }
16
17 inline int read(int pos)
18 {
19     int re(0);
20     while(pos>0)
21     {
22         re+=tree[pos];
23         pos-=lowbit(pos);
24     }
25     return re;
26 }
27
28 int find_Kth(int k)
29 {
30     int now=0;
31     for (char i=20;i>=0;--i)
32     {
33         now|=(1<<i);
34         if (now>MAXX || tree[now]>=k)
35             now^=(1<<i);
36         else k-=tree[now];
37     }
38     return now+1;
39 }
```

1.3 COT

```
1 #include<cstdio>
2 #include<algorithm>
3
4 #define MAXX 100111
5 #define MAX (MAXX*23)
6 #define N 18
7
8 int sz[MAX],lson[MAX],rson[MAX],cnt;
9 int head[MAXX];
10 int pre[MAXX][N];
11 int map[MAXX],m;
12
13 int edge[MAXX],nxt[MAXX<<1],to[MAXX<<1];
14 int n,i,j,k,q,l,r,mid;
15 int num[MAXX],dg[MAXX];
16
17 int make(int l,int r)
18 {
19     if(l==r)
20         return ++cnt;
21     int id(++cnt),mid((l+r)>>1);
22     lson[id]=make(l,mid);
23     rson[id]=make(mid+1,r);
24     return id;
25 }
```

```

26 inline int update(int id,int pos)
27 {
28     int re(++cnt);
29     l=1;
30     r=m;
31     int nid(re);
32     sz[nid]=sz[id]+1;
33     while(l<r)
34     {
35         mid=(l+r)>>1;
36         if(pos<=mid)
37         {
38             lson[nid]=++cnt;
39             rson[nid]=rson[id];
40             nid=lson[nid];
41             id=lson[id];
42             r=mid;
43         }
44         else
45         {
46             lson[nid]=lson[id];
47             rson[nid]=++cnt;
48             nid=rson[nid];
49             id=rson[id];
50             l=mid+1;
51         }
52     }
53     sz[nid]=sz[id]+1;
54 }
55 return re;
56 }
57
58 void rr(int now,int fa)
59 {
60     dg[now]=dg[fa]+1;
61     head[now]=update(head[fa],num[now]);
62     for(int i=edge[now];i;i=nxt[i])
63     {
64         if(to[i]!=fa)
65         {
66             j=1;
67             for(pre[to[i]][0]=now;j<N;++j)
68                 pre[to[i]][j]=pre[pre[to[i]][j-1]][j-1];
69             rr(to[i],now);
70         }
71     }
72
73 inline int query(int a,int b,int n,int k)
74 {
75     static int tmp,t;
76     l=1;
77     r=m;
78     a=head[a];
79     b=head[b];
80     t=num[n];
81     n=head[n];
82     while(l<r)
83     {
84         mid=(l+r)>>1;
85         tmp=sz[lson[a]]+sz[lson[b]]-2*sz[lson[n]]+(l<=t && t<=mid);
86         if(tmp>=k)
87         {
88             a=lson[a];
89             b=lson[b];
90             n=lson[n];
91             r=mid;
92         }
93         else
94         {
95             k-=tmp;
96             a=rson[a];
97             b=rson[b];
98             n=rson[n];
99             l=mid+1;
100         }
101     }
102     return l;
103 }
104
105 inline int lca(int a,int b)
106 {
107     static int i,j;
108     j=0;
109     if(dg[a]<dg[b])
110         std::swap(a,b);
111     for(i=dg[a]-dg[b];i>=1;++i)
112         a=pre[a][i];
113     if(a==b)
114         return a;
115     for(i=N-1;i>=0;--i)
116         if(pre[a][i]!=pre[b][i])
117         {
118             a=pre[a][i];
119             b=pre[b][i];
120         }

```

```

121     return pre[a][0];
122 }
123
124 int main()
125 {
126     scanf("%d%d",&n,&q);
127     for(i=1;i<=n;++i)
128     {
129         scanf("%d",&num[i]);
130         map[i]=num[i];
131     }
132     std::sort(map+1,map+n+1);
133     m=std::unique(map+1,map+n+1)-map-1;
134     for(i=1;i<=n;++i)
135         num[i]=std::lower_bound(map+1,map+m+1,num[i])-map;
136     for(i=1;i<=n;++i)
137     {
138         scanf("%d%d",&j,&k);
139         nxt[++cnt]=edge[j];
140         edge[j]=cnt;
141         to[cnt]=k;
142     }
143     nxt[++cnt]=edge[k];
144     edge[k]=cnt;
145     to[cnt]=j;
146 }
147 cnt=0;
148 head[0]=make(1,m);
149 rr(1,0);
150 while(q--)
151 {
152     scanf("%d%d%d",&i,&j,&k);
153     printf("%d\n",map[query(i,j,lca(i,j),k)]);
154 }
155 return 0;
156 }

```

1.4 hose

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 #include<cmath>
5
6 #define MAXX 50111
7
8 struct Q
9 {
10     int l,r,s,w;
11     bool operator<(const Q &i)const
12     {
13         return w==i.w?r<i.r:w<i.w;
14     }
15 }a[MAXX];
16
17 int c[MAXX];
18 long long col[MAXX],sz[MAXX],ans[MAXX];
19 int n,m,cnt,len;
20
21 long long gcd(long long a,long long b)
22 {
23     return a?gcd(b%a,a):b;
24 }
25
26 int i,j,k,now;
27 long long all,num;
28
29 int main()
30 {
31     scanf("%d%d",&n,&m);
32     for(i=1;i<=n;++i)
33         scanf("%d",&c[i]);
34     len=sqrt(m);
35     for(i=1;i<=m;++i)
36     {
37         scanf("%d",&a[i].l,&a[i].r);
38         if(a[i].l>a[i].r)
39             std::swap(a[i].l,a[i].r);
40         sz[i]=a[i].r-a[i].l+1;
41         a[i].w=a[i].l/len+1;
42         a[i].s=i;
43     }
44     std::sort(a+1,a+m+1);
45     i=1;
46     while(i<=m)
47     {
48         now=a[i].w;
49         memset(col,0,sizeof col);
50         for(j=a[i].l;j<=a[i].r;++j)
51             ans[a[i].s]+=2*(col[c[j]]++);
52         for(++i;a[i].w==now;++i)
53         {
54             ans[a[i].s]=ans[a[i-1].s];
55             for(j=a[i-1].r+1;j<=a[i].r;++j)
56                 ans[a[i].s]+=2*(col[c[j]]++);

```

```

57     if(a[i-1].l<a[i].l)
58         for(j=a[i-1].l;j<a[i].l;++j)
59             ans[a[i].s]-=2*(--col[c[j]]);
60     else
61         for(j=a[i].l;j<a[i-1].l;++j)
62             ans[a[i].s]+=2*(col[c[j]]++);
63     }
64 }
65 for(i=1;i<=m;++i)
66 {
67     if(sz[i]==1)
68         all=1ll;
69     else
70         all=sz[i]*(sz[i]-1);
71     num=gcd(ans[i],all);
72     printf("%lld/%lld\n",ans[i]/num,all/num);
73 }
74 return 0;
75 }

```

1.5 Leftist tree

```

1 #include<cstdio>
2 #include<algorithm>
3
4 #define MAXX 100111
5
6 int val[MAXX],l[MAXX],r[MAXX],d[MAXX];
7 int set[MAXX];
8
9 int merge(int a,int b)
10 {
11     if(!a)
12         return b;
13     if(!b)
14         return a;
15     if(val[a]<val[b]) // max-heap
16         std::swap(a,b);
17     r[a]=merge(r[a],b);
18     if(d[l[a]]<d[r[a]])
19         std::swap(l[a],r[a]);
20     d[a]=d[r[a]]+1;
21     set[l[a]]=set[r[a]]=a; // set a as father of its sons
22     return a;
23 }
24
25 inline int find(int &a)
26 {
27     while(set[a]) //brute-force to get the index of root
28         a=set[a];
29     return a;
30 }
31
32 inline void reset(int i)
33 {
34     l[i]=r[i]=d[i]=set[i]=0;
35 }
36
37 int n,i,j,k;
38
39 int main()
40 {
41     while(scanf("%d",&n)!=EOF)
42     {
43         for(i=1;i<=n;++i)
44         {
45             scanf("%d",&val[i]);
46             reset(i);
47         }
48         scanf("%d",&n);
49         while(n--)
50         {
51             scanf("%d%d",&i,&j);
52             if(find(i)==find(j))
53                 puts("-1");
54             else
55             {
56                 k=merge(l[i],r[i]);
57                 val[i]>>=1;
58                 reset(i);
59                 set[i]=merge(i,k)=0;
60
61                 k=merge(l[j],r[j]);
62                 val[j]>>=1;
63                 reset(j);
64                 set[j]=merge(j,k)=0;
65
66                 set[k=merge(i,j)]=0;
67                 printf("%d\n",val[k]);
68             }
69         }
70     }
71     return 0;
72 }
73 }

```

1.6 Network

```

1 //HLD.....备忘.....(:3JZ)_
2 #include<cstdio>
3 #include<algorithm>
4 #include<cstdlib>
5
6 #define MAXX 80111
7 #define MAXE (MAXX<<1)
8 #define N 18
9
10 int edge[MAXX],nxt[MAXE],to[MAXE],cnt;
11 int fa[MAXX][N],dg[MAXX];
12
13 inline int lca(int a,int b)
14 {
15     static int i,j;
16     j=0;
17     if(dg[a]<dg[b])
18         std::swap(a,b);
19     for(i=dg[a]-dg[b];i>=1;++j)
20         if(i&1)
21             a=fa[a][j];
22     if(a==b)
23         return a;
24     for(i=N-1;i>=0;--i)
25         if(fa[a][i]!=fa[b][i])
26         {
27             a=fa[a][i];
28             b=fa[b][i];
29         }
30     return fa[a][0];
31 }
32
33 inline void add(int a,int b)
34 {
35     nxt[++cnt]=edge[a];
36     edge[a]=cnt;
37     to[cnt]=b;
38 }
39
40 int sz[MAXX],pre[MAXX],next[MAXX];
41
42 void rr(int now)
43 {
44     sz[now]=1;
45     int max,id;
46     max=0;
47     for(int i=edge[now];i;i=nxt[i])
48         if(to[i]!=fa[now][0])
49         {
50             fa[to[i]][0]=now;
51             dg[to[i]]=dg[now]+1;
52             rr(to[i]);
53             sz[now]+=sz[to[i]];
54             if(sz[to[i]]>max)
55             {
56                 max=sz[to[i]];
57                 id=to[i];
58             }
59         }
60     if(max)
61     {
62         next[now]=id;
63         pre[id]=now;
64     }
65 }
66
67 #define MAXT (MAXX*N*5)
68
69 namespace Treap
70 {
71     int cnt;
72     int son[MAXT][2],key[MAXT],val[MAXT],sz[MAXT];
73
74     inline void init()
75     {
76         key[0]=RAND_MAX;
77         val[0]=0xc0c0c0c0;
78         cnt=0;
79     }
80
81     inline void up(int id)
82     {
83         sz[id]=sz[son[id][0]]+sz[son[id][1]]+1;
84     }
85     inline void rot(int &id,int tp)
86     {
87         static int k;
88         k=son[id][tp];
89         son[id][tp]=son[k][tp^1];
90         son[k][tp^1]=id;
91         up(id);
92         up(k);
93         id=k;
94     }
95 }

```

```

94     }
95     void insert(int &id,int v)
96     {
97         if(id)
98         {
99             int k(v>=val[id]);
100             insert(son[id][k],v);
101             if(key[son[id][k]]<key[id])
102                 rot(id,k);
103             else
104                 up(id);
105             return;
106         }
107         id++;cnt++;
108         key[id]=rand()-1;
109         val[id]=v;
110         sz[id]=1;
111         son[id][0]=son[id][1]=0;
112     }
113     void del(int &id,int v)
114     {
115         if(!id)
116             return;
117         if(val[id]==v)
118         {
119             int k(key[son[id][1]]<key[son[id][0]]);
120             if(!son[id][k])
121             {
122                 id=0;
123                 return;
124             }
125             rot(id,k);
126             del(son[id][k^1],v);
127         }
128         else
129             del(son[id][v>val[id]],v);
130         up(id);
131     }
132     int rank(int id,int v)
133     {
134         if(!id)
135             return 0;
136         if(val[id]<=v)
137             return sz[son[id][0]]+1+rank(son[id][1],v);
138         return rank(son[id][0],v);
139     }
140     void print(int id)
141     {
142         if(!id)
143             return;
144         print(son[id][0]);
145         printf("%d",val[id]);
146         print(son[id][1]);
147     }
148 }
149 int head[MAXX],root[MAXX],len[MAXX],pos[MAXX];
150 #define MAX (MAXX*6)
151 #define mid (l+r>>1)
152 #define lc lson[id],l,mid
153 #define rc rson[id],mid+1,r
154 int lson[MAX],rson[MAX];
155 int treap[MAX];
156 void make(int &id,int l,int r,int *the)
157 {
158     id++;cnt++;
159     static int k;
160     for(k=l;k<=r;++k)
161         Treap::insert(treap[id],the[k]);
162     if(l==r)
163     {
164         make(lc,the);
165         make(rc,the);
166     }
167 }
168 int query(int id,int l,int r,int a,int b,int q)
169 {
170     if(a<=l && r<=b)
171         return Treap::rank(treap[id],q);
172     int re=0;
173     if(a<=mid)
174         re=query(lc,a,b,q);
175     if(b>mid)
176         re+=query(rc,a,b,q);
177     return re;
178 }
179 inline int query(int a,int b,int v)
180 {
181     static int re;
182     for(re=0;root[a]!=root[b];a=fa[root[a]][0])
183         re+=query(head[root[a]],1,len[root[a]],1,pos[a],v);
184 }
185 re+=query(head[root[a]],1,len[root[a]],pos[b],pos[a],v);
186 return re;
187 }
188 inline void update(int id,int l,int r,int pos,int val,int n)
189 {
190     while(l<=r)
191     {
192         Treap::del(treap[id],val);
193         Treap::insert(treap[id],n);
194         if(l==r)
195             return;
196         if(pos<=mid)
197         {
198             id=lson[id];
199             r=mid;
200         }
201         else
202         {
203             id=rson[id];
204             l=mid+1;
205         }
206     }
207 }
208 int n,q,i,j,k;
209 int val[MAXX];
210 int main()
211 {
212     srand(1e9+7);
213     scanf("%d",&n,&q);
214     for(i=1;i<=n;++i)
215         scanf("%d",val+i);
216     for(k=1;k<=n;++k)
217     {
218         scanf("%d",&i,&j);
219         add(i,j);
220         add(j,i);
221     }
222     rr(rand()%n+1);
223     for(j=1;j<=n;++j)
224         for(i=1;i<=n;++i)
225             fa[i][j]=fa[fa[i][j-1]][j-1];
226     Treap::init();
227     cnt=0;
228     for(i=1;i<=n;++i)
229         if(!pre[i])
230         {
231             static int tmp[MAXX];
232             for(k=1,j=i;j=jnext[j],++k)
233             {
234                 pos[j]=k;
235                 root[j]=i;
236                 tmp[k]=val[j];
237             }
238             k--;
239             len[i]=k;
240             make(head[i],1,k,tmp);
241         }
242     while(q--)
243     {
244         scanf("%d",&k);
245         if(k)
246         {
247             static int a,b,c,d,l,r,ans,m;
248             scanf("%d",&a,&b);
249             c=lca(a,b);
250             if(dg[a]+dg[b]-2*dg[c]+1<k)
251             {
252                 puts("invalid request!");
253                 continue;
254             }
255             k=dg[a]+dg[b]-2*dg[c]+1-k+1;
256             if(dg[a]<dg[b])
257                 std::swap(a,b);
258             l=-1e9;
259             r=1e9;
260             if(b!=c)
261             {
262                 d=a;
263                 for(i=0,j=dg[a]-dg[c]-1;j;j>=1,++i)
264                     if(j&1)
265                         d=fa[d][i];
266                 while(l<=r)
267                 {
268                     m=l+r>>1;
269                     if(query(a,d,m)+query(b,c,m)>=k)
270                     {
271                         ans=m;
272                         r=m-1;
273                     }
274                     else
275                         l=m+1;
276                 }
277             }
278         }
279     }
280 }

```

```

286     }
287     else
288     {
289         while(l<=r)
290         {
291             m=l+r>>1;
292             if(query(a,c,m)>=k)
293             {
294                 ans=m;
295                 r=m-1;
296             }
297             else
298                 l=m+1;
299         }
300     }
301     printf("%d\n",ans);
302 }
303 else
304 {
305     scanf("%d%d",&i,&j);
306     update(head[root[i]],1,len[root[i]],pos[i],val[i],j);
307     val[i]=j;
308 }
309 }
310 return 0;
311 }

```

1.7 OTOCI

```

1 //记得随手 down 啊……亲……
2 //debug 时记得优先检查 up/down/select
3 #include<cstdio>
4 #include<algorithm>
5
6 #define MAXX 30111
7 #define lson nxt[id][0]
8 #define rson nxt[id][1]
9
10 int nxt[MAXX][2],fa[MAXX],pre[MAXX],val[MAXX],sum[MAXX];
11 bool rev[MAXX];
12
13 inline void up(int id)
14 {
15     static int i;
16     sum[id]=val[id];
17     for(i=0;i<2;++i)
18         if(nxt[id][i])
19             sum[id]+=sum[nxt[id][i]];
20 }
21
22 inline void rot(int id,int tp)
23 {
24     static int k;
25     k=pre[id];
26     nxt[k][tp^1]=nxt[id][tp];
27     if(nxt[id][tp])
28         pre[nxt[id][tp]]=k;
29     if(pre[k])
30         nxt[pre[k]][k==nxt[pre[k]][1]]=id;
31     pre[id]=pre[k];
32     nxt[id][tp]=k;
33     pre[k]=id;
34     up(k);
35     up(id);
36 }
37
38 inline void down(int id) //记得随手 down 啊……亲……
39 {
40     static int i;
41     if(rev[id])
42     {
43         rev[id]=false;
44         for(i=0;i<2;++i)
45             if(nxt[id][i])
46             {
47                 rev[nxt[id][i]]^=true;
48                 std::swap(nxt[nxt[id][i]][0],nxt[nxt[id][i]][1]);
49             }
50     }
51 }
52
53 inline void splay(int id)//记得随手 down 啊……亲……
54 {
55     down(id);
56     if(!pre[id])
57         return;
58     static int rt,k,st[MAXX];
59     for(rt=id,k=0;rt;rt=pre[rt])
60         st[k++]=rt;
61     rt=st[k-1];
62     while(k)
63         down(st[--k]);

```

```

64     for(std::swap(fa[id],fa[rt]);pre[id];rot(id,id==nxt[pre[id]][0]));
65     /* another faster methond:
66     std::swap(fa[id],fa[rt]);
67     do
68     {
69         rt=pre[id];
70         if(pre[rt])
71         {
72             k=(nxt[pre[rt]][0]==rt);
73             if(nxt[rt][k]==id)
74                 rot(id,k^1);
75             else
76                 rot(rt,k);
77             rot(id,k);
78         }
79         else
80             rot(id,id==nxt[rt][0]);
81     }
82     while(pre[id]);
83     */
84 }
85
86 inline int access(int id)
87 {
88     static int to;
89     for(to=0;id;id=fa[id])
90     {
91         splay(id);
92         if(rson)
93         {
94             pre[rson]=0;
95             fa[rson]=id;
96         }
97         rson=to;
98         if(to)
99         {
100             pre[to]=id;
101             fa[to]=0;
102         }
103         up(to=id);
104     }
105     return to;
106 }
107
108 inline int getrt(int id)
109 {
110     access(id);
111     splay(id);
112     while(nxt[id][0])
113     {
114         id=nxt[id][0];
115         down(id);
116     }
117     return id;
118 }
119
120 inline void makert(int id)
121 {
122     access(id);
123     splay(id);
124     if(nxt[id][0])
125     {
126         rev[id]^=true;
127         std::swap(lson,rson);
128     }
129 }
130
131 int n,i,j,k,q;
132 char buf[11];
133
134 int main()
135 {
136     scanf("%d",&n);
137     for(i=1;i<=n;++i)
138         scanf("%d",&val[i]);
139     scanf("%d",&q);
140     while(q--)
141     {
142         scanf("%s%d%d",buf,&i,&j);
143         switch(buf[0])
144         {
145             case 'b':
146                 if(getrt(i)==getrt(j))
147                     puts("no");
148                 else
149                 {
150                     puts("yes");
151                     makert(i);
152                     fa[i]=j;
153                 }
154                 break;
155             case 'p':
156                 access(i);
157                 splay(i);
158                 val[i]=j;

```

```

159         up(i);
160         break;
161     case 'e':
162         if(getrt(i)!=getrt(j))
163             puts("impossible");
164     else
165     {
166         makert(i);
167         access(j);
168         splay(j);
169         printf("%d\n",sum[j]);
170     }
171     break;
172 }
173 }
174 return 0;
175 }

```

1.8 picture

```

1 #include<cstdio>
2 #include<algorithm>
3 #include<map>
4
5 #define MAXX 5555
6 #define MAX MAXX<<3
7 #define inf 10011
8
9 int n,i;
10 int mid[MAX],cnt[MAX],len[MAX],seg[MAX];
11 bool rt[MAX],lf[MAX];
12
13 std::map<int,int>map;
14 std::map<int,int>::iterator it;
15 int rmap[inf];
16 long long sum;
17 int x1,x2,y1,y2,last;
18
19 void make(int id,int l,int r)
20 {
21     mid[id]=(l+r)>>1;
22     if(l!=r)
23     {
24         make(id<<1,l,mid[id]);
25         make(id<<1|1,mid[id]+1,r);
26     }
27 }
28
29 void update(int id,int ll,int rr,int l,int r,int val)
30 {
31     if(l==ll && rr==r)
32     {
33         cnt[id]+=val;
34         if(cnt[id])
35         {
36             rt[id]=lf[id]=true;
37             len[id]=rmap[r]-rmap[l-1];
38             seg[id]=1;
39         }
40     }
41     else
42     {
43         if(l!=r)
44         {
45             len[id]=len[id<<1]+len[id<<1|1];
46             seg[id]=seg[id<<1]+seg[id<<1|1];
47             if(rt[id<<1] && lf[id<<1|1])
48                 —seg[id];
49             rt[id]=rt[id<<1|1];
50             lf[id]=lf[id<<1];
51         }
52         else
53         {
54             len[id]=0;
55             rt[id]=lf[id]=false;
56             seg[id]=0;
57         }
58     }
59     return;
60 }
61
62 if(mid[id]>=r)
63     update(id<<1,ll,mid[id],l,r,val);
64 else
65 {
66     if(mid[id]<l)
67         update(id<<1|1,mid[id]+1,rr,l,r,val);
68     else
69     {
70         update(id<<1,ll,mid[id],l,mid[id],val);
71         update(id<<1|1,mid[id]+1,rr,mid[id]+1,r,val);
72     }
73 }
74
75 if(!cnt[id])
76 {
77     len[id]=len[id<<1]+len[id<<1|1];
78     seg[id]=seg[id<<1]+seg[id<<1|1];
79     if(rt[id<<1] && lf[id<<1|1])
80         —seg[id];
81     rt[id]=rt[id<<1|1];
82     lf[id]=lf[id<<1];
83 }

```

```

76     }
77 }
78
79 struct node
80 {
81     int l,r,h;
82     char val;
83     inline bool operator<(const node &a)const
84     {
85         return h==a.h?val<a.val:h<a.h; // trick watch out.
86         val<a.val? val>a.val?
87     }
88     inline void print()
89     {
90         printf("%d_%d_%d_%d\n",l,r,h,val);
91     }
92 }ln[inf];
93
94 int main()
95 {
96     make(1,1,inf);
97     scanf("%d",&n);
98     n<=1;
99     map.clear();
100     for(i=0;i<n;++i)
101     {
102         scanf("%d%d%d%d",&x1,&y1,&x2,&y2);
103         ln[i].l=x1;
104         ln[i].r=x2;
105         ln[i].h=y1;
106         ln[i].val=1;
107         ln[i].l=x1;
108         ln[i].r=x2;
109         ln[i].h=y2;
110         ln[i].val=-1;
111         map[x1]=1;
112         map[x2]=1;
113     }
114     i=1;
115     for(it=map.begin();it!=map.end();++it,++i)
116     {
117         it->second=i;
118         rmap[i]=it->first;
119     }
120     i=0;
121     std::sort(ln,ln+n);
122     update(1,1,inf,map[ln[0].l]+1,map[ln[0].r],ln[0].val);
123     sum+=len[1];
124     last=len[1];
125     for(i=1;i<n;++i)
126     {
127         sum+=2*seg[i]*(ln[i].h-ln[i-1].h);
128         update(1,1,inf,map[ln[i].l]+1,map[ln[i].r],ln[i].val);
129         sum+=abs(len[i]-last);
130         last=len[i];
131     }
132     printf("%lld\n",sum);
133     return 0;

```

1.9 Size Blanced Tree

```

1 template<class Tp>class sbt
2 {
3 public:
4     inline void init()
5     {
6         rt=cnt=l[0]=r[0]=sz[0]=0;
7     }
8     inline void ins(const Tp &a)
9     {
10         ins(rt,a);
11     }
12     inline void del(const Tp &a)
13     {
14         del(rt,a);
15     }
16     inline bool find(const Tp &a)
17     {
18         return find(rt,a);
19     }
20     inline Tp pred(const Tp &a)
21     {
22         return pred(rt,a);
23     }
24     inline Tp succ(const Tp &a)
25     {
26         return succ(rt,a);
27     }
28     inline bool empty()
29     {
30         return !sz[rt];
31     }
32     inline Tp min()
33     {

```



```

34     return min(rt);
35 }
36 inline Tp max()
37 {
38     return max(rt);
39 }
40 inline void delsmall(const Tp &a)
41 {
42     dels(rt,a);
43 }
44 inline int rank(const Tp &a)
45 {
46     return rank(rt,a);
47 }
48 inline Tp sel(const int &a)
49 {
50     return sel(rt,a);
51 }
52 inline Tp delsel(int a)
53 {
54     return delsel(rt,a);
55 }
56 private:
57 int cnt,rt,l[MAXX],r[MAXX],sz[MAXX];
58 Tp val[MAXX];
59 inline void rro(int &pos)
60 {
61     int k(l[pos]);
62     l[pos]=r[k];
63     r[k]=pos;
64     sz[k]=sz[pos];
65     sz[pos]=sz[l[pos]]+sz[r[pos]]+1;
66     pos=k;
67 }
68 inline void lro(int &pos)
69 {
70     int k(r[pos]);
71     r[pos]=l[k];
72     l[k]=pos;
73     sz[k]=sz[pos];
74     sz[pos]=sz[l[pos]]+sz[r[pos]]+1;
75     pos=k;
76 }
77 inline void mt(int &pos,bool flag)
78 {
79     if(!pos)
80         return;
81     if(flag)
82         if(sz[r[r[pos]]]>sz[l[pos]])
83             lro(pos);
84         else
85             if(sz[l[r[pos]]]>sz[l[pos]])
86             {
87                 rro(r[pos]);
88                 lro(pos);
89             }
90         else
91             return;
92     else
93         if(sz[l[l[pos]]]>sz[r[pos]])
94             rro(pos);
95         else
96             if(sz[r[l[pos]]]>sz[r[pos]])
97             {
98                 lro(l[pos]);
99                 rro(pos);
100             }
101         else
102             return;
103     mt(l[pos],false);
104     mt(r[pos],true);
105     mt(pos,false);
106     mt(pos,true);
107 }
108 void ins(int &pos,const Tp &a)
109 {
110     if(pos)
111     {
112         ++sz[pos];
113         if(a<val[pos])
114             ins(l[pos],a);
115         else
116             ins(r[pos],a);
117         mt(pos,a>val[pos]);
118         return;
119     }
120     pos==cnt;
121     l[pos]=r[pos]=0;
122     val[pos]=a;
123     sz[pos]=1;
124 }
125 Tp del(int &pos,const Tp &a)
126 {
127     --sz[pos];
128     if(val[pos]==a || (a<val[pos] && !l[pos]) || (a>val[
129         pos] && !r[pos]))
130     {
131         Tp ret(val[pos]);
132         if(!l[pos] || !r[pos])
133             pos=l[pos]+r[pos];
134         else
135             val[pos]=del(l[pos],val[pos]+1);
136         return ret;
137     }
138     else
139         if(a<val[pos])
140             return del(l[pos],a);
141         else
142             return del(r[pos],a);
143 }
144 bool find(int &pos,const Tp &a)
145 {
146     if(!pos)
147         return false;
148     if(a<val[pos])
149         return find(l[pos],a);
150     else
151         return (val[pos]==a || find(r[pos],a));
152 }
153 Tp pred(int &pos,const Tp &a)
154 {
155     if(!pos)
156         return a;
157     if(a>val[pos])
158     {
159         Tp ret(pred(r[pos],a));
160         if(ret==a)
161             return val[pos];
162         else
163             return ret;
164     }
165     return pred(l[pos],a);
166 }
167 Tp succ(int &pos,const Tp &a)
168 {
169     if(!pos)
170         return a;
171     if(a<val[pos])
172     {
173         Tp ret(succ(l[pos],a));
174         if(ret==a)
175             return val[pos];
176         else
177             return ret;
178     }
179     return succ(r[pos],a);
180 }
181 Tp min(int &pos)
182 {
183     if(l[pos])
184         return min(l[pos]);
185     else
186         return val[pos];
187 }
188 Tp max(int &pos)
189 {
190     if(r[pos])
191         return max(r[pos]);
192     else
193         return val[pos];
194 }
195 void dels(int &pos,const Tp &v)
196 {
197     if(!pos)
198         return;
199     if(val[pos]<v)
200     {
201         pos=r[pos];
202         dels(pos,v);
203         return;
204     }
205     dels(l[pos],v);
206     sz[pos]=1+sz[l[pos]]+sz[r[pos]];
207 }
208 int rank(const int &pos,const Tp &v)
209 {
210     if(val[pos]==v)
211         return sz[l[pos]]+1;
212     if(v<val[pos])
213         return rank(l[pos],v);
214     return rank(r[pos],v)+sz[l[pos]]+1;
215 }
216 Tp sel(const int &pos,const int &v)
217 {
218     if(sz[l[pos]]+1==v)
219         return val[pos];
220     if(v>sz[l[pos]])
221         return sel(r[pos],v-sz[l[pos]]-1);
222     return sel(l[pos],v);
223 }
224 Tp delsel(int &pos,int k)
225 {

```

```

225     —sz[pos];
226     if (sz[l[pos]]+1==k)
227     {
228         Tp re(val[pos]);
229         if (!l[pos] || !r[pos])
230             pos=l[pos]+r[pos];
231         else
232             val[pos]=del(l[pos],val[pos]+1);
233         return re;
234     }
235     if (k>sz[l[pos]])
236         return delsel(r[pos],k-1-sz[l[pos]]);
237     return delsel(l[pos],k);
238 }
239 };

```

1.10 sparse table - rectangle

```

1  #include<iostream>
2  #include<cstdio>
3  #include<algorithm>
4
5  #define MAXX 310
6
7  int mat[MAXX][MAXX];
8  int table[9][9][MAXX][MAXX];
9  int n;
10 short lg[MAXX];
11
12 int main()
13 {
14     for(int i(2);i<MAXX;++i)
15         lg[i]=lg[i>>1]+1;
16     int T;
17     std::cin >> T;
18     while (T—)
19     {
20         std::cin >> n;
21         for (int i = 0; i < n; ++i)
22             for (int j = 0; j < n; ++j)
23             {
24                 std::cin >> mat[i][j];
25                 table[0][0][i][j] = mat[i][j];
26             }
27
28         // 从小到大计算, 保证后来用到的都已经计算过
29         for(int i=0;i<lg[n];++i) // width
30         {
31             for(int j=0;j<lg[n];++j) //height
32             {
33                 if(i==0 && j==0)
34                     continue;
35                 for(int ii=0;ii+(1<<j)<=n;++ii)
36                     for(int jj=0;jj+(1<<i)<=n;++jj)
37                         if(i==0)
38                             table[i][j][ii][jj]=std::min(table[i][j-1][ii][jj],table[i][j-1][ii+(1<<(j-1))][jj]);
39                         else
40                             table[i][j][ii][jj]=std::min(table[i-1][j][ii][jj],table[i-1][j][ii+(1<<(i-1))][jj]);
41             }
42         }
43         long long N;
44         std::cin >> N;
45         int r1, c1, r2, c2;
46         for (int i = 0; i < N; ++i)
47         {
48             scanf("%d%d%d%d",&r1,&c1,&r2,&c2);
49             —r1;
50             —c1;
51             —r2;
52             —c2;
53             int w=lg[c2-c1+1];
54             int h=lg[r2-r1+1];
55             printf("%d\n",std::min(table[w][h][r1][c1],std::min(table[w][h][r1][c2-(1<<w)+1],std::min(table[w][h][r2-(1<<h)+1][c1],table[w][h][r2-(1<<h)+1][c2-(1<<w)+1]))));
56         }
57     }
58     return 0;
59 }

```

1.11 sparse table - square

```

1  int num[MAXX][MAXX],max[MAXX][MAXX][10];
2  short lg[MAXX];
3
4  int main()
5  {
6     for(i=2;i<MAXX;++i)
7         lg[i]=lg[i>>1]+1;

```

```

8     scanf("%hd%d",&n,&q);
9     for(i=0;i<n;++i)
10         for(j=0;j<n;++j)
11         {
12             scanf("%d",num[i][j]);
13             max[i][j][0]=num[i][j];
14         }
15     for(k=1;k<=lg[n];++k)
16     {
17         l=n+1-(1<<k);
18         for(i=0;i<l;++i)
19             for(j=0;j<l;++j)
20                 max[i][j][k]=std::max(std::max(max[i][j][k-1],max[i+(1<<(k-1))][j][k-1]),std::max(max[i][j+(1<<(k-1))][k-1],max[i+(1<<(k-1))][j+(1<<(k-1))][k-1]));
21     }
22     printf("Case_%hd:\n",t);
23     while(q—)
24     {
25         scanf("%hd%hd%hd",&i,&j,&l);
26         —i;
27         —j;
28         k=lg[l];
29         printf("%d\n",std::max(std::max(max[i][j][k],max[i][j+l-(1<<k)][k]),std::max(max[i+l-(1<<k)][j][k],max[i+l-(1<<k)][j+l-(1<<k)][k])));
30     }
31 }

```

1.12 sparse table

```

1  int num[MAXX],min[MAXX][20];
2  int lg[MAXX];
3
4  int main()
5  {
6     for(i=2;i<MAXX;++i)
7         lg[i]=lg[i>>1]+1;
8     scanf("%d",&n,&q);
9     for(i=1;i<=n;++i)
10     {
11         scanf("%d",num[i]);
12         min[i][0]=num[i];
13     }
14     for(j=1;j<=lg[n];++j)
15     {
16         l=n+1-(1<<j);
17         j_-=j-1;
18         j__=(1<<j_);
19         for(i=1;i<=l;++i)
20             min[i][j]=std::min(min[i][j_],min[i+j_][j_]);
21     }
22     printf("Case_%hd:\n",t);
23     while(q—)
24     {
25         scanf("%d",&i,&j);
26         k=lg[j-1];
27         printf("%d\n",std::min(min[i][k],min[j-(1<<k)+1][k]));
28     }
29 }
30 }

```

1.13 treap

```

1  #include<cstdlib>
2  #include<ctime>
3  #include<cstring>
4
5  struct node
6  {
7     node *ch[2];
8     int sz,val,key;
9     node() {memset(this,0,sizeof(node));}
10    node(int a);
11 }*null;
12 node::node(int a):sz(1),val(a),key(rand()-1){ch[0]=ch[1]=null;}
13
14 class Treap
15 {
16     inline void up(node *pos)
17     {
18         pos->sz=pos->ch[0]->sz+pos->ch[1]->sz+1;
19     }
20     inline void rot(node *&pos,int tp)
21     {
22         node *k(pos->ch[tp]);
23         pos->ch[tp]=k->ch[tp^1];
24         k->ch[tp^1]=pos;
25         up(pos);
26         up(k);
27         pos=k;
28     }
29 }

```

```

30
31 void insert(node *&pos,int val)
32 {
33     if(pos!=null)
34     {
35         int t(val>pos->val);
36         insert(pos->ch[t],val);
37         if(pos->ch[t]->key<pos->key)
38             rot(pos,t);
39         else
40             up(pos);
41         return;
42     }
43     pos=new node(val);
44 }
45 void rec(node *pos)
46 {
47     if(pos!=null)
48     {
49         rec(pos->ch[0]);
50         rec(pos->ch[1]);
51         delete pos;
52     }
53 }
54 inline int sel(node *pos,int k)
55 {
56     while(pos->ch[0]->sz+1!=k)
57         if(pos->ch[0]->sz>=k)
58             pos=pos->ch[0];
59         else
60         {
61             k--pos->ch[0]->sz+1;
62             pos=pos->ch[1];
63         }
64     return pos->val;
65 }
66 void del(node *&pos,int val)
67 {
68     if(pos!=null)
69     {
70         if(pos->val==val)
71         {
72             int t(pos->ch[1]->key<pos->ch[0]->key);
73             if(pos->ch[t]==null)
74             {
75                 delete pos;
76                 pos=null;
77                 return;
78             }
79             rot(pos,t);
80             del(pos->ch[t^1],val);
81         }
82         else
83             del(pos->ch[val>pos->val],val);
84         up(pos);
85     }
86 }
87 public:
88 node *rt;
89
90 Treap():rt(null){}
91 inline void insert(int val)
92 {
93     insert(rt,val);
94 }
95 inline void reset()
96 {
97     rec(rt);
98     rt=null;
99 }
100 inline int sel(int k)
101 {
102     if(k<1 || k>rt->sz)
103         return 0;
104     return sel(rt,rt->sz+1-k);
105 }
106 inline void del(int val)
107 {
108     del(rt,val);
109 }
110 inline int size()
111 {
112     return rt->sz;
113 }
114 }treap[MAXX];
115
116 init:
117 {
118     srand(time(0));
119     null=new node();
120     null->val=0xc0c0c0c0;
121     null->sz=0;
122     null->key=RAND_MAX;
123     null->ch[0]=null->ch[1]=null;
124     for(i=0;i<MAXX;++i)
125         treap[i].rt=null;

```

126 }

2 Geometry

2.1 3D

```

1 struct pv
2 {
3     double x,y,z;
4     pv() {}
5     pv(double xx,double yy,double zz):x(xx),y(yy),z(zz) {}
6     pv operator -(const pv& b)const
7     {
8         return pv(x-b.x,y-b.y,z-b.z);
9     }
10    pv operator *(const pv& b)const
11    {
12        return pv(y*b.z-z*b.y,z*b.x-x*b.z,x*b.y-y*b.x);
13    }
14    double operator &(const pv& b)const
15    {
16        return x*b.x+y*b.y+z*b.z;
17    }
18 };
19
20 //模
21 double Norm(pv p)
22 {
23     return sqrt(p&p);
24 }
25
26 //绕单位向量 V 旋转 theta 角度
27 pv Trans(pv pa,pv V,double theta)
28 {
29     double s = sin(theta);
30     double c = cos(theta);
31     double x,y,z;
32     x = V.x;
33     y = V.y;
34     z = V.z;
35     pv pp =
36         pv(
37             (x*x*(1-c)+c)*pa.x+(x*y*(1-c)-z*s)*pa.y+(x*z
38                 *(1-c)+y*s)*pa.z,
39             (y*x*(1-c)+z*s)*pa.x+(y*y*(1-c)+c)*pa.y+(y*z
40                 *(1-c)-x*s)*pa.z,
41             (x*z*(1-c)-y*s)*pa.x+(y*z*(1-c)+x*s)*pa.y+(z*z
42                 *(1-c)+c)*pa.z
43         );
44     return pp;
45 }
46
47 //经纬度转换
48
49 x=r*sinθ()*cosφ();
50 y=r*sinθ()*sinφ();
51 z=r*cosθ();
52
53 r=sqrt(x^2+y^2+z^2);///?
54 r=sqrt(x^2+y^2+z^2);///?φ
55
56 =atan(y/x);θ
57 =acos(z/r);θ
58
59 r∞[0,]∞π
60 [0,2]∞π
61 [0,]∞
62
63 lat1π[-/2,/2]∞
64 lng1π[-,]
65
66 pv getpv(double lat,double lng,double r)
67 {
68     lat += pi/2;
69     lng += pi;
70     return
71         pv(r*sin(lat)*cos(lng),r*sin(lat)*sin(lng),r*cos(lat));
72 }
73
74 //经纬度球面距离
75
76 #include<cstdio>
77 #include<cmath>
78
79 #define MAXX 1111
80
81 char buf[MAXX];
82 const double r=6875.0/2,pi=acos(-1.0);
83 double a,b,c,x1,x2,y2,ans;
84
85 int main()
86 {
87     double y1;
88     while(gets(buf)!=NULL)

```

```

86 {
87     gets(buf);
88     gets(buf);
89
90     scanf("%lf^%lf'%lf'\n", &a, &b, &c, buf);
91     x1=a+b/60+c/3600;
92     x1=x1*pi/180;
93     if(buf[0]=='S')
94         x1=-x1;
95
96     scanf("%s", buf);
97     scanf("%lf^%lf'%lf'\n", &a, &b, &c, buf);
98     y1=a+b/60+c/3600;
99     y1=y1*pi/180;
100     if(buf[0]=='W')
101         y1=-y1;
102
103     gets(buf);
104
105     scanf("%lf^%lf'%lf'\n", &a, &b, &c, buf);
106     x2=a+b/60+c/3600;
107     x2=x2*pi/180;
108     if(buf[0]=='S')
109         x2=-x2;
110
111     scanf("%s", buf);
112     scanf("%lf^%lf'%lf'\n", &a, &b, &c, buf);
113     y2=a+b/60+c/3600;
114     y2=y2*pi/180;
115     if(buf[0]=='W')
116         y2=-y2;
117
118     ans=acos(cos(x1)*cos(x2)*cos(y1-y2)+sin(x1)*sin(x2))*r;
119     printf("The distance to the iceberg: %.2lf miles.\n",
120         ans);
121     if(ans+0.005<100)
122         puts("DANGER!");
123     gets(buf);
124 }
125 return 0;
126 }
127
128 inline bool ZERO(const double &a)
129 {
130     return fabs(a)<eps;
131 }
132
133 //三维向量是否为零
134 inline bool ZERO(pv p)
135 {
136     return (ZERO(p.x) && ZERO(p.y) && ZERO(p.z));
137 }
138
139 //直线相交
140 bool LineIntersect(Line3D L1, Line3D L2)
141 {
142     pv s = L1.s-L1.e;
143     pv e = L2.s-L2.e;
144     pv p = s*e;
145     if (ZERO(p))
146         return false; //是否平行
147     p = (L2.s-L1.e)*(L1.s-L1.e);
148     return ZERO(p&L2.e); //是否共面
149 }
150
151 //线段相交
152 bool inter(pv a, pv b, pv c, pv d)
153 {
154     pv ret = (a-b)*(c-d);
155     pv t1 = (b-a)*(c-a);
156     pv t2 = (b-a)*(d-a);
157     pv t3 = (d-c)*(a-c);
158     pv t4 = (d-c)*(b-c);
159     return sgn(t1&ret)*sgn(t2&ret) < 0 && sgn(t3&ret)*sgn(t4&ret) < 0;
160 }
161
162 //点在直线上
163 bool OnLine(pv p, Line3D L)
164 {
165     return ZERO((p-L.s)*(L.e-L.s));
166 }
167
168 //点在线段上
169 bool OnSeg(pv p, Line3D L)
170 {
171     return (ZERO((L.s-p)*(L.e-p)) && EQ(Norm(p-L.s)+Norm(p-L.e), Norm(L.e-L.s)));
172 }
173
174 //点到直线距离
175 double Distance(pv p, Line3D L)
176 {
177     return (Norm((p-L.s)*(L.e-L.s))/Norm(L.e-L.s));

```

```

178 }
179
180 //线段夹角
181 //范围为  $\pi$  之间的弧度[0,]
182 double Inclination(Line3D L1, Line3D L2)
183 {
184     pv u = L1.e - L1.s;
185     pv v = L2.e - L2.s;
186     return acos( (u & v) / (Norm(u)*Norm(v)) );
187 }

```

2.2 3DCH

```

1 #include<cstdio>
2 #include<cmath>
3 #include<vector>
4 #include<algorithm>
5
6 #define MAXX 1111
7 #define eps 1e-8
8 #define inf 1e20
9
10 struct pv
11 {
12     double x,y,z;
13     pv(){}
14     pv(const double &xx,const double &yy,const double &zz):x(xx
15         ),y(yy),z(zz){}
16     inline pv operator-(const pv &i)const
17     {
18         return pv(x-i.x,y-i.y,z-i.z);
19     }
20     inline pv operator+(const pv &i)const
21     {
22         return pv(x+i.x,y+i.y,z+i.z);
23     }
24     inline pv operator+=(const pv &i)
25     {
26         x+=i.x;
27         y+=i.y;
28         z+=i.z;
29         return *this;
30     }
31     inline pv operator*(const pv &i)const //叉积
32     {
33         return pv(y*i.z-z*i.y,z*i.x-x*i.z,x*i.y-y*i.x);
34     }
35     inline pv operator*(const double a)const
36     {
37         return pv(x*a,y*a,z*a);
38     }
39     inline double operator^(const pv &i)const //点积
40     {
41         return x*i.x+y*i.y+z*i.z;
42     }
43     inline double len()
44     {
45         return sqrt(x*x+y*y+z*z);
46     }
47 };
48 struct pla
49 {
50     short a,b,c;
51     bool ok;
52     pla(){}
53     pla(const short &aa,const short &bb,const short &cc):a(aa),
54         b(bb),c(cc),ok(true){}
55     inline void set();
56     inline void print()
57     {
58         printf("%hd^%hd^%hd\n",a,b,c);
59     }
60 };
61 pv pnt[MAXX];
62 std::vector<pla> fac;
63 int to[MAXX][MAXX];
64
65 inline void pla::set()
66 {
67     to[a][b]=to[b][c]=to[c][a]=fac.size();
68 }
69
70 inline double ptof(const pv &p,const pla &f) //点面距离?
71 {
72     return (pnt[f.b]-pnt[f.a])*(pnt[f.c]-pnt[f.a])^(p-pnt[f.a])
73         ;
74 }
75 inline double vol(const pv &a,const pv &b,const pv &c,const pv
76     &d)//有向体积，即六面体
77     积*6
78 {
79     return (b-a)*(c-a)^(d-a);

```

```

78 }
79
80 inline double ptof(const pv &p,const short &f) //点到号面的距离pf
81 {
82     return fabs(vol(pnt[fac[f].a],pnt[fac[f].b],pnt[fac[f].c],p
83         )/((pnt[fac[f].b]-pnt[fac[f].a])*(pnt[fac[f].c]-pnt[
84             fac[f].a])).len());
85 }
86
87 void dfs(const short&,const short&);
88
89 void deal(const short &p,const short &a,const short &b)
90 {
91     if(fac[to[a][b]].ok)
92         if(ptof(pnt[p],fac[to[a][b]])>eps)
93             dfs(p,to[a][b]);
94     else
95     {
96         pla add(b,a,p);
97         add.set();
98         fac.push_back(add);
99     }
100 }
101
102 void dfs(const short &p,const short &now)
103 {
104     fac[now].ok=false;
105     deal(p,fac[now].b,fac[now].a);
106     deal(p,fac[now].c,fac[now].b);
107     deal(p,fac[now].a,fac[now].c);
108 }
109
110 inline void make(int n)
111 {
112     static int i,j;
113     fac.resize(0);
114     if(n<4)
115         return;
116
117     for(i=1;i<n;++i)
118         if((pnt[0]-pnt[i]).len()>eps)
119         {
120             std::swap(pnt[i],pnt[1]);
121             break;
122         }
123     if(i==n)
124         return;
125
126     for(i=2;i<n;++i)
127         if(((pnt[0]-pnt[1])*(pnt[1]-pnt[i])).len()>eps)
128         {
129             std::swap(pnt[i],pnt[2]);
130             break;
131         }
132     if(i==n)
133         return;
134
135     for(i=3;i<n;++i)
136         if(fabs((pnt[0]-pnt[1])*(pnt[1]-pnt[2])^(pnt[2]-pnt[i]
137             )>eps)
138         {
139             std::swap(pnt[3],pnt[i]);
140             break;
141         }
142     if(i==n)
143         return;
144
145     for(i=0;i<4;++i)
146     {
147         pla add((i+1)%4,(i+2)%4,(i+3)%4);
148         if(ptof(pnt[i],add)>0)
149             std::swap(add.c,add.b);
150         add.set();
151         fac.push_back(add);
152     }
153     for(;i<n;++i)
154         for(j=0;j<fac.size();++j)
155             if(fac[j].ok && ptof(pnt[i],fac[j])>eps)
156             {
157                 dfs(i,j);
158                 break;
159             }
160
161     short tmp(fac.size());
162     fac.resize(0);
163     for(i=0;i<tmp;++i)
164         if(fac[i].ok)
165             fac.push_back(fac[i]);
166 }
167
168 inline pv gc() //重心
169 {
170     pv re(0,0,0),o(0,0,0);
171     double all(0),v;
172     for(int i=0;i<fac.size();++i)
173     {
174         v=vol(o,pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
175         re+=(pnt[fac[i].a]+pnt[fac[i].b]+pnt[fac[i].c])*0.25f*v;
176         all+=v;
177     }
178     return re*(1/all);
179 }
180
181 inline bool same(const short &s,const short &t) //两面是否相等
182 {
183     pv &a=pnt[fac[s].a],&b=pnt[fac[s].b],&c=pnt[fac[s].c];
184     return fabs(vol(a,b,c,pnt[fac[t].a]))<eps && fabs(vol(a,b,c
185         ,pnt[fac[t].b]))<eps && fabs(vol(a,b,c,pnt[fac[t].c]))
186         <eps;
187 }
188
189 //表面多边形数目
190 inline int facetcnt()
191 {
192     int ans=0;
193     static int i,j;
194     for(i=0;i<fac.size();++i)
195     {
196         for(j=0;j<i;++j)
197             if(same(i,j))
198                 break;
199         if(j==i)
200             ++ans;
201     }
202     return ans;
203 }
204
205 //表面三角形数目
206 inline short trianglecnt()
207 {
208     return fac.size();
209 }
210
211 //三点构成的三角形面积*2
212 inline double area(const pv &a,const pv &b,const pv &c)
213 {
214     return ((b-a)*(c-a)).len();
215 }
216
217 //表面积
218 inline double area()
219 {
220     double ret(0);
221     static int i;
222     for(i=0;i<fac.size();++i)
223         ret+=area(pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
224     return ret/2;
225 }
226
227 //体积
228 inline double volume()
229 {
230     pv o(0,0,0);
231     double ret(0);
232     for(short i(0);i<fac.size();++i)
233         ret+=vol(o,pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
234     return fabs(ret/6);
235 }
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2.3 circle's area

```

1 //去重
2 {
3     for (int i = 0; i < n; i++)
4     {
5         scanf("%lf%lf%lf",&c[i].c.x,&c[i].c.y,&c[i].r);
6         del[i] = false;
7     }
8     for (int i = 0; i < n; i++)
9         if (del[i] == false)
10         {
11             if (c[i].r == 0.0)
12                 del[i] = true;
13             for (int j = 0; j < n; j++)
14                 if (i != j)
15                     if (del[j] == false)
16                         if (cmp(Point(c[i].c,c[j].c).Len()+c[i]
17                             ].r,c[j].r) <= 0)
18                             del[j] = true;
19         }
20     tn = n;
21     n = 0;
22     for (int i = 0; i < tn; i++)
23         if (del[i] == false)
24             c[n++] = c[i];
25 }
26 //ans[i表示被覆盖]次的面积i
27 const double pi = acos(-1.0);

```

```

28 const double eps = 1e-8;
29 struct Point
30 {
31     double x,y;
32     Point(){}
33     Point(double _x,double _y)
34     {
35         x = _x;
36         y = _y;
37     }
38     double Length()
39     {
40         return sqrt(x*x+y*y);
41     }
42 };
43 struct Circle
44 {
45     Point c;
46     double r;
47 };
48 struct Event
49 {
50     double tim;
51     int typ;
52     Event(){}
53     Event(double _tim,int _typ)
54     {
55         tim = _tim;
56         typ = _typ;
57     }
58 };
59
60 int cmp(const double& a,const double& b)
61 {
62     if (fabs(a-b) < eps)    return 0;
63     if (a < b)    return -1;
64     return 1;
65 }
66
67 bool Eventcmp(const Event& a,const Event& b)
68 {
69     return cmp(a.tim,b.tim) < 0;
70 }
71
72 double Area(double theta,double r)
73 {
74     return 0.5*r*r*(theta-sin(theta));
75 }
76
77 double xmult(Point a,Point b)
78 {
79     return a.x*b.y-a.y*b.x;
80 }
81
82 int n,cur,tote;
83 Circle c[1000];
84 double ans[1001],pre[1001],AB,AC,BC,theta,fai,a0,a1;
85 Event e[4000];
86 Point lab;
87
88 int main()
89 {
90     while (scanf("%d",&n) != EOF)
91     {
92         for (int i = 0;i < n;i++)
93             scanf("%lf%lf%lf",&c[i].c.x,&c[i].c.y,&c[i].r);
94         for (int i = 1;i <= n;i++)
95             ans[i] = 0.0;
96         for (int i = 0;i < n;i++)
97         {
98             tote = 0;
99             e[tote++] = Event(-pi,1);
100             e[tote++] = Event(pi,-1);
101             for (int j = 0;j < n;j++)
102                 if (j != i)
103                 {
104                     lab = Point(c[j].c.x-c[i].c.x,c[j].c.y-c[i].c.y);
105                     AB = lab.Length();
106                     AC = c[i].r;
107                     BC = c[j].r;
108                     if (cmp(AB+AC,BC) <= 0)
109                     {
110                         e[tote++] = Event(-pi,1);
111                         e[tote++] = Event(pi,-1);
112                         continue;
113                     }
114                     if (cmp(AB+BC,AC) <= 0) continue;
115                     if (cmp(AB,AC+BC) > 0) continue;
116                     theta = atan2(lab.y,lab.x);
117                     fai = acos((AC*AC+AB*AB-BC*BC)/(2.0*AC*AB));
118                     a0 = theta-fai;
119                     if (cmp(a0,-pi) < 0)    a0 += 2*pi;
120                     a1 = theta+fai;
121                     if (cmp(a1,pi) > 0)    a1 -= 2*pi;

```

```

122         if (cmp(a0,a1) > 0)
123         {
124             e[tote++] = Event(a0,1);
125             e[tote++] = Event(pi,-1);
126             e[tote++] = Event(-pi,1);
127             e[tote++] = Event(a1,-1);
128         }
129         else
130         {
131             e[tote++] = Event(a0,1);
132             e[tote++] = Event(a1,-1);
133         }
134     }
135     sort(e,e+tote,Eventcmp);
136     cur = 0;
137     for (int j = 0;j < tote;j++)
138     {
139         if (cur != 0 && cmp(e[j].tim,pre[cur]) != 0)
140         {
141             ans[cur] += Area(e[j].tim-pre[cur],c[i].r);
142             ans[cur] += xmult(Point(c[i].c.x+c[i].r*cos
143                                 (pre[cur]),c[i].c.y+c[i].r*sin(pre[cur]
144                                 )),
145                               Point(c[i].c.x+c[i].r*cos(e[j].tim)
146                                     ,c[i].c.y+c[i].r*sin(e[j].tim)
147                                     ))/2.0;
148             cur += e[j].typ;
149             pre[cur] = e[j].tim;
150         }
151     }
152     for (int i = 1;i < n;i++)
153         ans[i] -= ans[i+1];
154     for (int i = 1;i <= n;i++)
155         printf("[%d]_=%f\n",i,ans[i]);
156     return 0;

```

2.4 circle

```

1 //单位圆覆盖
2 #include<cstdio>
3 #include<cmath>
4 #include<vector>
5 #include<algorithm>
6
7 #define MAXX 333
8 #define eps 1e-8
9
10 struct pv
11 {
12     double x,y;
13     pv(){}
14     pv(const double &xx,const double &yy):x(xx),y(yy){}
15     inline pv operator-(const pv &i)const
16     {
17         return pv(x-i.x,y-i.y);
18     }
19     inline double cross(const pv &i)const
20     {
21         return x*i.y-y*i.x;
22     }
23     inline void print()
24     {
25         printf("%lf_ %lf\n",x,y);
26     }
27     inline double len()
28     {
29         return sqrt(x*x+y*y);
30     }
31 }pnt[MAXX];
32
33 struct node
34 {
35     double k;
36     bool flag;
37     node(){}
38     node(const double &kk,const bool &ff):k(kk),flag(ff){}
39     inline bool operator<(const node &i)const
40     {
41         return k<i.k;
42     }
43 };
44
45 std::vector<node>alpha;
46
47 short n,i,j,k,l;
48 short ans,sum;
49 double R=2;
50 double theta,phi,d;
51 const double pi(acos(-1.0));
52
53 int main()
54 {

```

```

55 alpha.reserve(MAXX<<1);
56 while(scanf("%hd",&n),n)
57 {
58     for(i=0;i<n;++i)
59         scanf("%lf%lf",&pnt[i].x,&pnt[i].y);
60     ans=0;
61     for(i=0;i<n;++i)
62     {
63         alpha.resize(0);
64         for(j=0;j<n;++j)
65             if(i!=j)
66             {
67                 if((d=(pnt[i]-pnt[j]).len())>R)
68                     continue;
69                 if((theta=atan2(pnt[j].y-pnt[i].y,pnt[j].x-
70 pnt[i].x))<0)
71                     theta+=2*pi;
72                 phi=acos(d/R);
73                 alpha.push_back(node(theta-phi,true));
74                 alpha.push_back(node(theta+phi,false));
75             }
76         std::sort(alpha.begin(),alpha.end());
77         for(j=0;j<alpha.size();++j)
78         {
79             if(alpha[j].flag)
80                 ++sum;
81             else
82                 --sum;
83             ans=std::max(ans,sum);
84         }
85         printf("%hd\n",ans+1);
86     }
87     return 0;
88 }
89
90 //最小覆盖圆
91
92 #include<cstdio>
93 #include<cmath>
94
95 #define MAXX 511
96 #define eps 1e-8
97
98 struct pv
99 {
100     double x,y;
101     pv(){ }
102     pv(const double &xx,const double &yy):x(xx),y(yy){ }
103     inline pv operator-(const pv &i)const
104     {
105         return pv(x-i.x,y-i.y);
106     }
107     inline pv operator+(const pv &i)const
108     {
109         return pv(x+i.x,y+i.y);
110     }
111     inline double cross(const pv &i)const
112     {
113         return x*i.y-y*i.x;
114     }
115     inline double len()
116     {
117         return sqrt(x*x+y*y);
118     }
119     inline pv operator/(const double &a)const
120     {
121         return pv(x/a,y/a);
122     }
123     inline pv operator*(const double &a)const
124     {
125         return pv(x*a,y*a);
126     }
127 }pnt[MAXX],o,tl,lt,aa,bb,cc,dd;
128
129 short n,i,j,k,l;
130 double r,u;
131
132 inline pv ins(const pv &a1,const pv &a2,const pv &b1,const pv &b2)
133 {
134     tl=a2-a1;
135     lt=b2-b1;
136     u=(b1-a1).cross(lt)/(tl).cross(lt);
137     return a1+tl*u;
138 }
139
140 inline pv get(const pv &a,const pv &b,const pv &c)
141 {
142     aa=(a+b)/2;
143     bb.x=aa.x-a.y+b.y;
144     bb.y=aa.y+a.x-b.x;
145     cc=(a+c)/2;
146     dd.x=cc.x-a.y+c.y;
147     dd.y=cc.y+a.x-c.x;
148     return ins(aa,bb,cc,dd);
149 }
150
151 int main()
152 {
153     while(scanf("%hd",&n),n)
154     {
155         for(i=0;i<n;++i)
156             scanf("%lf%lf",&pnt[i].x,&pnt[i].y);
157         o=pnt[0];
158         r=0;
159         for(i=1;i<n;++i)
160             if((pnt[i]-o).len()>r+eps)
161             {
162                 o=pnt[i];
163                 r=0;
164                 for(j=0;j<i;++j)
165                     if((pnt[j]-o).len()>r+eps)
166                     {
167                         o=(pnt[i]+pnt[j])/2;
168                         r=(o-pnt[j]).len();
169                         for(k=0;k<j;++k)
170                             if((o-pnt[k]).len()>r+eps)
171                             {
172                                 o=get(pnt[i],pnt[j],pnt[k]);
173                                 r=(o-pnt[i]).len();
174                             }
175                     }
176             }
177         printf("%.2lf%.2lf%.2lf\n",o.x,o.y,r);
178     }
179     return 0;
180 }
181
182 //两原面积交
183 double dis(int x,int y)
184 {
185     return sqrt((double)(x*x+y*y));
186 }
187
188 double area(int x1,int y1,int x2,int y2,double r1,double r2)
189 {
190     double s=dis(x2-x1,y2-y1);
191     if(r1+r2<s) return 0;
192     else if(r2-r1>s) return PI*r1*r1;
193     else if(r1-r2>s) return PI*r2*r2;
194     double q1=acos((r1*r1+s*s-r2*r2)/(2*r1*s));
195     double q2=acos((r2*r2+s*s-r1*r1)/(2*r2*s));
196     return (r1*r1*q1+r2*r2*q2-r1*s*sin(q1));
197 }
198
199 //三角形外接圆
200 {
201     for (int i = 0; i < 3; i++)
202         scanf("%lf%lf",&p[i].x,&p[i].y);
203     tp = pv((p[0].x+p[1].x)/2,(p[0].y+p[1].y)/2);
204     l[0] = Line(tp,pv(tp.x-(p[1].y-p[0].y),tp.y+(p[1].x-p[0].x)
205 ));
206     tp = pv((p[0].x+p[2].x)/2,(p[0].y+p[2].y)/2);
207     l[1] = Line(tp,pv(tp.x-(p[2].y-p[0].y),tp.y+(p[2].x-p[0].x)
208 ));
209     tp = LineToLine(l[0],l[1]);
210     r = pv(tp,p[0]).Length();
211     printf("%.6f,%.6f,%.6f\n",tp.x,tp.y,r);
212 }
213
214 //三角形内切圆
215 {
216     for (int i = 0; i < 3; i++)
217         scanf("%lf%lf",&p[i].x,&p[i].y);
218     if (xmult(pv(p[0],p[1]),pv(p[0],p[2])) < 0)
219         swap(p[1],p[2]);
220     for (int i = 0; i < 3; i++)
221         len[i] = pv(p[i],p[(i+1)%3]).Length();
222     tr = (len[0]+len[1]+len[2])/2;
223     r = sqrt((tr-len[0])*(tr-len[1])*(tr-len[2])/tr);
224     for (int i = 0; i < 2; i++)
225     {
226         v = pv(p[i],p[i+1]);
227         tv = pv(-v.y,v.x);
228         tr = tv.Length();
229         tv = pv(tv.x*r/tr,tv.y*r/tr);
230         tp = pv(p[i].x+tv.x,p[i].y+tv.y);
231         l[i].s = tp;
232         tp = pv(p[i+1].x+tv.x,p[i+1].y+tv.y);
233         l[i].e = tp;
234     }
235     tp = LineToLine(l[0],l[1]);
236     printf("%.6f,%.6f,%.6f\n",tp.x,tp.y,r);
237 }
238
239 2.5 closest point pair
240
241 //演算法笔记1
242
243 struct Point {double x, y;} p[10], t[10];

```

```

4 bool cmpx(const Point& i, const Point& j) {return i.x < j.x;} 95 }
5 bool cmpy(const Point& i, const Point& j) {return i.y < j.y;} 96 }
6 97 double closest_pair()
7 { 98 {
8     if (L >= R) return 1e9; // 沒有點、只有一個點。 99     sort(p, p+10, cmpx);
9 100     return DnC(0, N-1);
10 101 }
11 102 //mzry
12 103 //分治
13 104 double calc_dis(Point &a, Point &b) {
14 105     return sqrt((a.x-b.x)*(a.x-b.x) + (a.y-b.y)*(a.y-b.y));
15 106 }
16 107 //別忘了排序
17 108 bool operator<(const Point &a, const Point &b) {
18 109     if(a.y != b.y) return a.x < b.x;
19 110     return a.x < b.x;
20 111 }
21 112 double Gao(int l, int r, Point pnts[]) {
22 113     double ret = inf;
23 114     if(l == r) return ret;
24 115     if(l+1 == r) {
25 116         ret = min(calc_dis(pnts[l], pnts[l+1]), ret);
26 117         return ret;
27 118     }
28 119     if(l+2 == r) {
29 120         ret = min(calc_dis(pnts[l], pnts[l+1]), ret);
30 121         ret = min(calc_dis(pnts[l], pnts[l+2]), ret);
31 122         ret = min(calc_dis(pnts[l+1], pnts[l+2]), ret);
32 123         return ret;
33 124     }
34 125 }
35 126 int mid = l+r>>1;
36 127 ret = min (ret, Gao(l, mid, pnts));
37 128 ret = min (ret, Gao(mid+1, r, pnts));
38 129 }
39 130 for(int c = l ; c<=r; c++)
40 131     for(int d = c+1; d <=c+7 && d<=r; d++) {
41 132         ret = min(ret, calc_dis(pnts[c], pnts[d]));
42 133     }
43 134 return ret;
44 135 }
45 136 //增量
46 137 #include <iostream>
47 138 #include <cstdio>
48 139 #include <cstring>
49 140 #include <map>
50 141 #include <vector>
51 142 #include <cmath>
52 143 #include <algorithm>
53 144 #define Point pair<double, double>
54 145 using namespace std;
55 146 const int step[9][2] =
56 147     {{-1,-1},{-1,0},{-1,1},{0,-1},{0,0},{0,1},{1,-1},{1,0},{1,1}};
57 148
58 149 int n,x,y,nx,ny;
59 150 map<pair<int,int>, vector<Point > > g;
60 151 vector<Point > tmp;
61 152 Point p[20000];
62 153 double tx,ty,ans,nowans;
63 154 vector<Point >::iterator it,op,ed;
64 155 pair<int,int> gird;
65 156 bool flag;
66 157
67 158 double Dis(Point p0, Point p1)
68 159 {
69 160     return sqrt((p0.first-p1.first)*(p0.first-p1.first)+
70 161         (p0.second-p1.second)*(p0.second-p1.second));
71 162 }
72 163
73 164 double CalcDis(Point p0, Point p1, Point p2)
74 165 {
75 166     return Dis(p0,p1)+Dis(p0,p2)+Dis(p1,p2);
76 167 }
77 168
78 169 void build(int n, double w)
79 170 {
80 171     g.clear();
81 172     for (int i = 0; i < n; i++)
82 173         g[make_pair(((int) floor(p[i].first/w), (int) floor(p[i].second
83 174             /w)))] .push_back(p[i]);
84 175 }
85 176
86 177 int main()
87 178 {
88 179     int t;
89 180     scanf("%d",&t);
90 181     for (int ft = 1; ft <= t; ft++)
91 182     {
92 183         scanf("%d",&n);
93 184         for (int i = 0; i < n; i++)
94 185         {
95 186             scanf("%lf%lf",&tx,&ty);
96 187             p[i] = make_pair(tx,ty);

```



```

188 }
189 random_shuffle(p,p+n);
190 ans = CalcDis(p[0],p[1],p[2]);
191 build(3,ans/2.0);
192 for (int i = 3;i < n;i++)
193 {
194     x = (int)floor(2.0*p[i].first/ans);
195     y = (int)floor(2.0*p[i].second/ans);
196     tmp.clear();
197     for (int k = 0;k < 9;k++)
198     {
199         nx = x+step[k][0];
200         ny = y+step[k][1];
201         gird = make_pair(nx,ny);
202         if (g.find(gird) != g.end())
203         {
204             op = g[gird].begin();
205             ed = g[gird].end();
206             for (it = op;it != ed;it++)
207                 tmp.push_back(*it);
208         }
209     }
210     flag = false;
211     for (int j = 0;j < tmp.size();j++)
212         for (int k = j+1;k < tmp.size();k++)
213         {
214             nowans = CalcDis(p[i],tmp[j],tmp[k]);
215             if (nowans < ans)
216             {
217                 ans = nowans;
218                 flag = true;
219             }
220         }
221     if (flag == true)
222         build(i+1,ans/2.0);
223     else
224         g[make_pair((int)floor(2.0*p[i].first/ans),(int)floor(2.0*p[i].second/ans))].push_back(p[i]);
225 }
226 printf("%.3f\n",ans);
227 }
228 }

```

2.6 ellipse

```

1 /*
2  $\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$ 
3
4  $x = h + a \times \cos(t)$ 
5  $y = k + b \times \sin(t)$ 
6
7 area= $\pi \times a \times b$ 
8 distance from center to focus:  $f = \sqrt{a^2 - b^2}$ 
9 eccentricity:  $e = \sqrt{a - \frac{b^2}{a}} = \frac{f}{a}$ 
10 focal parameter:  $\frac{b^2}{\sqrt{a^2 - b^2}} = \frac{b^2}{f}$ 
11 */
12
13 inline double circumference(double a,double b) // accuracy: pow(0.5,53);
14 {
15     static double digits=53;
16     static double tol=sqrt(pow(0.5,digits));
17     double x=a;
18     double y=b;
19     if(x<y)
20         std::swap(x,y);
21     if(digits*y<tol*x)
22         return 4*x;
23     double s=0,m=1;
24     while(x>(tol+1)*y)
25     {
26         double tx=x;
27         double ty=y;
28         x=0.5f*(tx+ty);
29         y=sqrt(tx*ty);
30         m*=2;
31         s+=m*pow(x-y,2);
32     }
33     return pi*(pow(a+b,2)-s)/(x+y);
34 }

```

2.7 Graham's scan

```

1 pv pnt[MAXX];
2
3 inline bool com(const pv &a,const pv &b)
4 {
5     if (fabs(t=(a-pnt[0]).cross(b-pnt[0]))>eps)
6         return t>0;
7     return (a-pnt[0]).len()<(b-pnt[0]).len();
8 }

```

```

9
10 inline void graham(std::vector<pv> &ch,const int n)
11 {
12     std::nth_element(pnt,pnt,pnt+n);
13     std::sort(pnt+1,pnt+n,com);
14     ch.resize(0);
15     ch.push_back(pnt[0]);
16     ch.push_back(pnt[1]);
17     static int i;
18     for(i=2;i<n;++i)
19         if(fabs((pnt[i]-ch[0]).cross(ch[1]-ch[0]))>eps)
20         {
21             ch.push_back(pnt[i]);
22             break;
23         }
24     else
25         ch.back()=pnt[i];
26     for(;i<n;++i)
27     {
28         while((ch.back()-ch[ch.size()-2]).cross(pnt[i]-ch[ch.size()-2])<eps)
29             ch.pop_back();
30         ch.push_back(pnt[i]);
31     }
32 }

```

2.8 half-plane intersection

```

1 //解析几何方式abc
2 inline pv ins(const pv &p1,const pv &p2)
3 {
4     u=fabs(a*p1.x+b*p1.y+c);
5     v=fabs(a*p2.x+b*p2.y+c);
6     return pv((p1.x*v+p2.x*u)/(u+v),(p1.y*v+p2.y*u)/(u+v));
7 }
8
9 inline void get(const pv& p1,const pv& p2,double &a,double &b ,double &c)
10 {
11     a=p2.y-p1.y;
12     b=p1.x-p2.x;
13     c=p2.x*p1.y-p2.y*p1.x;
14 }
15
16 inline pv ins(const pv &x,const pv &y)
17 {
18     get(x,y,d,e,f);
19     return pv((b*f-c*e)/(a*e-b*d),(a*f-c*d)/(b*d-a*e));
20 }
21
22 std::vector<pv> p[2];
23 inline bool go()
24 {
25     k=0;
26     p[k].resize(0);
27     p[k].push_back(pv(-inf,inf));
28     p[k].push_back(pv(-inf,-inf));
29     p[k].push_back(pv(inf,-inf));
30     p[k].push_back(pv(inf,inf));
31     for(i=0;i<n;++i)
32     {
33         get(pnt[i],pnt[(i+1)%n],a,b,c);
34         c+=the*sqrt(a*a+b*b);
35         p[!k].resize(0);
36         for(l=0;l<p[k].size();++l)
37             if(a*p[k][l].x+b*p[k][l].y+c<eps)
38                 p[!k].push_back(p[k][l]);
39         else
40         {
41             m=(l+p[k].size()-1)%p[k].size();
42             if(a*p[k][m].x+b*p[k][m].y+c<-eps)
43                 p[!k].push_back(ins(p[k][m],p[k][l]));
44             m=(l+1)%p[k].size();
45             if(a*p[k][m].x+b*p[k][m].y+c<-eps)
46                 p[!k].push_back(ins(p[k][m],p[k][l]));
47         }
48         k=!k;
49         if(p[k].empty())
50             break;
51     }
52     //结果在p[k]中
53     return p[k].empty();
54 }
55
56 //计算几何方式
57 //本例求多边形核
58
59 inline pv ins(const pv &a,const pv &b)
60 {
61     u=fabs(ln.cross(a-pnt[i]));
62     v=fabs(ln.cross(b-pnt[i]))+u;
63     tl=b-a;
64     return pv(u*tl.x/v+a.x,u*tl.y/v+a.y);
65 }
66

```

```

67 int main()
68 {
69     j=0;
70     for(i=0;i<n;++i)
71     {
72         ln=pnt[(i+1)%n]-pnt[i];
73         p[!j].resize(0);
74         for(k=0;k<p[j].size();++k)
75             if(ln.cross(p[j][k]-pnt[i])<=0)
76                 p[!j].push_back(p[j][k]);
77         else
78         {
79             l=(k-1+p[j].size())%p[j].size();
80             if(ln.cross(p[j][l]-pnt[i])<0)
81                 p[!j].push_back(p[j][l]);
82             l=(k+1)%p[j].size();
83             if(ln.cross(p[j][l]-pnt[i])<0)
84                 p[!j].push_back(p[j][l]);
85         }
86         j=!j;
87     }
88     //结果在p[j]中
89 }
90
91 //mrzy
92
93 bool HPIcmp(Line a, Line b)
94 {
95     if (fabs(a.k - b.k) > eps)
96         return a.k < b.k;
97     return ((a.s - b.s) * (b.e - b.s)) < 0;
98 }
99
100 Line Q[100];
101
102 void HPI(Line line[], int n, Point res[], int &resn)
103 {
104     int tot = n;
105     std::sort(line, line + n, HPIcmp);
106     tot = 1;
107     for (int i = 1; i < n; i++)
108         if (fabs(line[i].k - line[i - 1].k) > eps)
109             line[tot++] = line[i];
110     int head = 0, tail = 1;
111     Q[0] = line[0];
112     Q[1] = line[1];
113     resn = 0;
114     for (int i = 2; i < tot; i++)
115     {
116         if (fabs((Q[tail].e-Q[tail].s)*(Q[tail-1].e-Q[tail-1].s)) < eps || fabs((Q[head].e-Q[head].s)*(Q[head+1].e-Q[head+1].s)) < eps)
117             return;
118         while (head < tail && (((Q[tail]&Q[tail-1]) - line[i].s) * (line[i].e-line[i].s)) > eps)
119             --tail;
120         while (head < tail && (((Q[head]&Q[head+1]) - line[i].s) * (line[i].e-line[i].s)) > eps)
121             ++head;
122         Q[++tail] = line[i];
123     }
124     while (head < tail && (((Q[tail]&Q[tail-1]) - Q[head].s) * (Q[head].e-Q[head].s)) > eps)
125         tail--;
126     while (head < tail && (((Q[head]&Q[head+1]) - Q[tail].s) * (Q[tail].e-Q[tail].s)) > eps)
127         head++;
128     if (tail <= head + 1)
129         return;
130     for (int i = head; i < tail; i++)
131         res[resn++] = Q[i] & Q[i + 1];
132     if (head < tail + 1)
133         res[resn++] = Q[head] & Q[tail];
134 }

```

2.9 intersection of circle and poly

```

1 pv c;
2 double r;
3
4 inline double cal(const pv &a,const pv &b)
5 {
6     static double A,B,C,x,y,ts;
7     A=(b-c).len();
8     B=(a-c).len();
9     C=(a-b).len();
10    if(A<r && B<r)
11        return (a-c).cross(b-c)/2;
12    x=((a-b).dot(c-b)+sqrt(r*r*C*C-sqr((a-b).cross(c-b))))/C;
13    y=((b-a).dot(c-a)+sqrt(r*r*C*C-sqr((b-a).cross(c-a))))/C;
14    ts=(a-c).cross(b-c)/2;
15
16    if(A<r && B>=r)
17        return asin(ts*(1-x/C)*2/r/B*(1-eps))*r*r/2+ts*x/C;
18    if(A>=r && B<r)

```

```

19        return asin(ts*(1-y/C)*2/r/A*(1-eps))*r*r/2+ts*y/C;
20
21    if(fabs((a-c).cross(b-c))>=r*C || (b-a).dot(c-a)<=0 || (a-b).dot(c-b)<=0)
22    {
23        if((a-c).dot(b-c)<0)
24        {
25            if((a-c).cross(b-c)<0)
26                return (-pi-asin((a-c).cross(b-c)/A/B*(1-eps)))*r*r/2;
27            return (pi-asin((a-c).cross(b-c)/A/B*(1-eps)))*r*r/2;
28        }
29        return asin((a-c).cross(b-c)/A/B*(1-eps))*r*r/2;
30    }
31
32    return (asin(ts*(1-x/C)*2/r/B*(1-eps))+asin(ts*(1-y/C)*2/r/A*(1-eps)))*r*r/2+ts*((y+x)/C-1);
33 }
34
35 inline double get(pv *the,int n)
36 {
37     double ans=0;
38     for(int i=0;i<n;++i)
39         ans+=cal(the[i],the[(i+1)%n]);
40     return ans;
41 }

```

2.10 k-d tree

```

1 /*
2  有个很关键的剪枝，在计算完与 mid 点的距离后，我们应该先进入左右哪个子树？我们
   应该先进入对于当前维度，查询点位于的那一边。显然，在查询点所在的子树，
   更容易找出正确解。
3
4  那么当进入完左或右子树后，以查询点为圆心做圆，如果当前维度，查询点距离 mid
   的距离（另一个子树中的点距离查询点的距离肯定大于这个距离）比堆里的最大
   值还大，那么就不再递归另一个子树。注意一下：如果堆里的元素个数不足 M，
   仍然还要进入另一棵子树。
5
6  说白了就是随便乱搞啦.....
7  */
8  // hysbz 2626
9  #include<cstdio>
10 #include<algorithm>
11 #include<queue>
12
13 inline long long sqr(long long a){ return a*a;}
14 typedef std::pair<long long,int> pli;
15
16 #define MAXX 100111
17 #define MAX (MAXX<<2)
18 #define inf 0x3f3f3f3fll
19 int idx;
20
21 struct PNT
22 {
23     long long x[2];
24     int lb;
25     bool operator<(const PNT &i)const
26     {
27         return x[idx]<i.x[idx];
28     }
29     pli dist(const PNT &i)const
30     {
31         return pli(-(sqr(x[0]-i.x[0])+sqr(x[1]-i.x[1])),lb);
32     }
33 }a[MAXX],the[MAX],p;
34
35 #define mid (l+r>>1)
36 #define lson (id<<1)
37 #define rson (id<<1|1)
38 #define lc lson,l,mid-1
39 #define rc rson,mid+1,r
40 int n,m;
41
42 long long rg[MAX][2][2];
43
44 void make(int id=1,int l=1,int r=n,int d=0)
45 {
46     the[id].lb=-1;
47     rg[id][0][0]=rg[id][1][0]=inf;
48     rg[id][0][1]=rg[id][1][1]=-inf;
49     if(l>r)
50         return;
51     idx=d;
52     std::nth_element(a+l,a+mid,a+r+1);
53     the[id]=a[mid];
54     rg[id][0][0]=rg[id][0][1]=the[id].x[0];
55     rg[id][1][0]=rg[id][1][1]=the[id].x[1];
56     make(lc,d^1);
57     make(rc,d^1);
58
59     rg[id][0][0]=std::min(rg[id][0][0],std::min(rg[lson][0][0],rg[rson][0][0]));

```

```

60 rg[id][1][0]=std::min(rg[id][1][0],std::min(rg[lson][1][0],25
    rg[rson][1][0]));
61
62 rg[id][0][1]=std::max(rg[id][0][1],std::max(rg[lson][0][1],28
    rg[rson][0][1]));
63 rg[id][1][1]=std::max(rg[id][1][1],std::max(rg[lson][1][1],30
    rg[rson][1][1]));
64 }
65
66 inline long long cal(int id)
67 {
68     static long long a[2];
69     static int i;
70     for(i=0;i<2;++i)
71         a[i]=std::max(abs(p.x[i]-rg[id][i][0]),abs(p.x[i]-rg[id]
            [i][1]));
72     return sqr(a[0])+sqr(a[1]);
73 }
74
75 std::priority_queue<pli>ans;
76
77 void query(const int id=1,const int d=0)
78 {
79     if(the[id].lb<0)
80         return;
81     pli tmp(the[id].dist(p));
82     int a(lson),b(rson);
83     if(p.x[d]<=the[id].x[d])
84         std::swap(a,b);
85     if(ans.size()<m)
86         ans.push(tmp);
87     else
88         if(tmp<ans.top())
89         {
90             ans.push(tmp);
91             ans.pop();
92         }
93     if(ans.size()<m || cal(a)>=-ans.top().first)
94         query(a,d^1);
95     if(ans.size()<m || cal(b)>=-ans.top().first)
96         query(b,d^1);
97 }
98
99 int q,i,j,k;
100
101 int main()
102 {
103     scanf("%d",&n);
104     for(i=1;i<=n;++i)
105     {
106         scanf("%lld%lld",&a[i].x[0],&a[i].x[1]);
107         a[i].lb=i;
108     }
109     make();
110     scanf("%d",&q);
111     while(q--)
112     {
113         scanf("%lld%lld",&p.x[0],&p.x[1]);
114         scanf("%d",&m);
115         while(!ans.empty())
116             ans.pop();
117         query();
118         printf("%d\n",ans.top().second);
119     }
120     return 0;
121 }

```

2.11 Manhattan MST

```

1 #include<iostream>
2 #include<cstdio>
3 #include<cstring>
4 #include<queue>
5 #include<cmath>
6 using namespace std;
7 const int srange = 10000000; //坐标范围
8 const int ra = 131072; //线段树常量
9 int c[ra*2], d[ra*2]; //线段树
10 int a[100000], b[100000]; //排序临时变量
11 int order[400000], torder[100000]; //排序结果
12 int Index[100000]; //排序结果取反(为了在常数时间内取得某数的位置)
13 int road[100000][8]; //每个点连接出去的条边8
14 int y[100000], x[100000]; //点坐标
15 int n; //点个数
16
17 int swap(int &a, int &b) //交换两个数
18 {
19     int t = a; a = b; b = t;
20 }
21
22 int insert(int a, int b, int i) //向线段树中插入一个数
23 {
24     a += ra;

```

```

while (a != 0)
{
    if (c[a] > b)
    {
        c[a] = b;
        d[a] = i;
    }
    else break;
    a >>= 1;
}
}

int find(int a) //从c[0..a中找最小的数, 线段树查询]
{
    a += ra;
    int ret = d[a], max = c[a];
    while (a > 1)
    {
        if ((a & 1) == 1)
            if (c[a-1] < max)
            {
                max = c[a-1];
                ret = d[a-1];
            }
        a >>= 1;
    }
    return ret;
}

int ta[65536], tb[100000]; //基数排序临时变量

int radixsort(int *p) //基数排序, 以为基准p
{
    memset(ta, 0, sizeof(ta));
    for (int i = 0; i < n; i++) ta[p[i] & 0xffff]++;
    for (int i = 0; i < 65535; i++) ta[i+1] += ta[i];
    for (int i = n-1; i >= 0; i--) tb[ta[i]-ta[i-1]] = order[i];
    memmove(order, tb, n * sizeof(int));
    memset(ta, 0, sizeof(ta));
    for (int i = 0; i < n; i++) ta[p[i] >> 16]++;
    for (int i = 0; i < 65535; i++) ta[i+1] += ta[i];
    for (int i = n-1; i >= 0; i--) tb[ta[i]-ta[i-1]] = order[i];
    memmove(order, tb, n * sizeof(int));
}

int work(int ii) //求每个点在一个方向上最近的点
{
    for (int i = 0; i < n; i++) //排序前的准备工作
    {
        a[i] = y[i] - x[i] + srange;
        b[i] = srange - y[i];
        order[i] = i;
    }
    radixsort(b); //排序
    radixsort(a);
    for (int i = 0; i < n; i++)
    {
        torder[i] = order[i];
        order[i] = i;
    }
    radixsort(a); //为线段树而做的排序
    radixsort(b);
    for (int i = 0; i < n; i++)
    {
        Index[order[i]] = i; //取反, 求orderIndex
    }
    for (int i = 1; i < ra + n; i++) c[i] = 0x7fffffff; //线段树初始化
    memset(d, 0xff, sizeof(d));
    for (int i = 0; i < n; i++) //线段树插入删除调用
    {
        int tt = torder[i];
        road[tt][ii] = find(Index[tt]);
        insert(Index[tt], y[tt] + x[tt], tt);
    }
}

int distanc(int a, int b) //求两点的距离, 之所以少一个是因为编译器不让使用作为函数名edistance
{
    return abs(x[a] - x[b]) + abs(y[a] - y[b]);
}

int ttb[400000]; //边排序的临时变量
int rx[400000], ry[400000], rd[400000]; //边的存储
int rr = 0;

int radixsort_2(int *p) //还是基数排序, copy+的产物paste
{
    memset(ta, 0, sizeof(ta));
    for (int i = 0; i < rr; i++) ta[p[i] & 0xffff]++;
    for (int i = 0; i < 65535; i++) ta[i+1] += ta[i];

```

```

115     for (int i = rr - 1; i >= 0; i--) ttb[ —ta[ p[ order[ i ]
        ] & 0xffff ] ] = order[ i ];
116 memmove( order, ttb, rr * sizeof( int ) );
117 memset( ta, 0, sizeof( ta ) );
118 for (int i = 0; i < rr; i++) ta[ p[ i ] >> 16 ]++;
119 for (int i = 0; i < 65535; i++) ta[ i + 1 ] += ta[ i ];
120 for (int i = rr - 1; i >= 0; i--) ttb[ —ta[ p[ order[ i ]
        ] >> 16 ] ] = order[ i ];
121 memmove( order, ttb, rr * sizeof( int ) );
122 }
123
124 int father[ 100000 ], rank[ 100000 ]; //并查集
125 int findfather( int x ) //并查集寻找代表元
126 {
127     if ( father[ x ] != -1 )
128         return ( father[ x ] = findfather( father[ x ] ) );
129     else return x;
130 }
131
132 long long kruskal() //最小生成树
133 {
134     rr = 0;
135     int tot = 0;
136     long long ans = 0;
137     for (int i = 0; i < n; i++) //得到边表
138     {
139         for (int j = 0; j < 4; j++)
140         {
141             if ( road[ i ][ j ] != -1 )
142             {
143                 rx[ rr ] = i;
144                 ry[ rr ] = road[ i ][ j ];
145                 rd[ rr++ ] = distanc( i, road[ i ][ j ] );
146             }
147         }
148     }
149     for (int i = 0; i < rr; i++) order[ i ] = i; //排序
150     radixsort_2( rd );
151     memset( father, 0xff, sizeof( father ) ); //并查集初始化
152     memset( rank, 0, sizeof( rank ) );
153     for (int i = 0; i < rr; i++) //最小生成树标准算法kruskal
154     {
155         if ( tot == n - 1 ) break;
156         int t = order[ i ];
157         int x = findfather( rx[ t ] ), y = findfather( ry[ t ] );
158         if ( x != y )
159         {
160             ans += rd[ t ];
161             tot++;
162             int &rxx = rank[ x ], &rky = rank[ y ];
163             if ( rxx > rky ) father[ y ] = x;
164             else
165             {
166                 father[ x ] = y;
167                 if ( rxx == rky ) rky++;
168             }
169         }
170     }
171     return ans;
172 }
173
174 int casenum = 0;
175
176 int main()
177 {
178     while ( cin >> n )
179     {
180         if ( n == 0 ) break;
181         for (int i = 0; i < n; i++)
182             scanf( "%d%d", &x[ i ], &y[ i ] );
183         memset( road, 0xff, sizeof( road ) );
184         for (int i = 0; i < 4; i++) //为了减少编程复
            杂度, work()函数只写了一种, 其他情况用转换坐标的方式类似处
            理
185         {
186             //为了降低算法复杂度, 只求出一个方向的边4
187             if ( i == 2 )
188             {
189                 for (int j = 0; j < n; j++) swap( x[ j ], y[ j ] );
190             }
191             if ( ( i & 1 ) == 1 )
192             {
193                 for (int j = 0; j < n; j++) x[ j ] = srange -
                    x[ j ];
194             }
195             work( i );
196             printf( "Case%d: Total Weight=", ++casenum );
197             cout << kruskal() << endl;
198         }
199     }
200 }

```

2.12 others

```

1| eps
2|
3| 如果 sqrt(a), asin(a), acos(a) 中的 a 是你自己算出来并传进来的, 那就得
    小心了。如果 a 本来应该是 0 的, 由于浮点误差, 可能实际是一个绝对值很
    小的负数 (比如  $-1^{-12}$ ), 这样 sqrt(a) 应得 0 的, 直接因 a 不在定义域
    而出错。类似地, 如果 a 本来应该是  $\pm 1$ , 则 asin(a)、acos(a) 也有可能
    出错。因此, 对于此种函数, 必需事先对 a 进行校正。
4|
5| 现在考虑一种情况, 题目要求输出保留两位小数。有个 case 的正确答案的精确值是
    0.005, 按理应该输出 0.01, 但你的结果可能是 0.005000000001(恭喜),
    也有可能是 0.004999999999(悲剧), 如果按照 printf("%.2lf", a) 输
    出, 那你的遭遇将和括号里的字相同。
6| 如果 a 为正, 则输出 a + eps, 否则输出 a - eps。
7|
8| 不要输出 -0.000
9|
10| 注意 double 的数据范围
11|
12| a==b fabs(a-b)<eps
13| a!=b fabs(a-b)>eps
14| a<b a+eps<b
15| a<=b a<b+eps
16| a>b a>b+eps
17| a>=b a+eps>b
18|
19| 三角函数
20|
21| cos/sin/tan 输入弧度
22| acos 输入 [-1,+1], 输出  $[0, \pi]$ 
23| asin 输入 [-1,+1], 输出  $[-\frac{\pi}{2}, +\frac{\pi}{2}]$ 
24| atan 输出  $[-\frac{\pi}{2}, +\frac{\pi}{2}]$ 
25| atan2 输入 (y,x) (注意顺序), 返回  $\tan(\frac{y}{x}) \in [-\pi, +\pi]$ 。xy 都是零的时候会发
    生除零错误
26|
27| other
28|
29| log 自然对数(ln)
30| log10 你猜……
31| ceil 向上
32| floor 向下
33|
34| round
35|
36| cpp: 四舍六入五留双
37| java: add 0.5, then floor
38| cpp:
39| (一) 当尾数小于或等于 4 时, 直接将尾数舍去。
40| (二) 当尾数大于或等于 6 时, 将尾数舍去并向前一位进位。
41| (三) 当尾数为 5, 而尾数后面的数字均为 0 时, 应看尾数 “5” 的前一位: 若前一
    位数字此时为奇数, 就应向前进一位; 若前一位数字此时为偶数, 则应将尾数舍
    去。数字 “0” 在此时应被视为偶数。
42| (四) 当尾数为 5, 而尾数 “5” 的后面还有任何不是 0 的数字时, 无论前一位在此
    时为奇数还是偶数, 也无论 “5” 后面不为 0 的数字在每一位上, 都应向前进一
    位。
43|
44| rotate mat:
45|  $\begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix}$ 

```

2.13 Pick's theorem

```

1| 给定顶点座标均是整数点（或正方形格点）的简单多边形
2|
3| A: 面积
4| i: 内部格点数目
5| b: 边上格点数目
6|  $A = i + \frac{b}{2} - 1$  取格点的组成图形的面积为 1 单位。在平行四边形格点, 皮克定理依然
    成立。套用于任意三角形格点, 皮克定理则是

```

2.14 PointInPoly

```

1| /*射线法
2| , 多边形可以是凸的或凹的的顶点数目要大于等于
3| poly3返回值为:
4|
5| 0 — 点在inpoly
6| 1 — 点在边界上poly
7| 2 — 点在外poly
8| */
9|
10| int inPoly(pv p, pv poly[], int n)
11| {
12|     int i, count;

```

```

13 Line ray, side;
14
15 count = 0;
16 ray.s = p;
17 ray.e.y = p.y;
18 ray.e.x = -1; //-, 注意取值防止越界! INF
19
20 for (i = 0; i < n; i++)
21 {
22     side.s = poly[i];
23     side.e = poly[(i+1)%n];
24
25     if(OnSeg(p, side))
26         return 1;
27
28     // 如果平行轴则不考虑side
29     if (side.s.y == side.e.y)
30         continue;
31
32     if (OnSeg(side.s, ray))
33     {
34         if (side.s.y > side.e.y)
35             count++;
36     }
37     else
38     {
39         if (OnSeg(side.e, ray))
40         {
41             if (side.e.y > side.s.y)
42                 count++;
43         }
44         else
45         {
46             if (inter(ray, side))
47                 count++;
48         }
49     }
50 }
51 return ((count % 2 == 1) ? 0 : 2);

```

2.15 rotating caliper

```

1 //最远点对
2
3 inline double go()
4 {
5     l=ans=0;
6     for(i=0;i<n;++i)
7     {
8         tl=pnt[(i+1)%n]-pnt[i];
9         while(abs(tl.cross(pnt[(l+1)%n]-pnt[i]))>=abs(tl.cross(
10             pnt[l]-pnt[i])))
11             l=(l+1)%n;
12         ans=std::max(ans,std::max(dist(pnt[l],pnt[i]),dist(pnt[
13             l],pnt[(i+1)%n])));
14     }
15     return ans;
16 }
17
18 //两凸包最近距离
19 double go()
20 {
21     sq=sp=0;
22     for(i=1;i<ch[1].size();++i)
23         if(ch[1][sq]<ch[1][i])
24             sq=i;
25     tp=sp;
26     tq=sq;
27     ans=(ch[0][sp]-ch[1][sq]).len();
28     do
29     {
30         a1=ch[0][sp];
31         a2=ch[0][(sp+1)%ch[0].size()];
32         b1=ch[1][sq];
33         b2=ch[1][(sq+1)%ch[1].size()];
34         tpv=b1-(b2-a1);
35         tpv.x = b1.x - (b2.x - a1.x);
36         tpv.y = b1.y - (b2.y - a1.y);
37         len=(tpv-a1).cross(a2-a1);
38         if(fabs(len)<eps)
39         {
40             ans=std::min(ans,p2l(a1,b1,b2));
41             ans=std::min(ans,p2l(a2,b1,b2));
42             ans=std::min(ans,p2l(b1,a1,a2));
43             ans=std::min(ans,p2l(b2,a1,a2));
44             sp=(sp+1)%ch[0].size();
45             sq=(sq+1)%ch[1].size();
46         }
47     }
48     else
49     {
50         if(len<-eps)
51         {
52             ans=std::min(ans,p2l(b1,a1,a2));
53             sp=(sp+1)%ch[0].size();
54         }
55     }
56     else
57     {
58         ans=std::min(ans,p2l(a1,b1,b2));
59         sq=(sq+1)%ch[1].size();
60     }
61 }

```

```

55 }
56 }while(tp!=sp || tq!=sq);
57 return ans;
58 }
59
60 //外接矩形 by mzry
61 inline void solve()
62 {
63     resa = resb = 1e100;
64     double dis1,dis2;
65     Point xp[4];
66     Line l[4];
67     int a,b,c,d;
68     int sa,sb,sc,sd;
69     a = b = c = d = 0;
70     sa = sb = sc = sd = 0;
71     Point va,vb,vc,vd;
72     for (a = 0; a < n; a++)
73     {
74         va = Point(p[a],p[(a+1)%n]);
75         vb = Point(-va.x,-va.y);
76         vc = Point(-va.y,va.x);
77         vd = Point(-vb.x,-vb.y);
78         if (sb < sa)
79         {
80             b = a;
81             sb = sa;
82         }
83         while (xmult(vb,Point(p[b],p[(b+1)%n])) < 0)
84         {
85             b = (b+1)%n;
86             sb++;
87         }
88         if (sc < sb)
89         {
90             c = b;
91             sc = sb;
92         }
93         while (xmult(vc,Point(p[c],p[(c+1)%n])) < 0)
94         {
95             c = (c+1)%n;
96             sc++;
97         }
98         if (sd < sc)
99         {
100             d = c;
101             sd = sc;
102         }
103         while (xmult(vd,Point(p[d],p[(d+1)%n])) < 0)
104         {
105             d = (d+1)%n;
106             sd++;
107         }
108
109         //卡在 p[a],p[b],p[c],p[d] 上
110         sa++;
111     }
112 }
113
114 //合并凸包给定凸多边形
115 P = { p(1) , ... , p(m) } 和 Q = { q(1) , ... , q(n) , 一个点
116     对 (p(i), q(j)) 形成 P 和 Q 之间的桥当且仅当:
117     (p(i), q(j)) 形成一个并踵点对。
118     p(i-1), p(i+1), q(j-1), q(j+1) 都位于由 (p(i), q(j)) 组成的线的同一
119     侧。假设多边形以标准形式给出并且顶点是以顺时针序排列, 算法如下: 、分
120     别计算
121
122     1 P 和 Q 拥有最大 y 坐标的顶点。如果存在不止一个这样的点, 取 x 坐标最大
123     的。、构造这些点的逐平切线,
124     2 以多边形处于其右侧为正方向 (因此他们指向 x 轴正方向)。、同时顺时针旋转两
125     条切线直到其中一条与边相交。
126     3 得到一个新的并踵点对 (p(i), q(j)) 。对于平行边的情况, 得到三个并踵点对。
127     、对于所有有效的并踵点对
128     4 (p(i), q(j)): 判定 p(i-1), p(i+1), q(j-1), q(j+1) 是否都位于连
129     接点 (p(i), q(j)) 形成的线的同一侧。如果是, 这个并踵点对就形成了一个
130     桥, 并标记他。、重复执行步骤和步骤直到切线回到他们原来的位置。
131     534、所有可能的桥此时都已经确定了。
132     6 通过连续连接桥间对应的凸包链来构造合并凸包。上述的结论确定了算法的正确性。
133     运行时间受步骤, 约束。
134
135     156 他们都为 O(N) 运行时间 (N 是顶点总数)。因此算法拥有现行的时间复杂度。
136     一个凸多边形间的桥实际上确定了另一个有用的概念: 多边形间公切线。同时,
137     桥也是计算凸多边形交的算法核心。
138
139 //临界切线、计算
140 1 P 上 y 坐标值最小的顶点 (称为 yminP ) 和 Q 上 y 坐标值最大的顶点 (称
141 为)。 ymaxQ、为多边形在
142 2 yminP 和 ymaxQ 处构造两条切线 LP 和 LQ 使得他们对应的多边形位于他们的

```

```

    右侧。此时 LP 和 LQ 拥有不同的方向，并且 yminP 和 ymaxQ 成为了 68
    多边形间的一个对踵点对。、令
136| 3 p(i)= , yminP q(j)= 。ymaxQ (p(i), q(j)) 构成了多边形间的一个对踵 69
    点对。检测是否有 p(i-1),p(i+1) 在线 (p(i), q(j)) 的一侧，并 70
    且 q(j-1),q(j+1) 在另一侧。如果成立， (p(i), q(j)) 确定了一条 71
    线。CS、旋转这两条线，
137| 4 直到其中一条和其对应的多边形的边重合。、一个新的对踵点对确定了。 72
138| 5 如果两条线都与边重合，总共三对对踵点对（原先的顶点和新的顶点的组合）需要 73
    考虑。对于所有的对踵点对，执行上面的测试。、重复执行步骤和步骤，
139| 645 直到新的点对为 (yminP,ymaxQ)。、输出 74
140| 7线。CS 75
141| 76
142| //最小最大周长面积外接矩形//、计算全部四个多边形的端点， 77
143| 1 称之为， xminP , xmaxP , yminP 。ymaxP、通过四个点构造 78
144| 2 P 的四条切线。他们确定了两个“卡壳”集合。、如果一条（或两条）线与一条边 79
    重合， 80
145| 3 那么计算由四条线决定的矩形的面积，并且保存为当前最小值。否则将当前最小值 81
    定义为无穷大。、顺时针旋转线直到其中一条和多边形的一条边重合。 82
146| 4、计算新矩形的周长面积， 83
147| 5/ 并且和当前最小值比较。如果小于当前最小值则更新，并保存确定最小值的矩形信 84
    息。、重复步骤和步骤， 85
148| 645 直到线旋转过的角度大于度。90、输出外接矩形的最小周长。 86
149| 7 87

```

2.16 shit

```

1| struct pv
2| {
3|     double x,y;
4|     pv():x(0),y(0){}
5|     pv(double xx,double yy):x(xx),y(yy){}
6|     inline pv operator+(const pv &i)const
7|     {
8|         return pv(x+i.x,y+i.y);
9|     }
10|    inline pv operator-(const pv &i)const
11|    {
12|        return pv(x-i.x,y-i.y);
13|    }
14|    inline bool operator ==(const pv &i)const
15|    {
16|        return fabs(x-i.x)<eps && fabs(y-i.y)<eps;
17|    }
18|    inline bool operator <(const pv &i)const
19|    {
20|        return y==i.y?x<i.x:y<i.y;
21|    }
22|    inline double cross(const pv &i)const
23|    {
24|        return x*i.y-y*i.x;
25|    }
26|    inline double dot(const pv &i)const
27|    {
28|        return x*i.x+y*i.y;
29|    }
30|    inline double len()
31|    {
32|        return sqrt(x*x+y*y);
33|    }
34|    inline pv rotate(pv p,double theta)
35|    {
36|        static pv v;
37|        v=*this-p;
38|        static double c,s;
39|        c=cos(theta);
40|        s=sin(theta);
41|        return pv(p.x+v.x*c-v.y*s,p.y+v.x*s+v.y*c);
42|    }
43|};
44|
45| inline int dblcmp(double d)
46| {
47|     if(fabs(d)<eps)
48|         return 0;
49|     return d>eps?-1;
50| }
51|
52| inline int cross(pv *a,pv *b) // 不相交0 不规范1 规范2
53| {
54|     int d1=dblcmp((a[1]-a[0]).cross(b[0]-a[0]));
55|     int d2=dblcmp((a[1]-a[0]).cross(b[1]-a[0]));
56|     int d3=dblcmp((b[1]-b[0]).cross(a[0]-b[0]));
57|     int d4=dblcmp((b[1]-b[0]).cross(a[1]-b[0]));
58|     if((d1^d2)==-2 && (d3^d4)==-2)
59|         return 2;
60|     return ((d1==0 && dblcmp((b[0]-a[0]).dot(b[0]-a[1]))<=0 )|
61|            (d2==0 && dblcmp((b[1]-a[0]).dot(b[1]-a[1]))<=0 )|
62|            (d3==0 && dblcmp((a[0]-b[0]).dot(a[0]-b[1]))<=0 )|
63|            (d4==0 && dblcmp((a[1]-b[0]).dot(a[1]-b[1]))<=0 ));
64| }
65|
66| inline bool pntonseg(const pv &p,const pv *a)
67| {

```

```

    return fabs((p-a[0]).cross(p-a[1]))<eps && (p-a[0]).dot(p-a
    [1])<eps;
}
pv rotate(pv v,pv p,double theta,double sc=1) // rotate vector
v, theta 0π [0,2]
{
    static pv re;
    re=p;
    v=v-p;
    p.x=sc*cos(theta);
    p.y=sc*sin(theta);
    re.x+=v.x*p.x-v.y*p.y;
    re.y+=v.x*p.y+v.y*p.x;
    return re;
}
struct line
{
    pv pnt[2];
    line(double a,double b,double c) // a*x + b*y + c = 0
    {
        #define maxl 1e2 //preciseness should not be too high ( compare
        with eps )
        if(fabs(b)>eps)
        {
            pnt[0]=pv(maxl,(c+a*maxl)/(-b));
            pnt[1]=pv(-maxl,(c-a*maxl)/(-b));
        }
        else
        {
            pnt[0]=pv(-c/a,maxl);
            pnt[1]=pv(-c/a,-maxl);
        }
    }
    #undef maxl
}
pv cross(const line &v)const
{
    double a=(v.pnt[1]-v.pnt[0]).cross(pnt[0]-v.pnt[0]);
    double b=(v.pnt[1]-v.pnt[0]).cross(pnt[1]-v.pnt[0]);
    return pv((pnt[0].x*b-pnt[1].x*a)/(b-a),(pnt[0].y*b-pnt
    [1].y*a)/(b-a));
}
};
inline std::pair<pv,double> getcircle(const pv &a,const pv &b,
const pv &c)
{
    static pv ct;
    ct=line(2*(b.x-a.x),2*(b.y-a.y),a.len()-b.len()).cross(line
    (2*(c.x-b.x),2*(c.y-b.y),b.len()-c.len()));
    return std::make_pair(ct,sqrt((ct-a).len()));
}

```

2.17 sort - polar angle

```

1| inline bool cmp(const Point& a,const Point& b)
2| {
3|     if (a.y*b.y <= 0)
4|     {
5|         if (a.y > 0 || b.y > 0)
6|             return a.y < b.y;
7|         if (a.y == 0 && b.y == 0)
8|             return a.x < b.x;
9|     }
10|    return a.cross(b) > 0;
11|}

```

2.18 triangle

```

1| Area:
2|  $p = \frac{a+b+c}{2}$ 
3|  $area = \sqrt{p \times (p-a) \times (p-b) \times (p-c)}$ 
4|  $area = \frac{a \times b \times \sin(\angle C)}{2}$ 
5|  $area = \frac{a^2 \times \sin(\angle B) \times \sin(\angle C)}{2 \times \sin(\angle B + \angle C)}$ 
6|  $area = \frac{a^2}{2 \times (\cot(\angle B) + \cot(\angle C))}$ 
7|
8| centroid:
9| center of mass
10| intersection of triangle's three triangle medians
11|
12| Trigonometric conditions:
13|  $\tan \frac{A}{2} \tan \frac{B}{2} + \tan \frac{B}{2} \tan \frac{C}{2} + \tan \frac{C}{2} \tan \frac{A}{2} = 1$ 
14|  $\sin^2 \frac{A}{2} + \sin^2 \frac{B}{2} + \sin^2 \frac{C}{2} + 2 \sin \frac{A}{2} \sin \frac{B}{2} \sin \frac{C}{2} = 1$ 
15|
16| Circumscribed circle:
17|  $diameter = \frac{abc}{2 \cdot area} = \frac{|AB||BC||CA|}{2|\Delta ABC|}$ 
    =  $\frac{abc}{2\sqrt{s(s-a)(s-b)(s-c)}}$ 
    =  $\frac{2abc}{\sqrt{(a+b+c)(-a+b+c)(a-b+c)(a+b-c)}}$ 

```

```

18| diameter =  $\sqrt{\frac{2 \cdot \text{area}}{\sin A \sin B \sin C}}$ 
19| diameter =  $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$ 
20|
21| Incircle:
22| inradius =  $\frac{2 \times \text{area}}{a+b+c}$ 
23| coordinates(x,y) =  $\left( \frac{ax_a + bx_b + cx_c}{a+b+c}, \frac{ay_a + by_b + cy_c}{a+b+c} \right) =$ 
 $\frac{a}{a+b+c}(x_a, y_a) + \frac{b}{a+b+c}(x_b, y_b) + \frac{c}{a+b+c}(x_c, y_c)$ 
24|
25| Excircles:
26| radius[a] =  $\frac{2 \times \text{area}}{b+c-a}$ 
27| radius[b] =  $\frac{2 \times \text{area}}{a+c-b}$ 
28| radius[c] =  $\frac{2 \times \text{area}}{a+b-c}$ 
29|
30| Steiner circumellipse (least area circumscribed ellipse)
31| area =  $\Delta \times \frac{4\pi}{3\sqrt{3}}$ 
32| center is the triangle's centroid.
33|
34| Steiner inellipse ( maximum area inellipse )
35| area =  $\Delta \times \frac{\pi}{3\sqrt{3}}$ 
36| center is the triangle's centroid.
37|
38| Fermat Point:
39| 当有一个内角不小于 120° 时, 费马点为此角对应顶点。
40|
41| 当三角形的内角都小于 120° 时
42|
43| 以三角形的每一边为底边, 向外做三个正三角形 ΔABC', ΔBCA', ΔCAB'。
44| 连接 CC', BB', AA', 则三条线段的交点就是所求的点。

```

3 Geometry/tmp

3.1 test

```

1| //三角形:
2| //1. 半周长  $P = \frac{a+b+c}{2}$ 
3| //2. 面积  $S = \frac{aH}{2} = \frac{ab \sin(C)}{2} = \sqrt{P \times (P-a) \times (P-b) \times (P-c)}$ 
4| //3. 中线  $Ma = \frac{\sqrt{2(b^2+c^2)-a^2}}{2} = \frac{\sqrt{b^2+c^2+2bc \cos(A)}}{2}$ 
5| //4. 角平分线  $Ta = \frac{\sqrt{bc((b+c)^2-a^2)}}{b+c} = \frac{2bc \cos(\frac{A}{2})}{b+c}$ 
6| //5. 高线  $Ha = b \sin(C) = c \sin(B) = \sqrt{b^2 - \frac{a^2+b^2-c^2}{2a}}$ 
7| //6. 内切圆半径  $r = \frac{S}{P} = \frac{\arcsin(\frac{B}{2}) \sin(\frac{C}{2})}{\sin(\frac{B+C}{2})} = 4R \sin(\frac{A}{2}) \sin(\frac{B}{2}) \sin(\frac{C}{2}) =$ 
 $\sqrt{\frac{(P-a)(P-b)(P-c)}{P}} = P \tan(\frac{A}{2}) \tan(\frac{B}{2}) \tan(\frac{C}{2})$ 
8| //7. 外接圆半径  $R = \frac{abc}{4S} = \frac{a}{2 \sin(A)} = \frac{b}{2 \sin(B)} = \frac{c}{2 \sin(C)}$ 
9| //四边形:
10| //D1,D2 为对角线,M 为对角线中点连线,A 为对角线夹角
11| //1.  $a^2 + b^2 + c^2 + d^2 = D_1^2 + D_2^2 + 4M^2$ 
12| //2.  $S = \frac{D_1 D_2 \sin(A)}{2}$ 
13| //(以下对圆的内接四边形)
14| //3.  $ac + bd = D_1 D_2$ 
15| //4.  $S = \sqrt{(P-a)(P-b)(P-c)(P-d)}$ , P 为半周长
16| //正 n 边形:
17| //R 为外接圆半径,r 为内切圆半径
18| //1. 中心角  $A = \frac{2\pi}{n}$ 
19| //2. 内角  $C = (n-2) \frac{\pi}{n}$ 
20| //3. 边长  $a = 2\sqrt{R^2 - r^2} = 2R \sin(\frac{A}{2}) = 2r \tan(\frac{A}{2})$ 
21| //4. 面积  $S = \frac{nar}{2} = nr^2 \tan(\frac{A}{2}) = \frac{nR^2 \sin(A)}{2} = \frac{na^2}{4 \tan(\frac{A}{2})}$ 
22| //圆:
23| //1. 弧长  $l = rA$ 
24| //2. 弦长  $a = 2\sqrt{2hr - h^2} = 2r \sin(\frac{A}{2})$ 
25| //3. 弓形高  $h = r - \sqrt{r^2 - \frac{a^2}{4}} = r(1 - \cos(\frac{A}{2})) = \frac{\arctan(\frac{A}{4})}{2}$ 
26| //4. 扇形面积  $S_1 = \frac{r^2}{2} = \frac{r^2 A}{2}$ 
27| //5. 弓形面积  $S_2 = \frac{rl - a(r-h)}{2} = \frac{r^2(A - \sin(A))}{2}$ 
28| //棱柱:
29| //1. 体积  $V = Ah$ , A 为底面积,h 为高
30| //2. 侧面积  $S = lp$ , l 为棱长,p 为直截面周长
31| //3. 全面积  $T = S + 2A$ 
32| //棱锥:
33| //1. 体积  $V = \frac{Ah}{3}$ , A 为底面积,h 为高
34| //(以下对正棱锥)
35| //2. 侧面积  $S = \frac{lp}{2}$ , l 为斜高,p 为底面周长
36| //3. 全面积  $T = S + A$ 
37| //球台:
38| //1. 体积  $V = (A_1 + A_2 + \sqrt{A_1 A_2}) \frac{h}{3}$ , A1.A2 为上下底面积,h 为高
39| //(以下对正球台)
40| //2. 侧面积  $S = \frac{(p_1 + p_2)l}{2}$ , p1.p2 为上下底面周长,l 为斜高
41| //3. 全面积  $T = S + A_1 + A_2$ 
42| //圆柱:

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43| //1. 侧面积  $S = 2\pi rh$ 
44| //2. 全面积  $T = 2\pi r(h+r)$ 
45| //3. 体积  $V = \pi r^2 h$ 
46| //圆锥:
47| //1. 斜高  $l = \sqrt{h^2 + r^2}$ 
48| //2. 侧面积  $S = \pi rl$ 
49| //3. 全面积  $T = \pi r(l+r)$ 
50| //4. 体积  $V = \pi r^2 \frac{h}{3}$ 
51| //圆台:
52| //1. 母线  $l = \sqrt{h^2 + (r_1 - r_2)^2}$ 
53| //2. 侧面积  $S = \pi(r_1 + r_2)l$ 
54| //3. 全面积  $T = \pi r_1(l + r_1) + \pi r_2(l + r_2)$ 
55| //4. 体积  $V = \pi(r_1^2 + r_2^2 + r_1 r_2) \frac{h}{3}$ 
56| //球:
57| //1. 全面积  $T = 4\pi r^2$ 
58| //2. 体积  $V = \pi r^3 \frac{4}{3}$ 
59| //球台:
60| //1. 侧面积  $S = 2\pi rh$ 
61| //2. 全面积  $T = \pi(2rh + r_1^2 + r_2^2)$ 
62| //3. 体积  $V = \frac{1}{6} \pi h(3(r_1^2 + r_2^2) + h^2)$ 
63| //球扇形:
64| //1. 全面积  $T = \pi r(2h + r_0)$ , h 为球冠高, r0 为球冠底面半径
65| //2. 体积  $V = \frac{2}{3} \pi r^2 h$ 
66|
67| //polygon
68| #include <stdlib.h>
69| #include <math.h>
70| #define MAXN 10000
71| #define offset 10000
72| #define eps 1e-8
73| #define zero(x) (((x)>0?(x):- (x))<eps)
74| #define _sign(x) ((x)>eps?1:((x)<=-eps?2:0))
75| struct point{double x,y};
76| struct line{point a,b;};
77| double xmult(point p1,point p2,point p0)
78| {
79|     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
80| }
81| //判定凸多边形, 顶点按顺时针或逆时针给出, 允许相邻边共线
82| int is_convex(int n,point* p)
83| {
84|     int i,s[3]={1,1,1};
85|     for (i=0;i<n&&s[1]|s[2];i++)
86|         s[_sign(xmult(p[(i+1)%n],p[(i+2)%n],p[i]))]=0;
87|     return s[1]|s[2];
88| }
89| //判定凸多边形, 顶点按顺时针或逆时针给出, 不允许相邻边共线
90| int is_convex_v2(int n,point* p)
91| {
92|     int i,s[3]={1,1,1};
93|     for (i=0;i<n&&s[0]&&s[1]|s[2];i++)
94|         s[_sign(xmult(p[(i+1)%n],p[(i+2)%n],p[i]))]=0;
95|     return s[0]&&s[1]|s[2];
96| }
97| //判点在凸多边形内或多边形边上, 顶点按顺时针或逆时针给出
98| int inside_convex(point q,int n,point* p)
99| {
100|     int i,s[3]={1,1,1};
101|     for (i=0;i<n&&s[1]|s[2];i++)
102|         s[_sign(xmult(p[(i+1)%n],q,p[i]))]=0;
103|     return s[1]|s[2];
104| }
105| //判点在凸多边形内, 顶点按顺时针或逆时针给出, 在多边形边上返回 0
106| int inside_convex_v2(point q,int n,point* p)
107| {
108|     int i,s[3]={1,1,1};
109|     for (i=0;i<n&&s[0]&&s[1]|s[2];i++)
110|         s[_sign(xmult(p[(i+1)%n],q,p[i]))]=0;
111|     return s[0]&&s[1]|s[2];
112| }
113| //判点在任意多边形内, 顶点按顺时针或逆时针给出
114| //on_edge 表示点在多边形边上时的返回值,offset 为多边形坐标上限
115| int inside_polygon(point q,int n,point* p,int on_edge=1)
116| {
117|     point q2;
118|     int i=0,count;
119|     while (i<n)
120|         for (count=i+1,q2.x=rand()+offset,q2.y=rand()+offset;i<
n;i++)
121|             if
122|                 (zero(xmult(q,p[i],p[(i+1)%n]))&&(p[i].x-q.x)*(
p[(i+1)%n].x-q.x)<eps&&(p[i].y-q.y)*(p[(i
+1)%n].y-q.y)<eps)
123|                     return on_edge;
124|                 else if (zero(xmult(q,q2,p[i])))
125|                     break;
126|                 else if
127|                     (xmult(q,p[i],q2)*xmult(q,p[(i+1)%n],q2)<=-eps&&
xmult(p[i],q,p[(i+1)%n])*xmult(p[i],q2,p[(
i+1)%n])<=-eps)
128|                         count++;

```

```

129     return count&1;
130 }
131 inline int opposite_side(point p1,point p2,point l1,point l2)
132 {
133     return xmult(l1,p1,l2)*xmult(l1,p2,l2)<-eps;
134 }
135 inline int dot_online_in(point p,point l1,point l2)
136 {
137     return zero(xmult(p,l1,l2))&&(l1.x-p.x)*(l2.x-p.x)<eps&&(
        .y-p.y)*(l2.y-p.y)<eps;
138 }
139 //判线段在任意多边形内，顶点按顺时针或逆时针给出，与边界相交返回 1
140 int inside_polygon(point l1,point l2,int n,point* p)
141 {
142     point t[MAXN],tt;
143     int i,j,k=0;
144     if (!inside_polygon(l1,n,p)||!inside_polygon(l2,n,p))
145         return 0;
146     for (i=0;i<n;i++)
147         if (opposite_side(l1,l2,p[i],p[(i+1)%n])&&opposite_side(
            p[i],p[(i+1)%n],l1,l2))
148             return 0;
149     else if (dot_online_in(l1,p[i],p[(i+1)%n]))
150         t[k++]=l1;
151     else if (dot_online_in(l2,p[i],p[(i+1)%n]))
152         t[k++]=l2;
153     else if (dot_online_in(p[i],l1,l2))
154         t[k++]=p[i];
155     for (i=0;i<k;i++)
156         for (j=i+1;j<k;j++)
157         {
158             tt.x=(t[i].x+t[j].x)/2;
159             tt.y=(t[i].y+t[j].y)/2;
160             if (!inside_polygon(tt,n,p))
161                 return 0;
162         }
163     return 1;
164 }
165 point intersection(line u,line v)
166 {
167     point ret=u.a;
168     double t=((u.a.x-v.a.x)*(v.a.y-v.b.y)-(u.a.y-v.a.y)*(v.a.x-
        v.b.x))/((u.a.x-u.b.x)*(v.a.y-v.b.y)-(u.a.y-u.b.y)*(v.a.x-v
        .b.x));
169     ret.x+=(u.b.x-u.a.x)*t;
170     ret.y+=(u.b.y-u.a.y)*t;
171     return ret;
172 }
173 }
174 point barycenter(point a,point b,point c)
175 {
176     line u,v;
177     u.a.x=(a.x+b.x)/2;
178     u.a.y=(a.y+b.y)/2;
179     u.b=c;
180     v.a.x=(a.x+c.x)/2;
181     v.a.y=(a.y+c.y)/2;
182     v.b=b;
183     return intersection(u,v);
184 }
185 //多边形重心
186 point barycenter(int n,point* p)
187 {
188     point ret,t;
189     double t1=0,t2;
190     int i;
191     ret.x=ret.y=0;
192     for (i=1;i<n-1;i++)
193         if (fabs(t2=xmult(p[0],p[i],p[i+1]))>eps)
194         {
195             t=barycenter(p[0],p[i],p[i+1]);
196             ret.x+=t.x*t2;
197             ret.y+=t.y*t2;
198             t1+=t2;
199         }
200     if (fabs(t1)>eps)
201         ret.x/=t1,ret.y/=t1;
202     return ret;
203 }
204 }
205 //cut polygon
206 //多边形切割
207 //可用于半平面交
208 #define MAXN 100
209 #define eps 1e-8
210 #define zero(x) (((x)>0?(x):-x)<eps)
211 struct point{double x,y;};
212 double xmult(point p1,point p2,point p0)
213 {
214     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
215 }
216 int same_side(point p1,point p2,point l1,point l2)
217 {
218     return xmult(l1,p1,l2)*xmult(l1,p2,l2)>eps;
219 }
220 }
221 point intersection(point u1,point u2,point v1,point v2)
222 {
223     point ret=u1;
224     double t=((u1.x-v1.x)*(v1.y-v2.y)-(u1.y-v1.y)*(v1.x-v2.x))/
        (((u1.x-u2.x)*(v1.y-v2.y)-(u1.y-u2.y)*(v1.x-v2.x));
225     ret.x+=(u2.x-u1.x)*t;
226     ret.y+=(u2.y-u1.y)*t;
227     return ret;
228 }
229 //将多边形沿 l1,l2 确定的直线切割在 side 侧切割，保证 l1,l2,side 不共
    线
230 void polygon_cut(int& n,point* p,point l1,point l2,point side)
231 {
232     point pp[100];
233     int m=0,i;
234     for (i=0;i<n;i++)
235     {
236         if (same_side(p[i],side,l1,l2))
237             pp[m++]=p[i];
238         if
239             (!same_side(p[i],p[(i+1)%n],l1,l2)&&!(zero(xmult(p[
                i],l1,l2))&&zero(xmult(p[(i+1)%n],l1,l2))))
240             pp[m++]=intersection(p[i],p[(i+1)%n],l1,l2);
241     }
242     for (n=i=0;i<m;i++)
243         if (!i||!zero(pp[i].x-pp[i-1].x)||!zero(pp[i].y-pp[i-
            1].y))
244             p[n++]=pp[i];
245     if (zero(p[n-1].x-p[0].x)&&zero(p[n-1].y-p[0].y))
246         n--;
247     if (n<3)
248         n=0;
249 }
250 //float
251 //浮点几何函数库
252 #include <math.h>
253 #define eps 1e-8
254 #define zero(x) (((x)>0?(x):-x)<eps)
255 struct point{double x,y;};
256 struct line{point a,b;};
257 //计算 cross product (P1-P0)x(P2-P0)
258 double xmult(point p1,point p2,point p0)
259 {
260     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
261 }
262 double xmult(double x1,double y1,double x2,double y2,double x0,
    double y0)
263 {
264     return (x1-x0)*(y2-y0)-(x2-x0)*(y1-y0);
265 }
266 //计算 dot product (P1-P0).(P2-P0)
267 double dmult(point p1,point p2,point p0)
268 {
269     return (p1.x-p0.x)*(p2.x-p0.x)+(p1.y-p0.y)*(p2.y-p0.y);
270 }
271 double dmult(double x1,double y1,double x2,double y2,double x0,
    double y0)
272 {
273     return (x1-x0)*(x2-x0)+(y1-y0)*(y2-y0);
274 }
275 //两点距离
276 double distance(point p1,point p2)
277 {
278     return sqrt((p1.x-p2.x)*(p1.x-p2.x)+(p1.y-p2.y)*(p1.y-p2.y)
        );
279 }
280 double distance(double x1,double y1,double x2,double y2)
281 {
282     return sqrt((x1-x2)*(x1-x2)+(y1-y2)*(y1-y2));
283 }
284 //判三点共线
285 int dots_inline(point p1,point p2,point p3)
286 {
287     return zero(xmult(p1,p2,p3));
288 }
289 int dots_inline(double x1,double y1,double x2,double y2,double
    x3,double y3)
290 {
291     return zero(xmult(x1,y1,x2,y2,x3,y3));
292 }
293 //判点是否在线段上，包括端点
294 int dot_online_in(point p,line l)
295 {
296     return zero(xmult(p,l.a,l.b))&&(l.a.x-p.x)*(l.b.x-p.x)<eps
        &&(l.a.y-p.y)*(l.b.y-p.y)<eps;
297 }
298 int dot_online_in(point p,point l1,point l2)
299 {
300     return zero(xmult(p,l1,l2))&&(l1.x-p.x)*(l2.x-p.x)<eps&&(l1
        .y-p.y)*(l2.y-p.y)<eps;
301 }
302 int dot_online_in(double x,double y,double x1,double y1,double
    x2,double y2)
303 }
304 }

```



```

305 {
306     return zero(xmult(x,y,x1,y1,x2,y2))&&(x1-x)*(x2-x)<eps&&(y1-y)*(y2-y)<eps;
307 }
308 //判点是否在线段上, 不包括端点
309 int dot_online_ex(point p,line l)
310 {
311     return
312         dot_online_in(p,l)&&(!zero(p.x-l.a.x)||!zero(p.y-l.a.y)
313             )&&(!zero(p.x-l.b.x)||!zero(p.y-l.b.y));
314 }
315 int dot_online_ex(point p,point l1,point l2)
316 {
317     return
318         dot_online_in(p,l1,l2)&&(!zero(p.x-l1.x)||!zero(p.y-l1.y)
319             y)&&(!zero(p.x-l2.x)||!zero(p.y-l2.y));
320 }
321 int dot_online_ex(double x,double y,double x1,double y1,double x2,double y2)
322 {
323     return
324         dot_online_in(x,y,x1,y1,x2,y2)&&(!zero(x-x1)||!zero(y-y1)
325             y1)&&(!zero(x-x2)||!zero(y-y2));
326 }
327 //判两点在线段同侧, 点在线段上返回 0
328 int same_side(point p1,point p2,line l)
329 {
330     return xmult(l.a,p1,l.b)*xmult(l.a,p2,l.b)>eps;
331 }
332 int same_side(point p1,point p2,point l1,point l2)
333 {
334     return xmult(l1,p1,l2)*xmult(l1,p2,l2)>eps;
335 }
336 //判两点在线段异侧, 点在线段上返回 0
337 int opposite_side(point p1,point p2,line l)
338 {
339     return xmult(l.a,p1,l.b)*xmult(l.a,p2,l.b)<-eps;
340 }
341 int opposite_side(point p1,point p2,point l1,point l2)
342 {
343     return xmult(l1,p1,l2)*xmult(l1,p2,l2)<-eps;
344 }
345 //判两直线平行
346 int parallel(line u,line v)
347 {
348     return zero((u.a.x-u.b.x)*(v.a.y-v.b.y)-(v.a.x-v.b.x)*(u.a.y-u.b.y));
349 }
350 int parallel(point u1,point u2,point v1,point v2)
351 {
352     return zero((u1.x-u2.x)*(v1.y-v2.y)-(v1.x-v2.x)*(u1.y-u2.y));
353 }
354 //判两直线垂直
355 int perpendicular(line u,line v)
356 {
357     return zero((u.a.x-u.b.x)*(v.a.x-v.b.x)+(u.a.y-u.b.y)*(v.a.y-v.b.y));
358 }
359 int perpendicular(point u1,point u2,point v1,point v2)
360 {
361     return zero((u1.x-u2.x)*(v1.x-v2.x)+(u1.y-u2.y)*(v1.y-v2.y));
362 }
363 //判两线段相交, 包括端点和部分重合
364 int intersect_in(line u,line v)
365 {
366     if (!dots_inline(u.a,u.b,v.a)||!dots_inline(u.a,u.b,v.b))
367         return !same_side(u.a,u.b,v)&&!same_side(v.a,v.b,u);
368     return dot_online_in(u.a,v)||dot_online_in(u.b,v)||
369         dot_online_in(v.a,u)||dot_online_in(v.b,u);
370 }
371 int intersect_in(point u1,point u2,point v1,point v2)
372 {
373     if (!dots_inline(u1,u2,v1)||!dots_inline(u1,u2,v2))
374         return !same_side(u1,u2,v1,v2)&&!same_side(v1,v2,u1,u2);
375     return
376         dot_online_in(u1,v1,v2)||dot_online_in(u2,v1,v2)||
377         dot_online_in(v1,u1,u2)||dot_online_in(v2,u1,u2);
378 }
379 //判两线段相交, 不包括端点和部分重合
380 int intersect_ex(line u,line v)
381 {
382     return opposite_side(u.a,u.b,v)&&opposite_side(v.a,v.b,u);
383 }
384 int intersect_ex(point u1,point u2,point v1,point v2)
385 {
386     return opposite_side(u1,u2,v1,v2)&&opposite_side(v1,v2,u1,u2);
387 }
388 //计算两直线交点, 注意事先判断直线是否平行!
389 //线段交点请另外判线段相交 (同时还是要判断是否平行!)
390 point intersection(line u,line v)
391 {
392     point ret=u.a;
393     double t=((u.a.x-v.a.x)*(v.a.y-v.b.y)-(u.a.y-v.a.y)*(v.a.x-v.b.x))
394         /((u.a.x-u.b.x)*(v.a.y-v.b.y)-(u.a.y-u.b.y)*(v.a.x-v.b.x));
395     ret.x+=(u.b.x-u.a.x)*t;
396     ret.y+=(u.b.y-u.a.y)*t;
397     return ret;
398 }
399 point intersection(point u1,point u2,point v1,point v2)
400 {
401     point ret=u1;
402     double t=((u1.x-v1.x)*(v1.y-v2.y)-(u1.y-v1.y)*(v1.x-v2.x))
403         /((u1.x-u2.x)*(v1.y-v2.y)-(u1.y-u2.y)*(v1.x-v2.x));
404     ret.x+=(u2.x-u1.x)*t;
405     ret.y+=(u2.y-u1.y)*t;
406     return ret;
407 }
408 //点到直线上的最近点
409 point ptoline(point p,line l)
410 {
411     point t=p;
412     t.x+=l.a.y-l.b.y,t.y+=l.b.x-l.a.x;
413     return intersection(p,t,l.a,l.b);
414 }
415 point ptoline(point p,point l1,point l2)
416 {
417     point t=p;
418     t.x+=l1.y-l2.y,t.y+=l2.x-l1.x;
419     return intersection(p,t,l1,l2);
420 }
421 //点到直线距离
422 double disptoline(point p,line l)
423 {
424     return fabs(xmult(p,l.a,l.b))/distance(l.a,l.b);
425 }
426 double disptoline(point p,point l1,point l2)
427 {
428     return fabs(xmult(p,l1,l2))/distance(l1,l2);
429 }
430 double disptoline(double x,double y,double x1,double y1,double x2,double y2)
431 {
432     return fabs(xmult(x,y,x1,y1,x2,y2))/distance(x1,y1,x2,y2);
433 }
434 //点到线段上的最近点
435 point ptoseg(point p,line l)
436 {
437     point t=p;
438     t.x+=l.a.y-l.b.y,t.y+=l.b.x-l.a.x;
439     if (xmult(l.a,t,p)*xmult(l.b,t,p)>eps)
440         return distance(p,l.a)<distance(p,l.b)?l.a:l.b;
441     return intersection(p,t,l.a,l.b);
442 }
443 point ptoseg(point p,point l1,point l2)
444 {
445     point t=p;
446     t.x+=l1.y-l2.y,t.y+=l2.x-l1.x;
447     if (xmult(l1,t,p)*xmult(l2,t,p)>eps)
448         return distance(p,l1)<distance(p,l2)?l1:l2;
449     return intersection(p,t,l1,l2);
450 }
451 //点到线段距离
452 double disptoseg(point p,line l)
453 {
454     point t=p;
455     t.x+=l.a.y-l.b.y,t.y+=l.b.x-l.a.x;
456     if (xmult(l.a,t,p)*xmult(l.b,t,p)>eps)
457         return distance(p,l.a)<distance(p,l.b)?distance(p,l.a):
458             distance(p,l.b);
459     return fabs(xmult(p,l.a,l.b))/distance(l.a,l.b);
460 }
461 double disptoseg(point p,point l1,point l2)
462 {
463     point t=p;
464     t.x+=l1.y-l2.y,t.y+=l2.x-l1.x;
465     if (xmult(l1,t,p)*xmult(l2,t,p)>eps)
466         return distance(p,l1)<distance(p,l2)?distance(p,l1):
467             distance(p,l2);
468     return fabs(xmult(p,l1,l2))/distance(l1,l2);
469 }
470 //矢量 V 以 P 为顶点逆时针旋转 angle 并放大 scale 倍
471 point rotate(point v,point p,double angle,double scale)
472 {
473     point ret=p;
474     v.x-=p.x,v.y-=p.y;
475     p.x=scale*cos(angle);
476     p.y=scale*sin(angle);
477     ret.x+=v.x*p.x-v.y*p.y;
478     ret.y+=v.x*p.y+v.y*p.x;
479     return ret;
480 }
481 //area

```

```

477 #include <math.h>
478 struct point{double x,y;};
479 //计算 cross product (P1-P0)x(P2-P0)
480 double xmult(point p1,point p2,point p0)
481 {
482     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
483 }
484 double xmult(double x1,double y1,double x2,double y2,double x0,
485             double y0)
486 {
487     return (x1-x0)*(y2-y0)-(x2-x0)*(y1-y0);
488 }
489 //计算三角形面积, 输入三顶点
490 double area_triangle(point p1,point p2,point p3)
491 {
492     return fabs(xmult(p1,p2,p3))/2;
493 }
494 double area_triangle(double x1,double y1,double x2,double y2,
495                     double x3,double y3)
496 {
497     return fabs(xmult(x1,y1,x2,y2,x3,y3))/2;
498 }
499 //计算三角形面积, 输入三边长
500 double area_triangle(double a,double b,double c)
501 {
502     double s=(a+b+c)/2;
503     return sqrt(s*(s-a)*(s-b)*(s-c));
504 }
505 //计算多边形面积, 顶点按顺时针或逆时针给出
506 double area_polygon(int n,point* p)
507 {
508     double s1=0,s2=0;
509     int i;
510     for (i=0;i<n;i++)
511         s1+=p[(i+1)%n].y*p[i].x,s2+=p[(i+1)%n].y*p[(i+2)%n].x;
512     return fabs(s1-s2)/2;
513 }
514 //surface of ball
515 #include <math.h>
516 const double pi=acos(-1);
517 //计算圆心角 lat 表示纬度,-90<=w<=90,lng 表示经度
518 //返回两点所在大圆劣弧对应圆心角,0<=angle<=pi
519 double angle(double lng1,double lat1,double lng2,double lat2)
520 {
521     double dlng=fabs(lng1-lng2)*pi/180;
522     while (dlng>=pi+pi)
523         dlng-=pi+pi;
524     if (dlng>pi)
525         dlng=pi+pi-dlng;
526     lat1*=pi/180,lat2*=pi/180;
527     return acos(cos(lat1)*cos(lat2)*cos(dlng)+sin(lat1)*sin(
528         lat2));
529 }
530 //计算距离,r 为球半径
531 double line_dist(double r,double lng1,double lat1,double lng2,
532                 double lat2)
533 {
534     double dlng=fabs(lng1-lng2)*pi/180;
535     while (dlng>=pi+pi)
536         dlng-=pi+pi;
537     if (dlng>pi)
538         dlng=pi+pi-dlng;
539     lat1*=pi/180,lat2*=pi/180;
540     return r*sqrt(2-2*(cos(lat1)*cos(lat2)*cos(dlng)+sin(lat1)
541         sin(lat2)));
542 }
543 //计算球面距离,r 为球半径
544 inline double sphere_dist(double r,double lng1,double lat1,
545                          double lng2,double lat2)
546 {
547     return r*angle(lng1,lat1,lng2,lat2);
548 }
549 //triangle
550 #include <math.h>
551 struct point{double x,y;};
552 struct line{point a,b;};
553 double distance(point p1,point p2)
554 {
555     return sqrt((p1.x-p2.x)*(p1.x-p2.x)+(p1.y-p2.y)*(p1.y-p2.y));
556 }
557 point intersection(line u,line v)
558 {
559     point ret=u.a;
560     double t=((u.a.x-v.a.x)*(v.a.y-v.b.y)-(u.a.y-v.a.y)*(v.a.x-
561         v.b.x))/((u.a.x-u.b.x)*(v.a.y-v.b.y)-(u.a.y-u.b.y)*(v.a.x-
562         v.b.x));
563     ret.x+=(u.b.x-u.a.x)*t;
564     ret.y+=(u.b.y-u.a.y)*t;
565     return ret;
566 }
567 //外心
568 point circumcenter(point a,point b,point c)
569 {
570     line u,v;
571     u.a.x=(a.x+b.x)/2;
572     u.a.y=(a.y+b.y)/2;
573     u.b.x=u.a.x-a.y+b.y;
574     u.b.y=u.a.y+a.x-b.x;
575     v.a.x=(a.x+c.x)/2;
576     v.a.y=(a.y+c.y)/2;
577     v.b.x=v.a.x-a.y+c.y;
578     v.b.y=v.a.y+a.x-c.x;
579     return intersection(u,v);
580 }
581 //内心
582 point incenter(point a,point b,point c)
583 {
584     line u,v;
585     double m,n;
586     u.a=a;
587     m=atan2(b.y-a.y,b.x-a.x);
588     n=atan2(c.y-a.y,c.x-a.x);
589     u.b.x=u.a.x+cos((m+n)/2);
590     u.b.y=u.a.y+sin((m+n)/2);
591     v.a=b;
592     m=atan2(a.y-b.y,a.x-b.x);
593     n=atan2(c.y-b.y,c.x-b.x);
594     v.b.x=v.a.x+cos((m+n)/2);
595     v.b.y=v.a.y+sin((m+n)/2);
596     return intersection(u,v);
597 }
598 //垂心
599 point perpercenter(point a,point b,point c)
600 {
601     line u,v;
602     u.a=c;
603     u.b.x=u.a.x-a.y+b.y;
604     u.b.y=u.a.y+a.x-b.x;
605     v.a=b;
606     v.b.x=v.a.x-a.y+c.y;
607     v.b.y=v.a.y+a.x-c.x;
608     return intersection(u,v);
609 }
610 //重心
611 //到三角形三顶点距离的平方和最小的点
612 //三角形内到三边距离之积最大的点
613 point barycenter(point a,point b,point c)
614 {
615     line u,v;
616     u.a.x=(a.x+b.x)/2;
617     u.a.y=(a.y+b.y)/2;
618     u.b=c;
619     v.a.x=(a.x+c.x)/2;
620     v.a.y=(a.y+c.y)/2;
621     v.b=b;
622     return intersection(u,v);
623 }
624 //费马点
625 //到三角形三顶点距离之和最小的点
626 point fermentpoint(point a,point b,point c)
627 {
628     point u,v;
629     double step=fabs(a.x)+fabs(a.y)+fabs(b.x)+fabs(b.y)+fabs(c.
630         x)+fabs(c.y);
631     int i,j,k;
632     u.x=(a.x+b.x+c.x)/3;
633     u.y=(a.y+b.y+c.y)/3;
634     while (step>1e-10)
635         for (k=0;k<10;step/=2,k++)
636             for (i=-1;i<=1;i++)
637                 for (j=-1;j<=1;j++)
638                     {
639                         v.x=u.x+step*i;
640                         v.y=u.y+step*j;
641                         if
642                             (distance(u,a)+distance(u,b)+distance(u
643                                 ,c)>distance(v,a)+distance(v,b)+
644                                 distance(v,c))
645                             u=v;
646                     }
647     return u;
648 }
649 //3-d
650 //三维几何函数库
651 #include <math.h>
652 #define eps 1e-8
653 #define zero(x) (((x)>0?(x):-x)<eps)
654 struct point3{double x,y,z;};
655 struct line3{point3 a,b;};
656 struct plane3{point3 a,b,c;};
657 //计算 cross product U x V
658 point3 xmult(point3 u,point3 v)
659 {
660     point3 ret;

```

```

655     ret.x=u.y*v.z-v.y*u.z;
656     ret.y=u.z*v.x-u.x*v.z;
657     ret.z=u.x*v.y-u.y*v.x;
658     return ret;
659 }
660 //计算 dot product U . V
661 double dmult(point3 u,point3 v)
662 {
663     return u.x*v.x+u.y*v.y+u.z*v.z;
664 }
665 //向量差 U - V
666 point3 subt(point3 u,point3 v)
667 {
668     point3 ret;
669     ret.x=u.x-v.x;
670     ret.y=u.y-v.y;
671     ret.z=u.z-v.z;
672     return ret;
673 }
674 //取平面法向量
675 point3 pvec(plane3 s)
676 {
677     return xmult(subt(s.a,s.b),subt(s.b,s.c));
678 }
679 point3 pvec(point3 s1,point3 s2,point3 s3)
680 {
681     return xmult(subt(s1,s2),subt(s2,s3));
682 }
683 //两点距离, 单参数取向向量大小
684 double distance(point3 p1,point3 p2)
685 {
686     return sqrt((p1.x-p2.x)*(p1.x-p2.x)+(p1.y-p2.y)*(p1.y-p2.y)+
687                 +(p1.z-p2.z)*(p1.z-p2.z));
688 }
689 //向量大小
690 double vlen(point3 p)
691 {
692     return sqrt(p.x*p.x+p.y*p.y+p.z*p.z);
693 }
694 //判三点共线
695 int dots_inline(point3 p1,point3 p2,point3 p3)
696 {
697     return vlen(xmult(subt(p1,p2),subt(p2,p3)))<eps;
698 }
699 //判四点共面
700 int dots_onplane(point3 a,point3 b,point3 c,point3 d)
701 {
702     return zero(dmult(pvec(a,b,c),subt(d,a)));
703 }
704 //判点是否在线段上, 包括端点和共线
705 int dot_online_in(point3 p,line3 l)
706 {
707     return zero(vlen(xmult(subt(p,l.a),subt(p,l.b))))&&(l.a.x-p
708     .x)*(l.b.x-p.x)<eps&&
709     (l.a.y-p.y)*(l.b.y-p.y)<eps&&(l.a.z-p.z)*(l.b.z-p.z)<
710     eps;
711 }
712 int dot_online_in(point3 p,point3 l1,point3 l2)
713 {
714     return zero(vlen(xmult(subt(p,l1),subt(p,l2))))&&(l1.x-p.x)
715     *(l2.x-p.x)<eps&&
716     (l1.y-p.y)*(l2.y-p.y)<eps&&(l1.z-p.z)*(l2.z-p.z)<eps;
717 }
718 //判点是否在线段上, 不包括端点
719 int dot_online_ex(point3 p,line3 l)
720 {
721     return dot_online_in(p,l)&&(!zero(p.x-l.a.x)||!zero(p.y-l.a
722     .y)||!zero(p.z-l.a.z))&&
723     (!zero(p.x-l.b.x)||!zero(p.y-l.b.y)||!zero(p.z-l.b.z));
724 }
725 int dot_online_ex(point3 p,point3 l1,point3 l2)
726 {
727     return dot_online_in(p,l1,l2)&&(!zero(p.x-l1.x)||!zero(p.y-
728     l1.y)||!zero(p.z-l1.z))&&
729     (!zero(p.x-l2.x)||!zero(p.y-l2.y)||!zero(p.z-l2.z));
730 }
731 //判点是否在空间三角形上, 包括边界, 三点共线无意义
732 int dot_inplane_in(point3 p,plane3 s)
733 {
734     return zero(vlen(xmult(subt(s.a,s.b),subt(s.a,s.c)))-vlen(
735     xmult(subt(p,s.a),subt(p,s.b)))-
736     vlen(xmult(subt(p,s.b),subt(p,s.c)))-vlen(xmult(
737     subt(p,s.c),subt(p,s.a))));
738 }
739 int dot_inplane_in(point3 p,point3 s1,point3 s2,point3 s3)
740 {
741     return zero(vlen(xmult(subt(s1,s2),subt(s1,s3)))-vlen(xmult(
742     subt(p,s1),subt(p,s2)))-
743     vlen(xmult(subt(p,s2),subt(p,s3)))-vlen(xmult(subt(
744     p,s3),subt(p,s1))));
745 }
746 //判点是否在空间三角形上, 不包括边界, 三点共线无意义
747 int dot_inplane_ex(point3 p,plane3 s)
748 {
749     return dot_inplane_in(p,s)&&vlen(xmult(subt(p,s.a),subt(p,s
750     .b)))>eps&&
751     vlen(xmult(subt(p,s.b),subt(p,s.c)))>eps&&vlen(xmult(
752     subt(p,s.c),subt(p,s.a)))>eps;
753 }
754 int dot_inplane_ex(point3 p,point3 s1,point3 s2,point3 s3)
755 {
756     return dot_inplane_in(p,s1,s2,s3)&&vlen(xmult(subt(p,s1),
757     subt(p,s2)))>eps&&
758     vlen(xmult(subt(p,s2),subt(p,s3)))>eps&&vlen(xmult(subt(
759     p,s3),subt(p,s1)))>eps;
760 }
761 //判两点在线段同侧, 点在线段上返回 0, 不共面无意义
762 int same_side(point3 p1,point3 p2,line3 l)
763 {
764     return dmult(xmult(subt(l.a,l.b),subt(p1,l.b)),xmult(subt(l
765     .a,l.b),subt(p2,l.b)))<-eps;
766 }
767 int same_side(point3 p1,point3 p2,point3 l1,point3 l2)
768 {
769     return dmult(xmult(subt(l1,l2),subt(p1,l2)),xmult(subt(l1,
770     l2),subt(p2,l2)))<-eps;
771 }
772 //判两点在线段异侧, 点在线段上返回 0, 不共面无意义
773 int opposite_side(point3 p1,point3 p2,line3 l)
774 {
775     return dmult(xmult(subt(l.a,l.b),subt(p1,l.b)),xmult(subt(l
776     .a,l.b),subt(p2,l.b)))<-eps;
777 }
778 int opposite_side(point3 p1,point3 p2,point3 l1,point3 l2)
779 {
780     return dmult(xmult(subt(l1,l2),subt(p1,l2)),xmult(subt(l1,
781     l2),subt(p2,l2)))<-eps;
782 }
783 //判两点在平面同侧, 点在平面上返回 0
784 int same_side(point3 p1,point3 p2,plane3 s)
785 {
786     return dmult(pvec(s),subt(p1,s.a))*dmult(pvec(s),subt(p2,s
787     .a))>eps;
788 }
789 int same_side(point3 p1,point3 p2,point3 s1,point3 s2,point3 s3
790 )
791 {
792     return dmult(pvec(s1,s2,s3),subt(p1,s1))*dmult(pvec(s1,s2,
793     s3),subt(p2,s1))>eps;
794 }
795 //判两点在平面异侧, 点在平面上返回 0
796 int opposite_side(point3 p1,point3 p2,plane3 s)
797 {
798     return dmult(pvec(s),subt(p1,s.a))*dmult(pvec(s),subt(p2,s
799     .a))<-eps;
800 }
801 int opposite_side(point3 p1,point3 p2,point3 s1,point3 s2,
802 point3 s3)
803 {
804     return dmult(pvec(s1,s2,s3),subt(p1,s1))*dmult(pvec(s1,s2,
805     s3),subt(p2,s1))<-eps;
806 }
807 //判两直线平行
808 int parallel(line3 u,line3 v)
809 {
810     return vlen(xmult(subt(u.a,u.b),subt(v.a,v.b)))<eps;
811 }
812 int parallel(point3 u1,point3 u2,point3 v1,point3 v2)
813 {
814     return vlen(xmult(subt(u1,u2),subt(v1,v2)))<eps;
815 }
816 //判两平面平行
817 int parallel(plane3 u,plane3 v)
818 {
819     return vlen(xmult(pvec(u),pvec(v)))<eps;
820 }
821 int parallel(point3 u1,point3 u2,point3 u3,point3 v1,point3 v2,
822 point3 v3)
823 {
824     return vlen(xmult(pvec(u1,u2,u3),pvec(v1,v2,v3)))<eps;
825 }
826 //判直线与平面平行
827 int parallel(line3 l,plane3 s)
828 {
829     return zero(dmult(subt(l.a,l.b),pvec(s)));
830 }
831 int parallel(point3 l1,point3 l2,point3 s1,point3 s2,point3 s3)
832 {
833     return zero(dmult(subt(l1,l2),pvec(s1,s2,s3)));
834 }
835 //判两直线垂直
836 int perpendicular(line3 u,line3 v)
837 {
838     return zero(dmult(subt(u.a,u.b),subt(v.a,v.b)));
839 }
840 int perpendicular(point3 u1,point3 u2,point3 v1,point3 v2)
841 {
842     return zero(dmult(subt(u1,u2),subt(v1,v2)));
843 }

```

```

819 //判两平面垂直
820 int perpendicular(plane3 u,plane3 v)
821 {
822     return zero(dmult(pvec(u),pvec(v)));
823 }
824 int perpendicular(point3 u1,point3 u2,point3 u3,point3 v1,
825     point3 v2,point3 v3)
826 {
827     return zero(dmult(pvec(u1,u2,u3),pvec(v1,v2,v3)));
828 }
829 //判直线与平面平行
830 int perpendicular(line3 l,plane3 s)
831 {
832     return vlen(xmult(subt(l.a,l.b),pvec(s)))<eps;
833 }
834 int perpendicular(point3 l1,point3 l2,point3 s1,point3 s2,
835     point3 s3)
836 {
837     return vlen(xmult(subt(l1,l2),pvec(s1,s2,s3)))<eps;
838 }
839 //判两线段相交, 包括端点和部分重合
840 int intersect_in(line3 u,line3 v)
841 {
842     if (!dots_onplane(u.a,u.b,v.a,v.b))
843         return 0;
844     if (!dots_inline(u.a,u.b,v.a)||!dots_inline(u.a,u.b,v.b))
845         return !same_side(u.a,u.b,v)&&!same_side(v.a,v.b,u);
846     return dot_online_in(u.a,v)||dot_online_in(u.b,v)||
847         dot_online_in(v.a,u)||dot_online_in(v.b,u);
848 }
849 int intersect_in(point3 u1,point3 u2,point3 v1,point3 v2)
850 {
851     if (!dots_onplane(u1,u2,v1,v2))
852         return 0;
853     if (!dots_inline(u1,u2,v1)||!dots_inline(u1,u2,v2))
854         return !same_side(u1,u2,v1,v2)&&!same_side(v1,v2,u1,u2);
855     return
856         dot_online_in(u1,v1,v2)||dot_online_in(u2,v1,v2)||
857         dot_online_in(v1,u1,u2)||dot_online_in(v2,u1,u
858             2);
859 }
860 //判两线段相交, 不包括端点和部分重合
861 int intersect_ex(line3 u,line3 v)
862 {
863     return dots_onplane(u.a,u.b,v.a,v.b)&&opposite_side(u.a,u.b,
864         v)&&opposite_side(v.a,v.b,u);
865 }
866 int intersect_ex(point3 u1,point3 u2,point3 v1,point3 v2)
867 {
868     return
869         dots_onplane(u1,u2,v1,v2)&&opposite_side(u1,u2,v1,v2)&&
870         opposite_side(v1,v2,u1,u2);
871 }
872 //判线段与空间三角形相交, 包括交于边界和 (部分) 包含
873 int intersect_in(line3 l,plane3 s)
874 {
875     return !same_side(l.a,l.b,s)&&!same_side(s.a,s.b,l.a,l.b,
876         c)&&
877         !same_side(s.b,s.c,l.a,l.b,s.a)&&!same_side(s.c,s.a,l.a,
878             l.b,s.b);
879 }
880 int intersect_in(point3 l1,point3 l2,point3 s1,point3 s2,point3
881     s3)
882 {
883     return !same_side(l1,l2,s1,s2,s3)&&!same_side(s1,s2,l1,l2,
884         s3)&&
885         !same_side(s2,s3,l1,l2,s1)&&!same_side(s3,s1,l1,l2,s2);
886 }
887 //判线段与空间三角形相交, 不包括交于边界和 (部分) 包含
888 int intersect_ex(line3 l,plane3 s)
889 {
890     return opposite_side(l.a,l.b,s)&&opposite_side(s.a,s.b,l.a,
891         l.b,s.c)&&
892         opposite_side(s.b,s.c,l.a,l.b,s.a)&&opposite_side(s.c,
893             a,l.a,l.b,s.b);
894 }
895 int intersect_ex(point3 l1,point3 l2,point3 s1,point3 s2,point3
896     s3)
897 {
898     return opposite_side(l1,l2,s1,s2,s3)&&opposite_side(s1,s2,
899         l1,l2,s3)&&
900         opposite_side(s2,s3,l1,l2,s1)&&opposite_side(s3,s1,l1,
901             l2,s2);
902 }
903 //计算两直线交点, 注意事先判断直线是否共面和平行!
904 //线段交点请另外判线段相交 (同时还是要判断是否平行!)
905 point3 intersection(line3 u,line3 v)
906 {
907     point3 ret=u.a;
908     double t=((u.a.x-v.a.x)*(v.a.y-v.b.y)-(u.a.y-v.a.y)*(v.a.
909         x-v.b.x))/((u.a.x-u.b.x)*(v.a.y-v.b.y)-(u.a.y-u.b.y)*(v.a.x-
910             v.b.x));
911     ret.x+=(u.b.x-u.a.x)*t;
912 }
913 ret.y+=(u.b.y-u.a.y)*t;
914 ret.z+=(u.b.z-u.a.z)*t;
915 return ret;
916 }
917 point3 intersection(point3 u1,point3 u2,point3 v1,point3 v2)
918 {
919     point3 ret=u1;
920     double t=((u1.x-v1.x)*(v1.y-v2.y)-(u1.y-v1.y)*(v1.x-v2.x))/
921         (((u1.x-u2.x)*(v1.y-v2.y)-(u1.y-u2.y)*(v1.x-v2.x)));
922     ret.x+=(u2.x-u1.x)*t;
923     ret.y+=(u2.y-u1.y)*t;
924     ret.z+=(u2.z-u1.z)*t;
925     return ret;
926 }
927 //计算直线与平面交点, 注意事先判断是否平行, 并保证三点不共线!
928 //线段和空间三角形交点请另外判断
929 point3 intersection(line3 l,plane3 s)
930 {
931     point3 ret=pvec(s);
932     double t=(ret.x*(s.a.x-l.a.x)+ret.y*(s.a.y-l.a.y)+ret.z*(s.
933         a.z-l.a.z))/
934         (ret.x*(l.b.x-l.a.x)+ret.y*(l.b.y-l.a.y)+ret.z*(l.b.z-l
935             .a.z));
936     ret.x=l.a.x+(l.b.x-l.a.x)*t;
937     ret.y=l.a.y+(l.b.y-l.a.y)*t;
938     ret.z=l.a.z+(l.b.z-l.a.z)*t;
939     return ret;
940 }
941 point3 intersection(point3 l1,point3 l2,point3 s1,point3 s2,
942     point3 s3)
943 {
944     point3 ret=pvec(s1,s2,s3);
945     double t=(ret.x*(s1.x-l1.x)+ret.y*(s1.y-l1.y)+ret.z*(s1.z-
946         l1.z))/
947         (ret.x*(l2.x-l1.x)+ret.y*(l2.y-l1.y)+ret.z*(l2.z-l1.z));
948     ret.x=l1.x+(l2.x-l1.x)*t;
949     ret.y=l1.y+(l2.y-l1.y)*t;
950     ret.z=l1.z+(l2.z-l1.z)*t;
951     return ret;
952 }
953 //计算两平面交线, 注意事先判断是否平行, 并保证三点不共线!
954 line3 intersection(plane3 u,plane3 v)
955 {
956     line3 ret;
957     ret.a=parallel(v.a,v.b,u.a,u.b,u.c)?intersection(v.b,v.c,u.
958         a,u.b,u.c):intersection(v.a,v.b,u.a,u.b,u.
959         c);
960     ret.b=parallel(v.c,v.a,u.a,u.b,u.c)?intersection(v.b,v.c,u.
961         a,u.b,u.c):intersection(v.c,v.a,u.a,u.b,u.
962         c);
963     return ret;
964 }
965 line3 intersection(point3 u1,point3 u2,point3 u3,point3 v1,
966     point3 v2,point3 v3)
967 {
968     line3 ret;
969     ret.a=parallel(v1,v2,u1,u2,u3)?intersection(v2,v3,u1,u2,u3)
970         :intersection(v1,v2,u1,u2,u3);
971     ret.b=parallel(v3,v1,u1,u2,u3)?intersection(v2,v3,u1,u2,u3)
972         :intersection(v3,v1,u1,u2,u3);
973     return ret;
974 }
975 //点到直线距离
976 double ptoline(point3 p,line3 l)
977 {
978     return vlen(xmult(subt(p,l.a),subt(l.b,l.a)))/distance(l.a,
979         l.b);
980 }
981 double ptoline(point3 p,point3 l1,point3 l2)
982 {
983     return vlen(xmult(subt(p,l1),subt(l2,l1)))/distance(l1,l2);
984 }
985 //点到平面距离
986 double ptoplane(point3 p,plane3 s)
987 {
988     return fabs(dmult(pvec(s),subt(p,s.a)))/vlen(pvec(s));
989 }
990 double ptoplane(point3 p,point3 s1,point3 s2,point3 s3)
991 {
992     return fabs(dmult(pvec(s1,s2,s3),subt(p,s1)))/vlen(pvec(s1,
993         s2,s3));
994 }
995 //直线到直线距离
996 double linetoline(line3 u,line3 v)
997 {
998     point3 n=xmult(subt(u.a,u.b),subt(v.a,v.b));
999     return fabs(dmult(subt(u.a,v.a),n))/vlen(n);
1000 }
1001 double linetoline(point3 u1,point3 u2,point3 v1,point3 v2)
1002 {
1003     point3 n=xmult(subt(u1,u2),subt(v1,v2));
1004     return fabs(dmult(subt(u1,v1),n))/vlen(n);
1005 }
1006 //两直线夹角 cos 值

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979 double angle_cos(line3 u,line3 v)
980 {
981     return dmult(subt(u.a,u.b),subt(v.a,v.b))/vlen(subt(u.a,u.b))
982     )/vlen(subt(v.a,v.b));
983 }
984 double angle_cos(point3 u1,point3 u2,point3 v1,point3 v2)
985 {
986     return dmult(subt(u1,u2),subt(v1,v2))/vlen(subt(u1,u2))/
987     vlen(subt(v1,v2));
988 }
989 //两平面夹角 cos 值
990 double angle_cos(plane3 u,plane3 v)
991 {
992     return dmult(pvec(u),pvec(v))/vlen(pvec(u))/vlen(pvec(v));
993 }
994 double angle_cos(point3 u1,point3 u2,point3 u3,point3 v1,point3 v2,point3 v3)
995 {
996     return dmult(pvec(u1,u2,u3),pvec(v1,v2,v3))/vlen(pvec(u1,u2,u3))
997     /vlen(pvec(v1,v2,v3));
998 }
999 //直线平面夹角 sin 值
1000 double angle_sin(line3 l,plane3 s)
1001 {
1002     return dmult(subt(l.a,l.b),pvec(s))/vlen(subt(l.a,l.b))/
1003     vlen(pvec(s));
1004 }
1005 double angle_sin(point3 l1,point3 l2,point3 s1,point3 s2,point3 s3)
1006 {
1007     return dmult(subt(l1,l2),pvec(s1,s2,s3))/vlen(subt(l1,l2))/
1008     vlen(pvec(s1,s2,s3));
1009 }
1010 //CH
1011 #include <stdlib.h>
1012 #define eps 1e-8
1013 #define zero(x) (((x)>0?(x):-(x))<eps)
1014 struct point{double x,y;};
1015 //计算 cross product (P1-P0)x(P2-P0)
1016 double xmult(point p1,point p2,point p0)
1017 {
1018     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
1019 }
1020 //graham 算法顺时针构造包含所有共线点的凸包,0(nlogn)
1021 point p1,p2;
1022 int graham_cp(const void* a,const void* b)
1023 {
1024     double ret=xmult(*(point*)a),*(point*)b,p1);
1025     return zero(ret)?(xmult(*(point*)a),*(point*)b),p2)
1026     >0?1:-1):(ret>0?1:-1);
1027 }
1028 void _graham(int n,point* p,int& s,point* ch)
1029 {
1030     int i,k=0;
1031     for (p1=p2=p[0],i=1;i<n;p2.x+=p[i].x,p2.y+=p[i].y,i++)
1032         if (p1.y-p[i].y>eps||((zero(p1.y-p[i].y)&&p1.x>p[i].x)&&
1033             p1=p[k=i];
1034     p2.x/=n,p2.y/=n;
1035     p[k]=p[0],p[0]=p1;
1036     qsort(p+1,n-1,sizeof(point),graham_cp);
1037     for (ch[0]=p[0],ch[1]=p[1],ch[2]=p[2],s=i=3;i<n;ch[s++]=p[i],i++)
1038         for (;s>2&&xmult(ch[s-2],p[i],ch[s-1])<-eps;s--);
1039 }
1040 //构造凸包接口函数,传入原始点集大小 n,点集 p(原有顺序被打乱!)
1041 //返回凸包大小,凸包的点在 convex 中
1042 //参数 maxsize 为 1 包含共线点,为 0 不包含共线点,缺省为 1
1043 //参数 clockwise 为 1 顺时针构造,为 0 逆时针构造,缺省为 1
1044 //在输入仅有若干共线点时算法不稳定,可能有此类情况请另行处理!
1045 //不能去掉点集中重合的点
1046 int graham(int n,point* p,point* convex,int maxsize=1,int dir=1)
1047 {
1048     point* temp=new point[n];
1049     int s,i;
1050     _graham(n,p,s,temp);
1051     for (convex[0]=temp[0],n=1,i=(dir?1:(s-1));dir?(i<s):i+=
1052         dir?1:-1))
1053         if (maxsize||!zero(xmult(temp[i-1],temp[i],temp[(i+1)%n])))
1054             convex[n++]=temp[i];
1055     delete []temp;
1056     return n;
1057 }
1058 //Pick's
1059 #define abs(x) ((x)>0?(x):-(x))
1060 struct point{int x,y;};
1061 int gcd(int a,int b)
1062 {
1063     return b?gcd(b,a%b):a;
1064 }
1065 //多边形上的网格点个数
1066 int grid_onedge(int n,point* p)
1067 {
1068     int i,ret=0;
1069     for (i=0;i<n;i++)
1070         ret+=gcd(abs(p[i].x-p[(i+1)%n].x),abs(p[i].y-p[(i+1)%n].y));
1071     return ret;
1072 }
1073 //多边形内的网格点个数
1074 int grid_inside(int n,point* p)
1075 {
1076     int i,ret=0;
1077     for (i=0;i<n;i++)
1078         ret+=p[(i+1)%n].y*(p[i].x-p[(i+2)%n].x);
1079     return (abs(ret)-grid_onedge(n,p))/2+1;
1080 }
1081 //circle
1082 #include <math.h>
1083 #define eps 1e-8
1084 struct point{double x,y;};
1085 double xmult(point p1,point p2,point p0)
1086 {
1087     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
1088 }
1089 double distance(point p1,point p2)
1090 {
1091     return sqrt((p1.x-p2.x)*(p1.x-p2.x)+(p1.y-p2.y)*(p1.y-p2.y));
1092 }
1093 double disptoline(point p,point l1,point l2)
1094 {
1095     return fabs(xmult(p,l1,l2))/distance(l1,l2);
1096 }
1097 point intersection(point u1,point u2,point v1,point v2)
1098 {
1099     point ret=u1;
1100     double t=((u1.x-v1.x)*(v1.y-v2.y)-(u1.y-v1.y)*(v1.x-v2.x))/
1101         ((u1.x-u2.x)*(v1.y-v2.y)-(u1.y-u2.y)*(v1.x-v2.x));
1102     ret.x+=(u2.x-u1.x)*t;
1103     ret.y+=(u2.y-u1.y)*t;
1104     return ret;
1105 }
1106 //判直线和圆相交,包括相切
1107 int intersect_line_circle(point c,double r,point l1,point l2)
1108 {
1109     return disptoline(c,l1,l2)<r+eps;
1110 }
1111 //判线段和圆相交,包括端点和相切
1112 int intersect_seg_circle(point c,double r,point l1,point l2)
1113 {
1114     double t1=distance(c,l1)-r,t2=distance(c,l2)-r;
1115     point t=c;
1116     if (t1<eps||t2<eps)
1117         return t1>-eps||t2>-eps;
1118     t.x+=l1.y-l2.y;
1119     t.y+=l2.x-l1.x;
1120     return xmult(l1,c,t)*xmult(l2,c,t)<eps&&disptoline(c,l1,l2)
1121         -r<eps;
1122 }
1123 //判圆和圆相交,包括相切
1124 int intersect_circle_circle(point c1,double r1,point c2,double r2)
1125 {
1126     return distance(c1,c2)<r1+r2+eps&&distance(c1,c2)>fabs(r1-r2)-eps;
1127 }
1128 //计算圆上到点 p 最近点,如 p 与圆心重合,返回 p 本身
1129 point dot_to_circle(point c,double r,point p)
1130 {
1131     point u,v;
1132     if (distance(p,c)<eps)
1133         return p;
1134     u.x=c.x+r*fabs(c.x-p.x)/distance(c,p);
1135     u.y=c.y+r*fabs(c.y-p.y)/distance(c,p)*((c.x-p.x)*(c.y-p.y)<0?-1:1);
1136     v.x=c.x-r*fabs(c.x-p.x)/distance(c,p);
1137     v.y=c.y-r*fabs(c.y-p.y)/distance(c,p)*((c.x-p.x)*(c.y-p.y)<0?-1:1);
1138     return distance(u,p)<distance(v,p)?u:v;
1139 }
1140 //计算直线与圆的交点,保证直线与圆有交点
1141 //计算线段与圆的交点可用这个函数后判点是否在线段上
1142 void intersection_line_circle(point c,double r,point l1,point l2,point& p1,point& p2)
1143 {
1144     point p=c;
1145     double t;
1146     p.x+=l1.y-l2.y;
1147     p.y+=l2.x-l1.x;
1148     p=intersection(p,c,l1,l2);
1149     t=sqrt(r*r-distance(p,c)*distance(p,c))/distance(l1,l2);
1150     p1.x=p.x+(l2.x-l1.x)*t;
1151     p1.y=p.y+(l2.y-l1.y)*t;
1152     p2.x=p.x-(l2.x-l1.x)*t;
1153     p2.y=p.y-(l2.y-l1.y)*t;

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1148     p2.y=p.y-(l2.y-l1.y)*t;
1149 }
1150 //计算圆与圆的交点, 保证圆与圆有交点, 圆心不重合
1151 void intersection_circle_circle(point c1,double r1,point c2,
    double r2,point& p1,point& p2)
1152 {
1153     point u,v;
1154     double t;
1155     t=(1+(r1*r1-r2*r2)/distance(c1,c2)/distance(c1,c2))/2;
1156     u.x=c1.x+(c2.x-c1.x)*t;
1157     u.y=c1.y+(c2.y-c1.y)*t;
1158     v.x=u.x+c1.y-c2.y;
1159     v.y=u.y-c1.x+c2.x;
1160     intersection_line_circle(c1,r1,u,v,p1,p2);
1161 }
1162
1163 //integer
1164 //整数几何函数库
1165 //注意某些情况下整数运算会出界!
1166 #define sign(a) ((a)>0?1:((a)<0?-1:0))
1167 struct point{int x,y;};
1168 struct line{point a,b;};
1169 //计算 cross product (P1-P0)x(P2-P0)
1170 int xmult(point p1,point p2,point p0)
1171 {
1172     return (p1.x-p0.x)*(p2.y-p0.y)-(p2.x-p0.x)*(p1.y-p0.y);
1173 }
1174 int xmult(int x1,int y1,int x2,int y2,int x0,int y0)
1175 {
1176     return (x1-x0)*(y2-y0)-(x2-x0)*(y1-y0);
1177 }
1178 //计算 dot product (P1-P0).(P2-P0)
1179 int dmult(point p1,point p2,point p0)
1180 {
1181     return (p1.x-p0.x)*(p2.x-p0.x)+(p1.y-p0.y)*(p2.y-p0.y);
1182 }
1183 int dmult(int x1,int y1,int x2,int y2,int x0,int y0)
1184 {
1185     return (x1-x0)*(x2-x0)+(y1-y0)*(y2-y0);
1186 }
1187 //判三点共线
1188 int dots_inline(point p1,point p2,point p3)
1189 {
1190     return !xmult(p1,p2,p3);
1191 }
1192 int dots_inline(int x1,int y1,int x2,int y2,int x3,int y3)
1193 {
1194     return !xmult(x1,y1,x2,y2,x3,y3);
1195 }
1196 //判点是否在线段上, 包括端点和部分重合
1197 int dot_online_in(point p,line l)
1198 {
1199     return !xmult(p,l.a,l.b)&&(l.a.x-p.x)*(l.b.x-p.x)<=0&&(l.a.y-p.y)*(l.b.y-p.y)<=0;
1200 }
1201 int dot_online_in(point p,point l1,point l2)
1202 {
1203     return !xmult(p,l1,l2)&&(l1.x-p.x)*(l2.x-p.x)<=0&&(l1.y-p.y)*(l2.y-p.y)<=0;
1204 }
1205 int dot_online_in(int x,int y,int x1,int y1,int x2,int y2)
1206 {
1207     return !xmult(x,y,x1,y1,x2,y2)&&(x1-x)*(x2-x)<=0&&(y1-y)*(y2-y)<=0;
1208 }
1209 //判点是否在线段上, 不包括端点
1210 int dot_online_ex(point p,line l)
1211 {
1212     return dot_online_in(p,l)&&(p.x!=l.a.x||p.y!=l.a.y)&&(p.x!=l.b.x||p.y!=l.b.y);
1213 }
1214 int dot_online_ex(point p,point l1,point l2)
1215 {
1216     return dot_online_in(p,l1,l2)&&(p.x!=l1.x||p.y!=l1.y)&&(p.x!=l2.x||p.y!=l2.y);
1217 }
1218 int dot_online_ex(int x,int y,int x1,int y1,int x2,int y2)
1219 {
1220     return dot_online_in(x,y,x1,y1,x2,y2)&&(x!=x1||y!=y1)&&(x!=x2||y!=y2);
1221 }
1222 //判两点在直线同侧, 点在直线上返回 0
1223 int same_side(point p1,point p2,line l)
1224 {
1225     return sign(xmult(l.a,p1,l.b))*xmult(l.a,p2,l.b)>0;
1226 }
1227 int same_side(point p1,point p2,point l1,point l2)
1228 {
1229     return sign(xmult(l1,p1,l2))*xmult(l1,p2,l2)>0;
1230 }
1231 //判两点在直线异侧, 点在直线上返回 0
1232 int opposite_side(point p1,point p2,line l)
1233 {
1234     return sign(xmult(l.a,p1,l.b))*xmult(l.a,p2,l.b)<0;
1235 }
1236 int opposite_side(point p1,point p2,point l1,point l2)
1237 {
1238     return sign(xmult(l1,p1,l2))*xmult(l1,p2,l2)<0;
1239 }
1240 //判两直线平行
1241 int parallel(line u,line v)
1242 {
1243     return (u.a.x-u.b.x)*(v.a.y-v.b.y)==(v.a.x-v.b.x)*(u.a.y-u.b.y);
1244 }
1245 int parallel(point u1,point u2,point v1,point v2)
1246 {
1247     return (u1.x-u2.x)*(v1.y-v2.y)==(v1.x-v2.x)*(u1.y-u2.y);
1248 }
1249 //判两直线垂直
1250 int perpendicular(line u,line v)
1251 {
1252     return (u.a.x-u.b.x)*(v.a.x-v.b.x)==-(u.a.y-u.b.y)*(v.a.y-v.b.y);
1253 }
1254 int perpendicular(point u1,point u2,point v1,point v2)
1255 {
1256     return (u1.x-u2.x)*(v1.x-v2.x)==-(u1.y-u2.y)*(v1.y-v2.y);
1257 }
1258 //判两线段相交, 包括端点和部分重合
1259 int intersect_in(line u,line v)
1260 {
1261     if (!dots_inline(u.a,u.b,v.a)||!dots_inline(u.a,u.b,v.b))
1262         return !same_side(u.a,u.b,v)&&!same_side(v.a,v.b,u);
1263     return dot_online_in(u.a,v)||dot_online_in(u.b,v)||dot_online_in(v.a,u)||dot_online_in(v.b,u);
1264 }
1265 int intersect_in(point u1,point u2,point v1,point v2)
1266 {
1267     if (!dots_inline(u1,u2,v1)||!dots_inline(u1,u2,v2))
1268         return !same_side(u1,u2,v1,v2)&&!same_side(v1,v2,u1,u2);
1269     return dot_online_in(u1,v1,v2)||dot_online_in(u2,v1,v2)||dot_online_in(v1,u1,u2)||dot_online_in(v2,u1,u2);
1270 }
1271 //判两线段相交, 不包括端点和部分重合
1272 int intersect_ex(line u,line v)
1273 {
1274     return opposite_side(u.a,u.b,v)&&opposite_side(v.a,v.b,u);
1275 }
1276 int intersect_ex(point u1,point u2,point v1,point v2)
1277 {
1278     return opposite_side(u1,u2,v1,v2)&&opposite_side(v1,v2,u1,u2);
1279 }
1280
1281
3.2 tmp
1 #include<vector>
2 #include<list>
3 #include<map>
4 #include<set>
5 #include<deque>
6 #include<queue>
7 #include<stack>
8 #include<bitset>
9 #include<algorithm>
10 #include<functional>
11 #include<numeric>
12 #include<utility>
13 #include<iostream>
14 #include<sstream>
15 #include<iomanip>
16 #include<cstdio>
17 #include<cmath>
18 #include<cstdlib>
19 #include<cctype>
20 #include<string>
21 #include<cstring>
22 #include<stdio.h>
23 #include<math>
24 #include<stdlib.h>
25 #include<ctime>
26 #include<climits>
27 #include<complex>
28 #define mp make_pair
29 #define pb push_back
30 using namespace std;
31 const double eps=1e-8;
32 const double pi=acos(-1.0);
33 const double inf=1e20;
34 const int maxp=8;
35 int dblcmp(double d)
36 {
37     if (fabs(d)<eps)return 0;
38     return d>eps?1:-1;
39 }
40 inline double sqr(double x){return x*x;}
```

```

41 struct point
42 {
43     double x,y;
44     point(){}
45     point(double _x,double _y):
46         x(_x),y(_y){};
47     void input()
48     {
49         scanf("%lf%lf",&x,&y);
50     }
51     void output()
52     {
53         printf("%.2f_%.2f\n",x,y);
54     }
55     bool operator==(point a)const
56     {
57         return dblcmp(a.x-x)==0&&dblcmp(a.y-y)==0;
58     }
59     bool operator<(point a)const
60     {
61         return dblcmp(a.x-x)==0?dblcmp(y-a.y)<0:x<a.x;
62     }
63     double len()
64     {
65         return hypot(x,y);
66     }
67     double len2()
68     {
69         return x*x+y*y;
70     }
71     double distance(point p)
72     {
73         return hypot(x-p.x,y-p.y);
74     }
75     point add(point p)
76     {
77         return point(x+p.x,y+p.y);
78     }
79     point sub(point p)
80     {
81         return point(x-p.x,y-p.y);
82     }
83     point mul(double b)
84     {
85         return point(x*b,y*b);
86     }
87     point div(double b)
88     {
89         return point(x/b,y/b);
90     }
91     double dot(point p)
92     {
93         return x*p.x+y*p.y;
94     }
95     double det(point p)
96     {
97         return x*p.y-y*p.x;
98     }
99     double rad(point a,point b)
100     {
101         point p=*this;
102         return fabs(atan2(fabs(a.sub(p).det(b.sub(p))),a.sub(p).dot(b.sub(p))));
103     }
104     point trunc(double r)
105     {
106         double l=len();
107         if (!dblcmp(l))return *this;
108         r/=l;
109         return point(x*r,y*r);
110     }
111     point rotleft()
112     {
113         return point(-y,x);
114     }
115     point rotright()
116     {
117         return point(y,-x);
118     }
119     point rotate(point p,double angle)//绕点逆时针旋转角度pangle
120     {
121         point v=this->sub(p);
122         double c=cos(angle),s=sin(angle);
123         return point(p.x+v.x*c-v.y*s,p.y+v.x*s+v.y*c);
124     }
125 };
126 struct line
127 {
128     point a,b;
129     line(){}
130     line(point _a,point _b)
131     {
132         a=_a;
133         b=_b;
134     }
135     bool operator==(line v)
136     {
137         return (a==v.a)&&(b==v.b);
138     }
139     //倾斜角angle
140     line(point p,double angle)
141     {
142         a=p;
143         if (dblcmp(angle-pi/2)==0)
144         {
145             b=a.add(point(0,1));
146         }
147         else
148         {
149             b=a.add(point(1,tan(angle)));
150         }
151     }
152     //ax+by+c=0
153     line(double _a,double _b,double _c)
154     {
155         if (dblcmp(_a)==0)
156         {
157             a=point(0,-_c/_b);
158             b=point(1,-_c/_b);
159         }
160         else if (dblcmp(_b)==0)
161         {
162             a=point(-_c/_a,0);
163             b=point(-_c/_a,1);
164         }
165         else
166         {
167             a=point(0,-_c/_b);
168             b=point(1,(-_c-_a)/_b);
169         }
170     }
171     void input()
172     {
173         a.input();
174         b.input();
175     }
176     void adjust()
177     {
178         if (b<a)swap(a,b);
179     }
180     double length()
181     {
182         return a.distance(b);
183     }
184     double angle()//直线倾斜角 0<=angle<180
185     {
186         double k=atan2(b.y-a.y,b.x-a.x);
187         if (dblcmp(k)<0)k+=pi;
188         if (dblcmp(k-pi)==0)k=pi;
189         return k;
190     }
191     //点和线段关系
192     //1 在逆时针
193     //2 在顺时针
194     //3 平行
195     int relation(point p)
196     {
197         int c=dblcmp(p.sub(a).det(b.sub(a)));
198         if (c<0)return 1;
199         if (c>0)return 2;
200         return 3;
201     }
202     bool pointonseg(point p)
203     {
204         return dblcmp(p.sub(a).det(b.sub(a)))==0&&dblcmp(p.sub(a).dot(p.sub(b)))<=0;
205     }
206     bool parallel(line v)
207     {
208         return dblcmp(b.sub(a).det(v.b.sub(v.a)))==0;
209     }
210     //2 规范相交
211     //1 非规范相交
212     //0 不相交
213     int segcrossseg(line v)
214     {
215         int d1=dblcmp(b.sub(a).det(v.a.sub(a)));
216         int d2=dblcmp(b.sub(a).det(v.b.sub(a)));
217         int d3=dblcmp(v.b.sub(v.a).det(a.sub(v.a)));
218         int d4=dblcmp(v.b.sub(v.a).det(b.sub(v.a)));
219         if ((d1^d2)==-2&&(d3^d4)==-2)return 2;
220         return (d1==0&&dblcmp(v.a.sub(a).dot(v.a.sub(b)))<=0||
221             d2==0&&dblcmp(v.b.sub(a).dot(v.b.sub(b)))<=0||
222             d3==0&&dblcmp(a.sub(v.a).dot(a.sub(v.b)))<=0||
223             d4==0&&dblcmp(b.sub(v.a).dot(b.sub(v.b)))<=0);
224     }
225     int linecrossseg(line v)//*this seg v line
226     {
227         int d1=dblcmp(b.sub(a).det(v.a.sub(a)));
228         int d2=dblcmp(b.sub(a).det(v.b.sub(a)));
229         if ((d1^d2)==-2)return 2;

```

```

230     return (d1==0||d2==0);
231 }
232 //0 平行
233 //1 重合
234 //2 相交
235 int linecrossline(line v)
236 {
237     if ((*this).parallel(v))
238     {
239         return v.relation(a)==3;
240     }
241     return 2;
242 }
243 point crosspoint(line v)
244 {
245     double a1=v.b.sub(v.a).det(a.sub(v.a));
246     double a2=v.b.sub(v.a).det(b.sub(v.a));
247     return point((a.x*a2-b.x*a1)/(a2-a1),(a.y*a2-b.y*a1)/(a2-a1));
248 }
249 double dispointtoline(point p)
250 {
251     return fabs(p.sub(a).det(b.sub(a)))/length();
252 }
253 double dispointtoseg(point p)
254 {
255     if (dblcmp(p.sub(b).dot(a.sub(b)))<0||dblcmp(p.sub(a).dot(b.sub(a)))<0)
256     {
257         return min(p.distance(a),p.distance(b));
258     }
259     return dispointtoline(p);
260 }
261 point lineprog(point p)
262 {
263     return a.add(b.sub(a).mul(b.sub(a).dot(p.sub(a))/b.sub(a).len2()));
264 }
265 point symetrypoint(point p)
266 {
267     point q=lineprog(p);
268     return point(2*q.x-p.x,2*q.y-p.y);
269 }
270 };
271 struct circle
272 {
273     point p;
274     double r;
275     circle(){}
276     circle(point _p,double _r):
277         p(_p),r(_r){};
278     circle(double x,double y,double _r):
279         p(point(x,y)),r(_r){};
280     circle(point a,point b,point c)//三角形的外接圆
281     {
282         p=line(a.add(b).div(2),a.add(b).div(2).add(b.sub(a).rotleft()).crosspoint(line(c.add(b).div(2),c.add(b).div(2).add(b.sub(c).rotleft()))));
283         r=p.distance(a);
284     }
285     circle(point a,point b,point c,bool t)//三角形的内切圆
286     {
287         line u,v;
288         double m=atan2(b.y-a.y,b.x-a.x),n=atan2(c.y-a.y,c.x-a.x);
289         u.a=a;
290         u.b=u.a.add(point(cos((n+m)/2),sin((n+m)/2)));
291         v.a=b;
292         m=atan2(a.y-b.y,a.x-b.x),n=atan2(c.y-b.y,c.x-b.x);
293         v.b=v.a.add(point(cos((n+m)/2),sin((n+m)/2)));
294         p=u.crosspoint(v);
295         r=line(a,b).dispointtoseg(p);
296     }
297     void input()
298     {
299         p.input();
300         scanf("%lf",&r);
301     }
302     void output()
303     {
304         printf("%.2lf,%.2lf,%.2lf\n",p.x,p.y,r);
305     }
306     bool operator==(circle v)
307     {
308         return ((p==v.p)&&dblcmp(r-v.r)==0);
309     }
310     bool operator<(circle v)const
311     {
312         return ((p<v.p)||((p==v.p)&&dblcmp(r-v.r)<0));
313     }
314     double area()
315     {
316         return pi*sqr(r);
317     }
318     double circumference()
319     {
320         return 2*pi*r;
321     }
322 }
323 //0 圆外
324 //1 圆上
325 //2 圆内
326 int relation(point b)
327 {
328     double dst=b.distance(p);
329     if (dblcmp(dst-r)<0)return 2;
330     if (dblcmp(dst-r)==0)return 1;
331     return 0;
332 }
333 int relationseg(line v)
334 {
335     double dst=v.dispointtoseg(p);
336     if (dblcmp(dst-r)<0)return 2;
337     if (dblcmp(dst-r)==0)return 1;
338     return 0;
339 }
340 int relationline(line v)
341 {
342     double dst=v.dispointtoline(p);
343     if (dblcmp(dst-r)<0)return 2;
344     if (dblcmp(dst-r)==0)return 1;
345     return 0;
346 }
347 //过a 两点b 半径的两个圆r
348 int getcircle(point a,point b,double r,circle&c1,circle&c2)
349 {
350     circle x(a,r),y(b,r);
351     int t=x.pointcrosscircle(y,c1.p,c2.p);
352     if (!t)return 0;
353     c1.r=c2.r=r;
354     return t;
355 }
356 //与直线相切u 过点q 半径的圆r1
357 int getcircle(line u,point q,double r1,circle &c1,circle &c2)
358 {
359     double dis=u.dispointtoline(q);
360     if (dblcmp(dis-r1*2)>0)return 0;
361     if (dblcmp(dis)==0)
362     {
363         c1.p=q.add(u.b.sub(u.a).rotleft().trunc(r1));
364         c2.p=q.add(u.b.sub(u.a).rotright().trunc(r1));
365         c1.r=c2.r=r1;
366         return 2;
367     }
368     line u1=line(u.a.add(u.b.sub(u.a).rotleft().trunc(r1)),u.b.add(u.b.sub(u.a).rotleft().trunc(r1)));
369     line u2=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.b.add(u.b.sub(u.a).rotright().trunc(r1)));
370     circle cc=circle(q,r1);
371     point p1,p2;
372     if (!cc.pointcrossline(u1,p1,p2))cc.pointcrossline(u2,p1,p2);
373     c1=circle(p1,r1);
374     if (p1==p2)
375     {
376         c2=c1;return 1;
377     }
378     c2=circle(p2,r1);
379     return 2;
380 }
381 //同时与直线u,相切v 半径的圆r1
382 int getcircle(line u,line v,double r1,circle &c1,circle &c2,circle &c3,circle &c4)
383 {
384     if (u.parallel(v))return 0;
385     line u1=line(u.a.add(u.b.sub(u.a).rotleft().trunc(r1)),u.b.add(u.b.sub(u.a).rotleft().trunc(r1)));
386     line u2=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.b.add(u.b.sub(u.a).rotright().trunc(r1)));
387     line v1=line(v.a.add(v.b.sub(v.a).rotleft().trunc(r1)),v.b.add(v.b.sub(v.a).rotleft().trunc(r1)));
388     line v2=line(v.a.add(v.b.sub(v.a).rotright().trunc(r1)),v.b.add(v.b.sub(v.a).rotright().trunc(r1)));
389     c1.r=c2.r=c3.r=c4.r=r1;
390     c1.p=u1.crosspoint(v1);
391     c2.p=u1.crosspoint(v2);
392     c3.p=u2.crosspoint(v1);
393     c4.p=u2.crosspoint(v2);
394     return 4;
395 }
396 //同时与不相交圆cx,相切cy 半径为的圆r1
397 int getcircle(circle cx,circle cy,double r1,circle&c1,circle&c2)
398 {
399     circle x(cx.p,r1+cx.r),y(cy.p,r1+cy.r);
400     int t=x.pointcrosscircle(y,c1.p,c2.p);
401     if (!t)return 0;
402     c1.r=c2.r=r1;
403     return t;
404 }

```



```

404| int pointcrossline(line v,point &p1,point &p2)//求与线段交点493|
    先判断relationseg
405| {
406|     if (!(*this).relationline(v))return 0;
407|     point a=v.lineprog(p);
408|     double d=v.dispointtoline(p);
409|     d=sqrt(r*r-d*d);
410|     if (dblcmp(d)==0)
411|     {
412|         p1=a;
413|         p2=a;
414|         return 1;
415|     }
416|     p1=a.sub(v.b.sub(v.a).trunc(d));
417|     p2=a.add(v.b.sub(v.a).trunc(d));
418|     return 2;
419| }
420| //5 相离
421| //4 外切
422| //3 相交
423| //2 内切
424| //1 内含
425| int relationcircle(circle v)
426| {
427|     double d=p.distance(v.p);
428|     if (dblcmp(d-r-v.r)>0)return 5;
429|     if (dblcmp(d-r-v.r)==0)return 4;
430|     double l=fabs(r-v.r);
431|     if (dblcmp(d-r-v.r)<0&&dblcmp(d-l)>0)return 3;
432|     if (dblcmp(d-l)==0)return 2;
433|     if (dblcmp(d-l)<0)return 1;
434| }
435| int pointcrosscircle(circle v,point &p1,point &p2)
436| {
437|     int rel=relationcircle(v);
438|     if (rel==1||rel==5)return 0;
439|     double d=p.distance(v.p);
440|     double l=(d+(sqrt(r)-sqrt(v.r))/d)/2;
441|     double h=sqrt(sqrt(r)-sqrt(l));
442|     p1=p.add(v.p.sub(p).trunc(l).add(v.p.sub(p).rotleft(
443|         trunc(h)));
444|     p2=p.add(v.p.sub(p).trunc(l).add(v.p.sub(p).rotright(
445|         trunc(h)));
446|     if (rel==2||rel==4)
447|     {
448|         return 1;
449|     }
450|     return 2;
451| }
452| //过一点做圆的切线 先判断点和圆关系()
453| int tangentline(point q,line &u,line &v)
454| {
455|     int x=relation(q);
456|     if (x==2)return 0;
457|     if (x==1)
458|     {
459|         u=line(q,q.add(q.sub(p).rotleft()));
460|         v=u;
461|         return 1;
462|     }
463|     double d=p.distance(q);
464|     double l=sqrt(r)/d;
465|     double h=sqrt(sqrt(r)-sqrt(l));
466|     u=line(q,p.add(q.sub(p).trunc(l).add(q.sub(p).rotleft(
467|         trunc(h)));
468|     v=line(q,p.add(q.sub(p).trunc(l).add(q.sub(p).rotright(
469|         trunc(h)));
470|     return 2;
471| }
472| double areacircle(circle v)
473| {
474|     int rel=relationcircle(v);
475|     if (rel>=4)return 0.0;
476|     if (rel<=2)return min(area(),v.area());
477|     double d=p.distance(v.p);
478|     double hf=(r+v.r+d)/2.0;
479|     double ss=2*sqrt(hf*(hf-r)*(hf-v.r)*(hf-d));
480|     double a1=acos((r*r*d+d-v.r*v.r)/(2.0*r*d));
481|     a1=a1*r*r;
482|     double a2=acos((v.r*v.r+d*d-r*r)/(2.0*v.r*d));
483|     a2=a2*v.r*v.r;
484|     return a1+a2-ss;
485| }
486| double areatriangle(point a,point b)
487| {
488|     if (dblcmp(p.sub(a).det(p.sub(b))==0))return 0.0;
489|     point q[5];
490|     int len=0;
491|     q[len++]=a;
492|     line l(a,b);
493|     point p1,p2;
494|     if (pointcrossline(l,q[1],q[2])==2)
495|     {
496|         if (dblcmp(a.sub(q[1]).dot(b.sub(q[1]))<0)q[len
497|             ++]=q[1];
498|         if (dblcmp(a.sub(q[2]).dot(b.sub(q[2]))<0)q[len
499|             ++]=q[2];
500|     }
501|     q[len++]=b;
502|     if (len==4&&(dblcmp(q[0].sub(q[1]).dot(q[2].sub(q[1]))
503|         >0))swap(q[1],q[2]));
504|     double res=0;
505|     int i;
506|     for (i=0;i<len-1;i++)
507|     {
508|         if (relation(q[i])==0||relation(q[i+1])==0)
509|         {
510|             double arg=p.rad(q[i],q[i+1]);
511|             res+=r*r*arg/2.0;
512|         }
513|         else
514|         {
515|             res+=fabs(q[i].sub(p).det(q[i+1].sub(p))/2.0);
516|         }
517|     }
518|     return res;
519| }
520| };
521| struct polygon
522| {
523|     int n;
524|     point p[maxp];
525|     line l[maxp];
526|     void input()
527|     {
528|         n=4;
529|         p[0].input();
530|         p[2].input();
531|         double dis=p[0].distance(p[2]);
532|         p[1]=p[2].rotate(p[0],pi/4);
533|         p[1]=p[0].add((p[1].sub(p[0])).trunc(dis/sqrt(2.0)));
534|         p[3]=p[2].rotate(p[0],2*pi-pi/4);
535|         p[3]=p[0].add((p[3].sub(p[0])).trunc(dis/sqrt(2.0)));
536|     }
537|     void add(point q)
538|     {
539|         p[n++]=q;
540|     }
541|     void getline()
542|     {
543|         for (int i=0;i<n;i++)
544|         {
545|             l[i]=line(p[i],p[(i+1)%n]);
546|         }
547|     }
548| }
549| struct cmp
550| {
551|     point p;
552|     cmp(const point &p0){p=p0;}
553|     bool operator()(const point &aa,const point &bb)
554|     {
555|         point a=aa,b=bb;
556|         int d=dblcmp(a.sub(p).det(b.sub(p)));
557|         if (d==0)
558|         {
559|             return dblcmp(a.distance(p)-b.distance(p))<0;
560|         }
561|         return d>0;
562|     }
563| };
564| void norm()
565| {
566|     point mi=p[0];
567|     for (int i=1;i<n;i++)mi=min(mi,p[i]);
568|     sort(p,p+n,cmp(mi));
569| }
570| void getconvex(polygon &convex)
571| {
572|     int i,j,k;
573|     sort(p,p+n);
574|     convex.n=n;
575|     for (i=0;i<min(n,2);i++)
576|     {
577|         convex.p[i]=p[i];
578|     }
579|     if (n<=2)return;
580|     int &top=convex.n;
581|     top=1;
582|     for (i=2;i<n;i++)
583|     {
584|         while (top&&convex.p[top].sub(p[i]).det(convex.p[
585|             top-1].sub(p[i]))<=0)
586|             top--;
587|         convex.p[++top]=p[i];
588|     }
589|     int temp=top;
590|     convex.p[++top]=p[n-2];
591|     for (i=n-3;i>=0;i--)
592|     {
593|         while (top!=temp&&convex.p[top].sub(p[i]).det(
594|             convex.p[top-1].sub(p[i]))<=0)

```

```

585         top--;
586         convex.p[++top]=p[i];
587     }
588 }
589 bool isconvex()
590 {
591     bool s[3];
592     memset(s,0,sizeof(s));
593     int i,j,k;
594     for (i=0;i<n;i++)
595     {
596         j=(i+1)%n;
597         k=(j+1)%n;
598         s[dblcmp(p[j].sub(p[i]).det(p[k].sub(p[i])))>0]=1;
599         if (s[0]&& s[2]) return 0;
600     }
601     return 1;
602 }
603 //3 点上
604 //2 边上
605 //1 内部
606 //0 外部
607 int relationpoint(point q)
608 {
609     int i,j;
610     for (i=0;i<n;i++)
611     {
612         if (p[i]==q) return 3;
613     }
614     getline();
615     for (i=0;i<n;i++)
616     {
617         if (l[i].pointonseg(q)) return 2;
618     }
619     int cnt=0;
620     for (i=0;i<n;i++)
621     {
622         j=(i+1)%n;
623         int k=dblcmp(q.sub(p[j]).det(p[i].sub(p[j])));
624         int u=dblcmp(p[i].y-q.y);
625         int v=dblcmp(p[j].y-q.y);
626         if (k>0&&u<0&&v>=0) cnt++;
627         if (k<0&&v<0&&u>=0) cnt--;
628     }
629     return cnt!=0;
630 }
631 //1 在多边形内长度为正
632 //2 相交或与边平行
633 //0 无任何交点
634 int relationline(line u)
635 {
636     int i,j,k=0;
637     getline();
638     for (i=0;i<n;i++)
639     {
640         if (l[i].segcrossseg(u)==2) return 1;
641         if (l[i].segcrossseg(u)==1) k=1;
642     }
643     if (!k) return 0;
644     vector<point> vp;
645     for (i=0;i<n;i++)
646     {
647         if (l[i].segcrossseg(u))
648         {
649             if (l[i].parallel(u))
650             {
651                 vp.pb(u.a);
652                 vp.pb(u.b);
653                 vp.pb(l[i].a);
654                 vp.pb(l[i].b);
655                 continue;
656             }
657             vp.pb(l[i].crosspoint(u));
658         }
659     }
660     sort(vp.begin(),vp.end());
661     int sz=vp.size();
662     for (i=0;i<sz-1;i++)
663     {
664         point mid=vp[i].add(vp[i+1]).div(2);
665         if (relationpoint(mid)==1) return 1;
666     }
667     return 2;
668 }
669 //直线切割凸多边形左侧u
670 //注意直线方向
671 void convexcut(line u,polygon &po)
672 {
673     int i,j,k;
674     int &top=po.n;
675     top=0;
676     for (i=0;i<n;i++)
677     {
678         int d1=dblcmp(p[i].sub(u.a).det(u.b.sub(u.a)));
679         int d2=dblcmp(p[(i+1)%n].sub(u.a).det(u.b.sub(u.a)));
680         if (d1>=0) po.p[top++]=p[i];
681         if (d1*d2<0) po.p[top++]=u.crosspoint(line(p[i],p[(i+1)%n]));
682     }
683 }
684 double getcircumference()
685 {
686     double sum=0;
687     int i;
688     for (i=0;i<n;i++)
689     {
690         sum+=p[i].distance(p[(i+1)%n]);
691     }
692     return sum;
693 }
694 double getarea()
695 {
696     double sum=0;
697     int i;
698     for (i=0;i<n;i++)
699     {
700         sum+=p[i].det(p[(i+1)%n]);
701     }
702     return fabs(sum)/2;
703 }
704 bool getdir()//代表逆时针1 代表顺时针0
705 {
706     double sum=0;
707     int i;
708     for (i=0;i<n;i++)
709     {
710         sum+=p[i].det(p[(i+1)%n]);
711     }
712     if (dblcmp(sum)>0) return 1;
713     return 0;
714 }
715 point getbarycentre()
716 {
717     point ret(0,0);
718     double area=0;
719     int i;
720     for (i=1;i<n-1;i++)
721     {
722         double tmp=p[i].sub(p[0]).det(p[i+1].sub(p[0]));
723         if (dblcmp(tmp)==0) continue;
724         area+=tmp;
725         ret.x+=(p[0].x+p[i].x+p[i+1].x)/3*tmp;
726         ret.y+=(p[0].y+p[i].y+p[i+1].y)/3*tmp;
727     }
728     if (dblcmp(area)) ret=ret.div(area);
729     return ret;
730 }
731 double areaintersection(polygon po)
732 {
733 }
734 double areaunion(polygon po)
735 {
736     return getarea()+po.getarea()-areaintersection(po);
737 }
738 double areacircle(circle c)
739 {
740     int i,j,k,l,m;
741     double ans=0;
742     for (i=0;i<n;i++)
743     {
744         int j=(i+1)%n;
745         if (dblcmp(p[j].sub(c.p).det(p[i].sub(c.p)))>=0)
746         {
747             ans+=c.areastriangle(p[i],p[j]);
748         }
749         else
750         {
751             ans-=c.areastriangle(p[i],p[j]);
752         }
753     }
754     return fabs(ans);
755 }
756 //多边形和圆关系
757 //0 一部分在圆外
758 //1 与圆某条边相切
759 //2 完全在圆内
760 int relationcircle(circle c)
761 {
762     getline();
763     int i,x=2;
764     if (relationpoint(c.p)!=1) return 0;
765     for (i=0;i<n;i++)
766     {
767         if (c.relationseg(l[i])==2) return 0;
768         if (c.relationseg(l[i])==1) x=1;
769     }
770     return x;
771 }
772 void find(int st,point tri[],circle &c)

```

```

773 {
774     if (!st)
775     {
776         c=circle(point(0,0),-2);
777     }
778     if (st==1)
779     {
780         c=circle(tri[0],0);
781     }
782     if (st==2)
783     {
784         c=circle(tri[0].add(tri[1]).div(2),tri[0].distance(tri[1])/2.0);
785     }
786     if (st==3)
787     {
788         c=circle(tri[0],tri[1],tri[2]);
789     }
790 }
791 void solve(int cur,int st,point tri[],circle &c)
792 {
793     find(st,tri,c);
794     if (st==3)return;
795     int i;
796     for (i=0;i<cur;i++)
797     {
798         if (dblcmp(p[i].distance(c.p)-c.r)>0)
799         {
800             tri[st]=p[i];
801             solve(i,st+1,tri,c);
802         }
803     }
804 }
805 circle mincircle()//点集最小圆覆盖
806 {
807     random_shuffle(p,p+n);
808     point tri[4];
809     circle c;
810     solve(n,0,tri,c);
811     return c;
812 }
813 int circlecover(double r)//单位圆覆盖
814 {
815     int ans=0,i,j;
816     vector<pair<double,int> >v;
817     for (i=0;i<n;i++)
818     {
819         v.clear();
820         for (j=0;j<n;j++)if (i!=j)
821         {
822             point q=p[i].sub(p[j]);
823             double d=q.len();
824             if (dblcmp(d-2*r)<=0)
825             {
826                 double arg=atan2(q.y,q.x);
827                 if (dblcmp(arg)<0)arg+=2*pi;
828                 double t=acos(d/(2*r));
829                 v.push_back(make_pair(arg-t+2*pi,-1));
830                 v.push_back(make_pair(arg+t+2*pi,1));
831             }
832         }
833         sort(v.begin(),v.end());
834         int cur=0;
835         for (j=0;j<v.size();j++)
836         {
837             if (v[j].second==-1)++cur;
838             else --cur;
839             ans=max(ans,cur);
840         }
841     }
842     return ans+1;
843 }
844 int pointinpolygon(point q)//点在凸多边形内部的判定
845 {
846     if (getdir())reverse(p,p+n);
847     if (dblcmp(q.sub(p[0]).det(p[n-1].sub(p[0]))==0)
848     {
849         if (line(p[n-1],p[0]).pointonseg(q))return n-1;
850         return -1;
851     }
852     int low=1,high=n-2,mid;
853     while (low<=high)
854     {
855         mid=(low+high)>>1;
856         if (dblcmp(q.sub(p[0]).det(p[mid].sub(p[0]))>=0&&
857             dblcmp(q.sub(p[0]).det(p[mid+1].sub(p[0]))<0)
858         {
859             polygon c;
860             c.p[0]=p[mid];
861             c.p[1]=p[mid+1];
862             c.p[2]=p[0];
863             c.n=3;
864             if (c.relationpoint(q))return mid;
865             return -1;
866         }
867         if (dblcmp(q.sub(p[0]).det(p[mid].sub(p[0]))>0)
868     }
869     {
870         low=mid+1;
871     }
872     else
873     {
874         high=mid-1;
875     }
876     }
877     return -1;
878 }
879 struct polygons
880 {
881     vector<polygon>p;
882     polygons()
883     {
884         p.clear();
885     }
886     void clear()
887     {
888         p.clear();
889     }
890     void push(polygon q)
891     {
892         if (dblcmp(q.getarea()))p.pb(q);
893     }
894     vector<pair<double,int> >e;
895     void ins(point s,point t,point X,int i)
896     {
897         double r=fabs(t.x-s.x)>eps?(X.x-s.x)/(t.x-s.x):(X.y-s.y)/(t.y-s.y);
898         r=min(r,1.0);r=max(r,0.0);
899         e.pb(mp(r,i));
900     }
901     double polyareaunion()
902     {
903         double ans=0.0;
904         int c0,c1,c2,i,j,k,w;
905         for (i=0;i<p.size();i++)
906         {
907             if (p[i].getdir()==0)reverse(p[i].p,p[i].p+p[i].n);
908         }
909         for (i=0;i<p.size();i++)
910         {
911             for (k=0;k<p[i].n;k++)
912             {
913                 point &s=p[i].p[k],&t=p[i].p[(k+1)%p[i].n];
914                 if (!dblcmp(s.det(t)))continue;
915                 e.clear();
916                 e.pb(mp(0.0,1));
917                 e.pb(mp(1.0,-1));
918                 for (j=0;j<p.size();j++)if (i!=j)
919                 {
920                     for (w=0;w<p[j].n;w++)
921                     {
922                         point a=p[j].p[w],b=p[j].p[(w+1)%p[j].n];
923                         c0=dblcmp(t.sub(s).det(c.sub(s)));
924                         c1=dblcmp(t.sub(s).det(a.sub(s)));
925                         c2=dblcmp(t.sub(s).det(b.sub(s)));
926                         if (c1*c2<0)ins(s,t,line(s,t).crosspoint(line(a,b)),-c2);
927                         else if (!c1&&c0*c2<0)ins(s,t,a,-c2);
928                         else if (!c1&&!c2)
929                         {
930                             int c3=dblcmp(t.sub(s).det(p[j].p[(w+2)%p[j].n].sub(s)));
931                             int dp=dblcmp(t.sub(s).dot(b.sub(a)));
932                             if (dp&&c0)ins(s,t,a,dp>0?c0*((j>i)^(c0<0)):-c0);
933                             if (dp&&c3)ins(s,t,b,dp>0?-c3*((j>i)^(c3<0)):c3);
934                         }
935                     }
936                 }
937             }
938             sort(e.begin(),e.end());
939             int ct=0;
940             double tot=0.0,last;
941             for (j=0;j<e.size();j++)
942             {
943                 if (ct==p.size())tot+=e[j].first-last;
944                 ct+=e[j].second;
945                 last=e[j].first;
946             }
947             ans+=s.det(t)*tot;
948         }
949     }
950     return fabs(ans)*0.5;
951 }
952 const int maxn=500;
953 struct circles
954 {
955     circle c[maxn];
956     double ans[maxn];//ans[i表示被覆盖了]次的面积i

```

```

956 double pre[maxn];
957 int n;
958 circles(){}
959 void add(circle cc)
960 {
961     c[n++] = cc;
962 }
963 bool inner(circle x, circle y)
964 {
965     if (x.relationcircle(y) != 1) return 0;
966     return dblcmp(x.r - y.r) <= 0 ? 1 : 0;
967 }
968 void init_or() // 圆的面积并去掉内含的圆
969 {
970     int i, j, k = 0;
971     bool mark[maxn] = {0};
972     for (i = 0; i < n; i++)
973     {
974         for (j = 0; j < n; j++) if (i != j && !mark[j])
975         {
976             if ((c[i] == c[j]) || inner(c[i], c[j])) break;
977         }
978         if (j < n) mark[i] = 1;
979     }
980     for (i = 0; i < n; i++) if (!mark[i]) c[k++] = c[i];
981     n = k;
982 }
983 void init_and() // 圆的面积交去掉内含的圆
984 {
985     int i, j, k = 0;
986     bool mark[maxn] = {0};
987     for (i = 0; i < n; i++)
988     {
989         for (j = 0; j < n; j++) if (i != j && !mark[j])
990         {
991             if ((c[i] == c[j]) || inner(c[j], c[i])) break;
992         }
993         if (j < n) mark[i] = 1;
994     }
995     for (i = 0; i < n; i++) if (!mark[i]) c[k++] = c[i];
996     n = k;
997 }
998 double areaarc(double th, double r)
999 {
1000     return 0.5 * sqr(r) * (th - sin(th));
1001 }
1002 void getarea()
1003 {
1004     int i, j, k;
1005     memset(ans, 0, sizeof(ans));
1006     vector<pair<double, int>> v;
1007     for (i = 0; i < n; i++)
1008     {
1009         v.clear();
1010         v.push_back(make_pair(-pi, 1));
1011         v.push_back(make_pair(pi, -1));
1012         for (j = 0; j < n; j++) if (i != j)
1013         {
1014             point q = c[j].p.sub(c[i].p);
1015             double ab = q.len(), ac = c[i].r, bc = c[j].r;
1016             if (dblcmp(ab + ac - bc) <= 0)
1017             {
1018                 v.push_back(make_pair(-pi, 1));
1019                 v.push_back(make_pair(pi, -1));
1020                 continue;
1021             }
1022             if (dblcmp(ab + bc - ac) <= 0) continue;
1023             if (dblcmp(ab - ac - bc) > 0) continue;
1024             double th = atan2(q.y, q.x), fai = acos((ac * ac + ab * ab - bc * bc) / (2.0 * ac * ab));
1025             double a0 = th - fai;
1026             if (dblcmp(a0 + pi) < 0) a0 += 2 * pi;
1027             double a1 = th + fai;
1028             if (dblcmp(a1 - pi) > 0) a1 -= 2 * pi;
1029             if (dblcmp(a0 - a1) > 0)
1030             {
1031                 v.push_back(make_pair(a0, 1));
1032                 v.push_back(make_pair(pi, -1));
1033                 v.push_back(make_pair(-pi, 1));
1034                 v.push_back(make_pair(a1, -1));
1035             }
1036             else
1037             {
1038                 v.push_back(make_pair(a0, 1));
1039                 v.push_back(make_pair(a1, -1));
1040             }
1041         }
1042     }
1043     sort(v.begin(), v.end());
1044     int cur = 0;
1045     for (j = 0; j < v.size(); j++)
1046     {
1047         if (cur && dblcmp(v[j].first - pre[cur]) < 0)
1048         {
1049             ans[cur] += areaarc(v[j].first - pre[cur], c[i].r);
1050             ans[cur] += 0.5 * point(c[i].p.x + c[i].r * cos(pre[cur]), c[i].p.y + c[i].r * sin(pre[cur])).
1051                 det(point(c[i].p.x + c[i].r * cos(v[j].first), c[i].p.y + c[i].r * sin(v[j].first)));
1052             cur = v[j].second;
1053             pre[cur] = v[j].first;
1054         }
1055     }
1056     for (i = 1; i <= n; i++)
1057     {
1058         ans[i] = ans[i + 1];
1059     }
1060 }
1061 struct halfplane: public line
1062 {
1063     double angle;
1064     halfplane(){}
1065     // 表示向量 a -> 逆时针b左侧()的半平面
1066     halfplane(point _a, point _b)
1067     {
1068         a = _a;
1069         b = _b;
1070     }
1071     halfplane(line v)
1072     {
1073         a = v.a;
1074         b = v.b;
1075     }
1076     void calcangle()
1077     {
1078         angle = atan2(b.y - a.y, b.x - a.x);
1079     }
1080     bool operator<(const halfplane &b) const
1081     {
1082         return angle < b.angle;
1083     }
1084 };
1085 struct halfplanes
1086 {
1087     int n;
1088     halfplane hp[maxp];
1089     point p[maxp];
1090     int que[maxp];
1091     int st, ed;
1092     void push(halfplane tmp)
1093     {
1094         hp[n++] = tmp;
1095     }
1096     void unique()
1097     {
1098         int m = 1;
1099         for (i = 1; i < n; i++)
1100         {
1101             if (dblcmp(hp[i].angle - hp[i - 1].angle)) hp[m++] = hp[i];
1102             else if (dblcmp(hp[m - 1].b.sub(hp[m - 1].a).det(hp[i].a.sub(hp[m - 1].a)) > 0) hp[m - 1] = hp[i];
1103         }
1104         n = m;
1105     }
1106     bool halfplaneinsert()
1107     {
1108         int i;
1109         for (i = 0; i < n; i++) hp[i].calcangle();
1110         sort(hp, hp + n);
1111         unique();
1112         que[st = 0] = 0;
1113         que[ed = 1] = 1;
1114         p[1] = hp[0].crosspoint(hp[1]);
1115         for (i = 2; i < n; i++)
1116         {
1117             while (st < ed && dblcmp((hp[i].b.sub(hp[i].a).det(p[ed].sub(hp[i].a))) < 0) ed--;
1118             while (st < ed && dblcmp((hp[i].b.sub(hp[i].a).det(p[st + 1].sub(hp[i].a))) < 0) st++;
1119             que[++ed] = i;
1120             if (hp[i].parallel(hp[que[ed - 1]])) return false;
1121             p[ed] = hp[i].crosspoint(hp[que[ed - 1]]);
1122         }
1123         while (st < ed && dblcmp(hp[que[st]].b.sub(hp[que[st]].a).det(p[ed].sub(hp[que[st]].a))) < 0) ed--;
1124         while (st < ed && dblcmp(hp[que[ed]].b.sub(hp[que[ed]].a).det(p[st + 1].sub(hp[que[ed]].a))) < 0) st++;
1125         if (st + 1 >= ed) return false;
1126         return true;
1127     }
1128     void getconvex(polygon &con)
1129     {
1130         p[st] = hp[que[st]].crosspoint(hp[que[ed]]);
1131         con.n = ed - st + 1;
1132         int j = st, i = 0;
1133         for (; j <= ed; j++, i++)
1134         {
1135             con.p[i] = p[j];
1136         }
1137     }
1138 }

```

```

1136     }
1137 }
1138 };
1139 struct point3
1140 {
1141     double x,y,z;
1142     point3(){
1143     point3(double _x,double _y,double _z):
1144         x(_x),y(_y),z(_z){};
1145     void input()
1146     {
1147         scanf("%lf%lf%lf",&x,&y,&z);
1148     }
1149     void output()
1150     {
1151         printf("%.2lf %.2lf %.2lf\n",x,y,z);
1152     }
1153     bool operator==(point3 a)
1154     {
1155         return dblcmp(a.x-x)==0&&dblcmp(a.y-y)==0&&dblcmp(a.z-z)==0;
1156     }
1157     bool operator<(point3 a)const
1158     {
1159         return dblcmp(a.x-x)==0?dblcmp(y-a.y)==0?dblcmp(z-a.z)<0:y<a.y:x<a.x;
1160     }
1161     double len()
1162     {
1163         return sqrt(len2());
1164     }
1165     double len2()
1166     {
1167         return x*x+y*y+z*z;
1168     }
1169     double distance(point3 p)
1170     {
1171         return sqrt((p.x-x)*(p.x-x)+(p.y-y)*(p.y-y)+(p.z-z)*(p.z-z));
1172     }
1173     point3 add(point3 p)
1174     {
1175         return point3(x+p.x,y+p.y,z+p.z);
1176     }
1177     point3 sub(point3 p)
1178     {
1179         return point3(x-p.x,y-p.y,z-p.z);
1180     }
1181     point3 mul(double d)
1182     {
1183         return point3(x*d,y*d,z*d);
1184     }
1185     point3 div(double d)
1186     {
1187         return point3(x/d,y/d,z/d);
1188     }
1189     double dot(point3 p)
1190     {
1191         return x*p.x+y*p.y+z*p.z;
1192     }
1193     point3 det(point3 p)
1194     {
1195         return point3(y*p.z-p.y*z,p.x*z-x*p.z,x*p.y-p.x*y);
1196     }
1197     double rad(point3 a,point3 b)
1198     {
1199         point3 p=(a-b);
1200         return acos(a.sub(p).dot(b.sub(p))/(a.distance(p)*b.distance(p)));
1201     }
1202     point3 trunc(double r)
1203     {
1204         r/=len();
1205         return point3(x*r,y*r,z*r);
1206     }
1207     point3 rotate(point3 o,double r)
1208     {
1209     };
1210 };
1211 struct line3
1212 {
1213     point3 a,b;
1214     line3(){
1215     line3(point3 _a,point3 _b)
1216     {
1217         a=_a;
1218         b=_b;
1219     }
1220     bool operator==(line3 v)
1221     {
1222         return (a==v.a)&&(b==v.b);
1223     }
1224     void input()
1225     {
1226         a.input();
1227         b.input();
1228     }
1229     double length()
1230     {
1231         return a.distance(b);
1232     }
1233     bool pointonseg(point3 p)
1234     {
1235         return dblcmp(p.sub(a).det(p.sub(b)).len())==0&&dblcmp(a.sub(p).dot(b.sub(p)))<=0;
1236     }
1237     double dispointtoline(point3 p)
1238     {
1239         return b.sub(a).det(p.sub(a)).len()/a.distance(b);
1240     }
1241     double dispointtoseg(point3 p)
1242     {
1243         if (dblcmp(p.sub(b).dot(a.sub(b)))<0||dblcmp(p.sub(a).dot(b.sub(a)))<0)
1244         {
1245             return min(p.distance(a),p.distance(b));
1246         }
1247         return dispointtoline(p);
1248     }
1249     point3 lineprog(point3 p)
1250     {
1251         return a.add(b.sub(a).trunc(b.sub(a).dot(p.sub(a))/b.distance(a)));
1252     }
1253     point3 rotate(point3 p,double ang)//绕此向量逆时针角度pang
1254     {
1255         if (dblcmp((p.sub(a).det(p.sub(b)).len()))==0)return p;
1256         point3 f1=b.sub(a).det(p.sub(a));
1257         point3 f2=b.sub(a).det(f1);
1258         double len=fabs(a.sub(p).det(b.sub(p)).len()/a.distance(b));
1259         f1=f1.trunc(len);f2=f2.trunc(len);
1260         point3 h=p.add(f2);
1261         point3 pp=h.add(f1);
1262         return h.add((p.sub(h)).mul(cos(ang*1.0))).add((pp.sub(h)).mul(sin(ang*1.0)));
1263     }
1264 };
1265 struct plane
1266 {
1267     point3 a,b,c,o;
1268     plane(){
1269     plane(point3 _a,point3 _b,point3 _c)
1270     {
1271         a=_a;
1272         b=_b;
1273         c=_c;
1274         o=pvec();
1275     }
1276     plane(double _a,double _b,double _c,double _d)
1277     {
1278         //ax+by+cz+d=0
1279         o=point3(_a,_b,_c);
1280         if (dblcmp(_a)!=0)
1281         {
1282             a=point3((-_d-_c-_b)/_a,1,1);
1283         }
1284         else if (dblcmp(_b)!=0)
1285         {
1286             a=point3(1,(-_d-_c-_a)/_b,1);
1287         }
1288         else if (dblcmp(_c)!=0)
1289         {
1290             a=point3(1,1,(-_d-_a-_b)/_c);
1291         }
1292     }
1293     void input()
1294     {
1295         a.input();
1296         b.input();
1297         c.input();
1298         o=pvec();
1299     }
1300     point3 pvec()
1301     {
1302         return b.sub(a).det(c.sub(a));
1303     }
1304     bool pointonplane(point3 p)//点是否在平面上
1305     {
1306         return dblcmp(p.sub(a).dot(o))==0;
1307     }
1308     //0 不在
1309     //1 在边界上
1310     //2 在内部
1311     int pointontriangle(point3 p)//点是否在空间三角形上abc
1312     {
1313         if (!pointonplane(p))return 0;
1314         double s=a.sub(b).det(c.sub(b)).len();
1315         double s1=p.sub(a).det(p.sub(b)).len();
1316         double s2=p.sub(a).det(p.sub(c)).len();
1317         double s3=p.sub(b).det(p.sub(c)).len();

```

```

1318 |         if (dblcmp(s-s1-s2-s3))return 0;
1319 |         if (dblcmp(s1)&&dblcmp(s2)&&dblcmp(s3))return 2;
1320 |         return 1;
1321 |     }
1322 |     //判断两平面关系
1323 |     //0 相交
1324 |     //1 平行但不重合
1325 |     //2 重合
1326 |     bool relationplane(plane f)
1327 |     {
1328 |         if (dblcmp(o.det(f.o).len()))return 0;
1329 |         if (pointonplane(f.a))return 2;
1330 |         return 1;
1331 |     }
1332 |     double angleplane(plane f)//两平面夹角
1333 |     {
1334 |         return acos(o.dot(f.o)/(o.len()*f.o.len()));
1335 |     }
1336 |     double dispoint(point3 p)//点到平面距离
1337 |     {
1338 |         return fabs(p.sub(a).dot(o)/o.len());
1339 |     }
1340 |     point3 pttoplane(point3 p)//点到平面最近点
1341 |     {
1342 |         line3 u=line3(p,p.add(o));
1343 |         crossline(u,p);
1344 |         return p;
1345 |     }
1346 |     int crossline(line3 u,point3 &p)//平面和直线的交点
1347 |     {
1348 |         double x=o.dot(u.b.sub(a));
1349 |         double y=o.dot(u.a.sub(a));
1350 |         double d=x-y;
1351 |         if (dblcmp(fabs(d))==0)return 0;
1352 |         p=u.a.mul(x).sub(u.b.mul(y)).div(d);
1353 |         return 1;
1354 |     }
1355 |     int crossplane(plane f,line3 &u)//平面和平面的交线
1356 |     {
1357 |         point3 oo=o.det(f.o);
1358 |         point3 v=o.det(oo);
1359 |         double d=fabs(f.o.dot(v));
1360 |         if (dblcmp(d)==0)return 0;
1361 |         point3 q=a.add(v.mul(f.o.dot(f.a.sub(a))/d));
1362 |         u=line3(q,q.add(oo));
1363 |         return 1;
1364 |     }
1365 | };

```

4 Graph

4.1 2SAT

```

1 /*
2 x & y == true:
3 ~x -> x
4 ~y -> y
5
6 x & y == false:
7 x -> ~y
8 y -> ~x
9
10 x | y == true:
11 ~x -> y
12 ~y -> x
13
14 x | y == false:
15 x -> ~x
16 y -> ~y
17
18 x ^ y == true:
19 ~x -> y
20 y -> ~x
21 x -> ~y
22 ~y -> x
23
24 x ^ y == false:
25 x -> y
26 y -> x
27 ~x -> ~y
28 ~y -> ~x
29 */
30 #include<cstdio>
31 #include<cstring>
32
33 #define MAXX 16111
34 #define MAXE 200111
35 #define v to[i]
36
37 int edge[MAXX],to[MAXE],nxt[MAXE],cnt;
38 inline void add(int a,int b)
39 {
40     nxt[++cnt]=edge[a];

```

```

41     edge[a]=cnt;
42     to[cnt]=b;
43 }
44
45 bool done[MAXX];
46 int st[MAXX];
47
48 bool dfs(const int now)
49 {
50     if(done[now^1])
51         return false;
52     if(done[now])
53         return true;
54     done[now]=true;
55     st[cnt++]=now;
56     for(int i=edge[now];i;i=nxt[i])
57         if(!dfs(v))
58             return false;
59     return true;
60 }
61
62 int n,m;
63 int i,j,k;
64
65 inline bool go()
66 {
67     memset(done,0,sizeof done);
68     for(i=0;i<n;i+=2)
69         if(!done[i] && !done[i^1])
70         {
71             cnt=0;
72             if(!dfs(i))
73             {
74                 while(cnt)
75                     done[st[--cnt]]=false;
76                 if(!dfs(i^1))
77                     return false;
78             }
79         }
80     return true;
81 }
82 //done array will be a solution with minimal lexicographical
83 // or maybe we can solve it with dual SCC method, and get a
84 // solution by reverse the edges of DAG then product a
85 // topsort

```

4.2 Articulation

```

1 void dfs(int now,int fa) // now 从 1 开始
2 {
3     int p(0);
4     dfn[now]=low[now]=cnt++;
5     for(std::list<int>::const_iterator it(edge[now].begin());it
6         !=edge[now].end();++it)
7         if(dfn[*it]==-1)
8         {
9             dfs(*it,now);
10            ++p;
11            low[now]=std::min(low[now],low[*it]);
12            if((now==1 && p>1) || (now!=1 && low[*it]>=dfn[now
13                ])) // 如果从出发点出发的子节点不能由兄弟节点到达, 那么
14                // 出发点为割点. 如果现节点不是出发点, 但是其子孙节点不
15                // 能达到祖先节点, 那么该节点为割点
16                ans.insert(now);
17            }
18        else
19            if(*it!=fa)
20                low[now]=std::min(low[now],dfn[*it]);
21    }

```

4.3 Augmenting Path Algorithm for Maximum Cardinality Bipartite Matching

```

1 #include<cstdio>
2 #include<cstring>
3
4 #define MAXX 111
5
6 bool Map[MAXX][MAXX],visit[MAXX];
7 int link[MAXX],n,m;
8 bool dfs(int t)
9 {
10     for (int i=0; i<m; i++)
11         if (!visit[i] && Map[t][i]){
12             visit[i] = true;
13             if (link[i]==-1 || dfs(link[i])){
14                 link[i] = t;
15                 return true;
16             }
17         }
18     return false;
19 }

```

```

20 int main()
21 {
22     int k,a,b,c;
23     while (scanf("%d",&n),n){
24         memset(Map,false,sizeof(Map));
25         scanf("%d",&m,&k);
26         while (k--){
27             scanf("%d%d",&a,&b,&c);
28             if (b && c)
29                 Map[b][c] = true;
30         }
31         memset(link,-1,sizeof(link));
32         int ans = 0;
33         for (int i=0; i<n; i++){
34             memset(visit,false,sizeof(visit));
35             if (dfs(i))
36                 ans++;
37         }
38         printf("%d\n",ans);
39     }
40 }

```

4.4 Biconnected Component - Edge

```

1 // hdu 4612
2 #include<stdio>
3 #include<algorithm>
4 #include<set>
5 #include<cstring>
6 #include<stack>
7 #include<queue>
8
9 #define MAXX 200111
10 #define MAXE (100011*2)
11 #pragma comment(linker, "/STACK:16777216")
12
13 int edge[MAXX],to[MAXE],nxt[MAXE],cnt;
14 #define v to[i]
15 inline void add(int a,int b)
16 {
17     nxt[++cnt]=edge[a];
18     edge[a]=cnt;
19     to[cnt]=b;
20 }
21
22 int dfn[MAXX],low[MAXX],col[MAXX],belong[MAXX];
23 int idx,bcnt;
24 std::stack<int>st;
25
26 void tarjan(int now,int last)
27 {
28     col[now]=1;
29     st.push(now);
30     dfn[now]=low[now]=++idx;
31     bool flag(false);
32     for(int i=edge[now];i;i=nxt[i])
33     {
34         if(v==last && !flag)
35         {
36             flag=true;
37             continue;
38         }
39         if(!col[v])
40         {
41             tarjan(v,now);
42             low[now]=std::min(low[now],low[v]);
43             /*
44             if(low[v]>dfn[now])
45             then this is a bridge
46             */
47         }
48         else
49             if(col[v]==1)
50                 low[now]=std::min(low[now],dfn[v]);
51     }
52     col[now]=2;
53     if(dfn[now]==low[now])
54     {
55         ++bcnt;
56         static int x;
57         do
58         {
59             x=st.top();
60             st.pop();
61             belong[x]=bcnt;
62         }while(x!=now);
63     }
64 }
65
66 std::set<int>set[MAXX];
67
68 int dist[MAXX];
69 std::queue<int>q;
70 int n,m,i,j,k;
71

```

```

72 inline int go(int s)
73 {
74     static std::set<int>::const_iterator it;
75     memset(dist,0x3f,sizeof dist);
76     dist[s]=0;
77     q.push(s);
78     while(!q.empty())
79     {
80         s=q.front();
81         q.pop();
82         for(it=set[s].begin();it!=set[s].end();++it)
83             if(dist[*it]>dist[s]+1)
84             {
85                 dist[*it]=dist[s]+1;
86                 q.push(*it);
87             }
88     }
89     return std::max_element(dist+1,dist+1+bcnt)-dist;
90 }
91
92 int main()
93 {
94     while(scanf("%d%d",&n,&m),(n||m))
95     {
96         cnt=0;
97         memset(edge,0,sizeof edge);
98         while(m-->0)
99         {
100             scanf("%d%d",&i,&j);
101             add(i,j);
102             add(j,i);
103         }
104
105         memset(dfn,0,sizeof dfn);
106         memset(belong,0,sizeof belong);
107         memset(low,0,sizeof low);
108         memset(col,0,sizeof col);
109         bcnt=idx=0;
110         while(!st.empty())
111             st.pop();
112
113         tarjan(1,-1);
114         for(i=1;i<=bcnt;++i)
115             set[i].clear();
116         for(i=1;i<=n;++i)
117             for(j=edge[i];j;j=nxt[j])
118                 set[belong[i]].insert(belong[to[j]]);
119         for(i=1;i<=bcnt;++i)
120             set[i].erase(i);
121         /*
122         printf("%d\n",dist[go(1)]);
123         for(i=1;i<=bcnt;++i)
124             printf("%d\n",dist[i]);
125         puts("");
126         */
127         printf("%d\n",bcnt-1-dist[go(1)]);
128     }
129     return 0;
130 }

```

4.5 Biconnected Component

```

1 #include<stdio>
2 #include<cstring>
3 #include<stack>
4 #include<queue>
5 #include<algorithm>
6
7 const int MAXN=100000*2;
8 const int MAXM=200000;
9
10 //0-based
11
12 struct edges
13 {
14     int to,next;
15     bool cut,visit;
16 } edge[MAXM<<1];
17
18 int head[MAXN],low[MAXN],dpt[MAXN],L;
19 bool visit[MAXN],cut[MAXN];
20 int idx;
21 std::stack<int> st;
22 int bcc[MAXN];
23
24 void init(int n)
25 {
26     L=0;
27     memset(head,-1,4*n);
28     memset(visit,0,n);
29 }
30
31 void add_edge(int u,int v)
32 {
33     edge[L].cut=edge[L].visit=false;

```

```

34 |     edge[L].to=v;
35 |     edge[L].next=head[u];
36 |     head[u]=L++;
37 | }
38 |
39 | void dfs(int u,int fu,int deg)
40 | {
41 |     cut[u]=false;
42 |     visit[u]=true;
43 |     low[u]=dpt[u]=deg;
44 |     int tot=0;
45 |     for (int i=head[u]; i!=-1; i=edge[i].next)
46 |     {
47 |         int v=edge[i].to;
48 |         if (edge[i].visit)
49 |             continue;
50 |         st.push(i/2);
51 |         edge[i].visit=edge[i^1].visit=true;
52 |         if (visit[v])
53 |         {
54 |             low[u]=dpt[v]>low[u]?low[u]:dpt[v];
55 |             continue;
56 |         }
57 |         dfs(v,u,deg+1);
58 |         edge[i].cut=edge[i^1].cut=(low[v]>dpt[u] || edge[i].cut);
59 |         if (u!=fu) cut[u]=low[v]>=dpt[u]?1:cut[u];
60 |         if (low[v]>=dpt[u] || u==fu)
61 |         {
62 |             while (st.top()!=i/2)
63 |             {
64 |                 int x=st.top()*2,y=st.top()*2+1;
65 |                 bcc[st.top()]=idx;
66 |                 st.pop();
67 |             }
68 |             bcc[i/2]=idx++;
69 |             st.pop();
70 |         }
71 |         low[u]=low[v]>low[u]?low[u]:low[v];
72 |         tot++;
73 |     }
74 |     if (u==fu && tot>1)
75 |         cut[u]=true;
76 | }
77 |
78 | int main()
79 | {
80 |     int n,m;
81 |     while (scanf("%d%d",&n,&m)!=EOF)
82 |     {
83 |         init(n);
84 |         for (int i=0; i<m; i++)
85 |         {
86 |             int u,v;
87 |             scanf("%d%d",&u,&v);
88 |             add_edge(u,v);
89 |             add_edge(v,u);
90 |         }
91 |         idx=0;
92 |         for (int i=0; i<n; i++)
93 |             if (!visit[i])
94 |                 dfs(i,i,0);
95 |     }
96 |     return 0;
97 | }

```

4.6 Blossom algorithm

```

1 | #include<cstdio>
2 | #include<vector>
3 | #include<cstring>
4 | #include<algorithm>
5 |
6 | #define MAXX 233
7 |
8 | bool map[MAXX][MAXX];
9 | std::vector<int> p[MAXX];
10 | int m[MAXX];
11 | int vis[MAXX];
12 | int q[MAXX],*qf,*qb;
13 |
14 | int n;
15 |
16 | inline void label(int x,int y,int b)
17 | {
18 |     static int i,z;
19 |     for (i=b+1; i<p[x].size(); ++i)
20 |         if (vis[z=p[x][i]]==1)
21 |         {
22 |             p[z]=p[y];
23 |             p[z].insert(p[z].end(),p[x].rbegin(),p[x].rend()-i);
24 |             vis[z]=0;
25 |             *qb++=z;
26 |         }

```

```

27 | }
28 |
29 | inline bool bfs(int now)
30 | {
31 |     static int i,x,y,z,b;
32 |     for (i=0; i<n; ++i)
33 |         p[i].resize(0);
34 |     p[now].push_back(now);
35 |     memset(vis,-1,sizeof vis);
36 |     vis[now]=0;
37 |     qf=qb=q;
38 |     *qb++=now;
39 |
40 |     while (qf<qb)
41 |         for (x=*qf++; y=0; y<n; ++y)
42 |             if (map[x][y] && m[y]!=y && vis[y]!=1)
43 |             {
44 |                 if (vis[y]==-1)
45 |                     if (m[y]==-1)
46 |                     {
47 |                         for (i=0; i+1<p[x].size(); i+=2)
48 |                         {
49 |                             m[p[x][i]]=p[x][i+1];
50 |                             m[p[x][i+1]]=p[x][i];
51 |                         }
52 |                         m[x]=y;
53 |                         m[y]=x;
54 |                         return true;
55 |                     }
56 |                 else
57 |                 {
58 |                     p[z=m[y]]=p[x];
59 |                     p[z].push_back(y);
60 |                     p[z].push_back(z);
61 |                     vis[y]=1;
62 |                     vis[z]=0;
63 |                     *qb++=z;
64 |                 }
65 |             }
66 |         else
67 |         {
68 |             for (b=0; b<p[x].size() && b<p[y].size() && p
69 |                 [x][b]==p[y][b]; ++b);
70 |             label(x,y,b);
71 |             label(y,x,b);
72 |         }
73 |     }
74 |     return false;
75 | }
76 | int i,j,k;
77 | int ans;
78 |
79 | int main()
80 | {
81 |     scanf("%d",&n);
82 |     for (i=0; i<n; ++i)
83 |         p[i].reserve(n);
84 |     while (scanf("%d_%d",&i,&j)!=EOF)
85 |     {
86 |         --i;
87 |         --j;
88 |         map[i][j]=map[j][i]=true;
89 |     }
90 |     memset(m,-1,sizeof m);
91 |     for (i=0; i<n; ++i)
92 |         if (m[i]==-1)
93 |         {
94 |             if (bfs(i))
95 |                 ++ans;
96 |             else
97 |                 m[i]=i;
98 |         }
99 |     printf("%d\n",ans<<1);
100 |     for (i=0; i<n; ++i)
101 |         if (i<m[i])
102 |             printf("%d_%d\n",i+1,m[i]+1);
103 |     return 0;
104 | }

```

4.7 Bridge

```

1 | void dfs(const short &now,const short &fa)
2 | {
3 |     dfn[now]=low[now]=cnt++;
4 |     for (int i(0); i<edge[now].size(); ++i)
5 |         if (dfn[edge[now][i]]==1)
6 |         {
7 |             dfs(edge[now][i],now);
8 |             low[now]=std::min(low[now],low[edge[now][i]]);
9 |             if (low[edge[now][i]]>dfn[now]) //如果子节点不能够走到
10 |                 父节点之前去, 那么该边为桥
11 |             {
12 |                 if (edge[now][i]<now)

```



```

13         j=edge[now][i];
14         k=now;
15     }
16     else
17     {
18         j=now;
19         k=edge[now][i];
20     }
21     ans.push_back(node(j,k));
22 }
23 }
24 else
25     if(edge[now][i]!=fa)
26         low[now]=std::min(low[now],low[edge[now][i]]);
27 }

```

4.8 Chu-Liu:Edmonds' Algorithm

```

1 #include<cstdio>
2 #include<cstring>
3 #include<vector>
4
5 #define MAXX 1111
6 #define MAXE 10111
7 #define inf 0x3f3f3f3f
8
9 int n,m,i,j,k,ans,u,v,tn,rt,sum,on,om;
10 int pre[MAXX],id[MAXX],in[MAXX],vis[MAXX];
11
12 struct edge
13 {
14     int a,b,c;
15     edge() {}
16     edge(int aa,int bb,int cc):a(aa),b(bb),c(cc) {}
17 };
18 std::vector<edge>ed(MAXE);
19
20 int main()
21 {
22     while(scanf("%d%d",&n,&m)!=EOF)
23     {
24         on=n;
25         om=m;
26         ed.resize(0);
27         sum=1;
28         while(m--)
29         {
30             scanf("%d%d%d",&i,&j,&k);
31             if(i!=j)
32             {
33                 ed.push_back(edge(i,j,k));
34                 sum+=k;
35             }
36         }
37         ans=0;
38         rt=n;
39         for(i=0;i<n;++i)
40             ed.push_back(edge(n,i,sum));
41         ++n;
42         while(true)
43         {
44             memset(in,0x3f,sizeof in);
45             for(i=0;i<ed.size();++i)
46                 if(ed[i].a!=ed[i].b && in[ed[i].b]>ed[i].c)
47                 {
48                     in[ed[i].b]=ed[i].c;
49                     pre[ed[i].b]=ed[i].a;
50                     if(ed[i].a==rt)
51                         j=i;
52                 }
53             for(i=0;i<n;++i)
54                 if(i!=rt && in[i]==inf)
55                     goto ot;
56             memset(id,-1,sizeof id);
57             memset(vis,-1,sizeof vis);
58             tn=in[rt]=0;
59             for(i=0;i<n;++i)
60             {
61                 ans+=in[i];
62                 for(v=i;vis[v]!=i && id[v]==-1 && v!=rt;v=pre[v])
63                     vis[v]=i;
64                 if(v!=rt && id[v]==-1)
65                 {
66                     for(u=pre[v];u!=v;u=pre[u])
67                         id[u]=tn;
68                     id[v]=tn++;
69                 }
70             }
71             if(!tn)
72                 break;
73             for(i=0;i<n;++i)
74                 if(id[i]==-1)
75                     id[i]=tn++;
76             for(i=0;i<ed.size();++i)

```

```

77         {
78             v=ed[i].b;
79             ed[i].a=id[ed[i].a];
80             ed[i].b=id[ed[i].b];
81             if(ed[i].a!=ed[i].b)
82                 ed[i].c-=in[v];
83         }
84         n=tn;
85         rt=id[rt];
86     }
87     if(ans>=2*sum)
88         puts("impossible");
89     else
90         printf("%d%d\n",ans-sum,j-om);
91     puts("");
92 }
93 return 0;
94 }

```

4.9 Count MST

```

1 //hdu 4408
2 #include<cstdio>
3 #include<cstring>
4 #include<algorithm>
5
6 #define MAXX 111
7
8 long long mod;
9 long long a[MAXX][MAXX];
10
11 inline long long det(int n)
12 {
13     static int i,j,k;
14     static long long re,t;
15     for(i=0;i<n;++i)
16         for(j=0;j<n;++j)
17             a[i][j]%=mod;
18     re=1ll;
19     for(i=0;i<n;++i)
20     {
21         for(j=i+1;j<n;++j)
22             while(a[j][i])
23             {
24                 t=a[i][i]/a[j][i];
25                 for(k=i;k<n;++k)
26                     a[i][k]=(a[i][k]-a[j][k]*t)%mod;
27                 for(k=i;k<n;++k)
28                     std::swap(a[i][k],a[j][k]);
29                 re=-re;
30             }
31         if(!a[i][i])
32             return 0ll;
33         re=re*a[i][i]%mod;
34     }
35     return (re+mod)%mod;
36 }
37
38 struct E
39 {
40     int a,b,c;
41     bool operator<(const E &i)const
42     {
43         return c<i.c;
44     }
45 }edge[1111];
46
47 int set[2][MAXX];
48 int find(int a,int t)
49 {
50     return set[t][a]?set[t][a]:find(set[t][a],t):a;
51 }
52
53 int id[MAXX],dg[MAXX];
54 int map[MAXX][MAXX];
55 int n,m,i,j,k;
56 long long ans;
57 int cnt;
58
59 int main()
60 {
61     while(scanf("%d%d%d",&n,&m,&mod),(n||m||mod))
62     {
63         for(i=0;i<m;++i)
64             scanf("%d%d%d",&edge[i].a,&edge[i].b,&edge[i].c);
65         std::sort(edge,edge+m);
66         memset(set[0],0,sizeof set[0]);
67         ans=cnt=1;
68         for(i=0;i<m;i=j)
69         {
70             for(j=i;j<m;++j)
71                 if(edge[i].c!=edge[j].c)
72                     break;
73             memset(dg,0,sizeof dg);
74             memset(map,0,sizeof map);

```

```

75 | memset(set[1],0,sizeof set[0]);
76 | static int t,x,y;
77 | t=0;
78 | for(k=i;k<j;++k)
79 | {
80 |     x=find(edge[k].a,0);
81 |     y=find(edge[k].b,0);
82 |     if(x!=y)
83 |     {
84 |         ++map[x][y];
85 |         ++map[y][x];
86 |         ++dg[x];
87 |         ++dg[y];
88 |         x=find(x,1);
89 |         y=find(y,1);
90 |         if(x!=y)
91 |             set[1][x]=y;
92 |         ++t;
93 |     }
94 | }
95 | for(k=i;k<j;++k)
96 | {
97 |     x=find(edge[k].a,0);
98 |     y=find(edge[k].b,0);
99 |     if(x!=y)
100 |     {
101 |         ++cnt;
102 |         set[0][x]=y;
103 |     }
104 | }
105 | if(t)
106 | {
107 |     for(k=1;k<=n;++k)
108 |         if(dg[k] && find(k,1)==k)
109 |         {
110 |             memset(a,0,sizeof a);
111 |             t=0;
112 |             static int ii,jj;
113 |             for(ii=1;ii<=n;++ii)
114 |                 if(dg[ii] && find(ii,1)==k)
115 |                     id[ii]=t++;
116 |             for(ii=1;ii<=n;++ii)
117 |                 if(dg[ii] && find(ii,1)==k)
118 |                 {
119 |                     a[id[ii]][id[ii]]=dg[ii];
120 |                     for(jj=1;jj<=n;++jj)
121 |                     {
122 |                         if(!dg[jj] || ii==jj ||
123 |                            find(jj,1)!=k)
124 |                             continue;
125 |                         if(map[ii][jj])
126 |                         {
127 |                             static long long cnt;
128 |                             cnt=-map[ii][jj];
129 |                             a[id[ii]][id[jj]]=(cnt%1
130 |                                mod+mod)%mod;
131 |                         }
132 |                     }
133 |                     ans=(ans*det(t-1))%mod;
134 |                 }
135 |             }
136 |             if(cnt!=n)
137 |                 puts("0");
138 |             else
139 |                 printf("%lld\n",(ans%mod+mod)%mod);
140 |         }
141 |     }
142 | return 0;

```

4.10 Covering problems

```

1 | 最大团以及相关知识
2 |
3 | 独立集：独立集是指图的顶点集的一个子集，该子集的导出子图的点互不相邻。如果
4 | 一个独立集不是任何一个独立集的子集，那么称这个独立集是一个极大独立集。
5 | 一个图中包含顶点数目最多的独立集称为最大独立集。最大独立集一定是极大独立
6 | 集，但是极大独立集不一定是最大的独立集。
7 |
8 | 支配集：与独立集相对应的就是支配集，支配集也是图顶点集的一个子集，设  $S$  是图
9 |  $G$  的一个支配集，则对于图中的任意一个顶点  $u$ ，要么属于集合  $S$ ，要么与  $S$ 
10 | 中的顶点相邻。在  $S$  中除去任何元素后  $S$  不再是支配集，则支配集  $S$  是极
11 | 小支配集。称  $G$  的所有支配集中顶点个数最少的支配集为最小支配集，最小支
12 | 配集中的顶点个数成为支配数。
13 |
14 | 最小点（对边）的覆盖：最小点的覆盖也是图的顶点集的一个子集，如果我们选中一
15 | 个点，则称这个点将以他为端点的所有边都覆盖了。将图中所有的边都覆盖所用
16 | 顶点数最少，这个集合就是最小的点的覆盖。
17 |
18 | 最大团：图  $G$  的顶点的子集，设  $D$  是最大团，则  $D$  中任意两点相邻。若  $u, v$  是
19 |  $G$  的一个极大团，则  $u, v$  有边相连，其补图  $u, v$  没有边相连，所以图  $G$  的最大团
20 | 等于其补图的最大独立集。给定无向图  $G = (V, E)$ ，如果  $U$  属于  $V$ ，并且对于任
21 | 意  $u, v$  包含于  $U$  有  $\langle u, v \rangle$  包含于  $E$ ，则称  $U$  是  $G$  的完全子图， $G$ 

```

的完全子图 U 是 G 的团，当且仅当 U 不包含在 G 的更大的完全子图中， G 的最大团是指 G 中所含顶点数目最多的团。如果 U 属于 V ，并且对于任意 u, v 包含于 U 有 $\langle u, v \rangle$ 包含于 E ，则称 U 是 G 的空子图， G 的空子图 U 是 G 的独立集，当且仅当 U 不包含在 G 的更大的独立集， G 的最大团是指 G 中所含顶点数目最多的独立集。

```

10 |
11 | 性质：
12 | 最大独立集 + 最小覆盖集 =  $V$ 
13 | 最大团 = 补图的最大独立集
14 | 最小覆盖集 = 最大匹配
15 |
16 | minimum cover:
17 | vertex cover vertex bipartite graph = maximum cardinality
18 | bipartite matching
19 | 找完最大二分匹配後，有三種情况要分別處理：
20 | 甲、 $X$  側未匹配點的交錯樹們。
21 | 乙、 $Y$  側未匹配點的交錯樹們。
22 | 丙、層層疊疊的交錯環們（包含單獨的匹配邊）。
23 | 這三個情况互不干涉。用 Graph Traversal 建立甲、乙的交錯樹們，剩下部分就
24 | 是丙。
25 | 要找點覆蓋，甲、乙是取盡奇數距離的點，丙是取盡偶數距離的點、或者是取盡奇數距
26 | 離的點，每塊連通分量可以各自為政。另外，小心處理的話，是可以印出字典順
27 | 序最小的點覆蓋的。
28 | 已經有最大匹配時，求點覆蓋的時間複雜度等同於一次 Graph Traversal 的時間。
29 |
30 | vertex cover edge
31 | edge cover vertex
32 | 首先在圖上求得一個 Maximum Matching 之後，對於那些單身的點，都由匹配點連
33 | 過去。如此便形成了 Minimum Edge Cover。
34 |
35 | edge cover edge
36 | path cover vertex
37 | general graph: NP-H
38 | tree: DP
39 | DAG: 将每个节点拆分为入点和出点, ans = 节点数 - 匹配数
40 |
41 | path cover edge
42 | minimize the count of euler path ( greedy is ok? )
43 | dg[i] 表示每个点的 id-od, ans =  $\sum dg[i], \forall dg[i] > 0$ 
44 |
45 | cycle cover vertex
46 | general: NP-H
47 | weighted: do like path cover vertex, with KM algorithm
48 |
49 | cycle cover edge
50 | NP-H

```

4.11 difference constraints

```

1 | for a - b <= c
2 |     add(b,a,c);
3 |
4 | 最短路得最远解
5 | 最长路得最近解
6 | //根据情况反转边?(反转方向及边权)
7 |
8 | 全 0 点得普通解

```

4.12 Dinitz's algorithm

```

1 | #include<cstdio>
2 | #include<algorithm>
3 | #include<cstring>
4 |
5 | #define MAXX 111
6 | #define MAXM (MAXX*MAXX*4)
7 | #define inf 0x3f3f3f3f
8 |
9 | int n;
10 | int w[MAXX],h[MAXX],q[MAXX];
11 | int edge[MAXX],to[MAXM],cap[MAXM],nxt[MAXM],cnt;
12 | int source,sink;
13 |
14 | inline void add(int a,int b,int c)
15 | {
16 |     nxt[cnt]=edge[a];
17 |     edge[a]=cnt;
18 |     to[cnt]=b;
19 |     cap[cnt]=c;
20 |     ++cnt;
21 | }
22 |
23 | inline bool bfs()
24 | {
25 |     static int *qf,*qb;
26 |     static int i;
27 |     memset(h,-1,sizeof h);
28 |     qf=qb=q;
29 |     h[*qb++]=source=0;
30 |     for(;qf!=qb;++qf)

```

```

31     for(i=edge[*qf];i!=-1;i=nxt[i])
32         if(cap[i] && h[to[i]]!=-1)
33             h[*qb++=to[i]]=h[*qf]+1;
34     return h[sink]!=-1;
35 }
36
37 int dfs(int now,int maxcap)
38 {
39     if(now==sink)
40         return maxcap;
41     flow(maxcap),d;
42     for(int &i(w[now]);i!=-1;i=nxt[i])
43         if(cap[i] && h[to[i]]==h[now]+1) // && (flow=dfs(to[i],
44             std::min(maxcap,cap[i])))
45         {
46             d=dfs(to[i],std::min(flow,cap[i]));
47             cap[i]-=d;
48             cap[i^1]+=d;
49             flow-=d;
50             if(!flow)
51                 return maxcap;
52         }
53     return maxcap-flow;
54 }
55
56 int nc,np,m,i,j,k;
57 int ans;
58
59 int main()
60 {
61     while(scanf("%d%d%d",&n,&np,&nc,&m)!=EOF)
62     {
63         cnt=0;
64         memset(edge,-1,sizeof edge);
65         while(m--)
66         {
67             while(getchar()!='(');
68             scanf("%d",&i);
69             while(getchar()!='(');
70             scanf("%d",&j);
71             while(getchar()!='(');
72             scanf("%d",&k);
73             if(i!=j)
74             {
75                 ++i;
76                 ++j;
77                 add(i,j,k);
78                 add(j,i,0);
79             }
80             source++;
81             while(np--)
82             {
83                 while(getchar()!='(');
84                 scanf("%d",&i);
85                 while(getchar()!='(');
86                 scanf("%d",&j);
87                 ++i;
88                 add(source,i,j);
89                 add(i,source,0);
90             }
91             sink++;
92             while(nc--)
93             {
94                 while(getchar()!='(');
95                 scanf("%d",&i);
96                 while(getchar()!='(');
97                 scanf("%d",&j);
98                 ++i;
99                 add(i,sink,j);
100                add(sink,i,0);
101            }
102            ans=0;
103            while(bfs())
104            {
105                memcpy(w,edge,sizeof edge);
106                ans+=dfs(source,inf);
107                /*
108                while((k=dfs(source,inf)))
109                    ans+=k;
110                */
111            }
112            printf("%d\n",ans);
113        }
114        return 0;
115    }

```

4.13 Flow network

```

1 Maximum weighted closure of a graph:
2
3 所有由这个子图中的点出发的边都指向这个子图，那么这个子图为原图的一个
  closure（闭合子图）
4
5 每个节点向其所有依赖节点连边，容量 inf

```

```

6 源点向所有正权值节点连边，容量为该权值
7 所有负权值节点向汇点连边，容量为该权值绝对值
8 以上均为有向边
9 最大权为 sum{正权值}-{新图的最小割}
10 残量图中所有由源点可达的点即为所选子图
11
12
13 Eulerian circuit:
14 计入度和出度之差
15 无向边任意定向
16 出入度之差为奇数则无解
17 然后构图:
18 原图有向边不变，容量 1 // 好像需要在新图中忽略有向边?
19 无向边按之前认定方向，容量 1
20 源点向所有度数为正的点连边，容量 abs(度数/2)
21 所有度数为负的点向汇点连边，容量 abs(度数/2)
22 两侧均满流则有解
23 相当于规约为可行流问题
24 注意连通性的 trick
25
26
27 终点到起点加一条有向边即可将 path 问题转为 circuit 问题
28
29
30 Feasible flow problem:
31 由超级源点出发的边全部满流则有解
32 有源汇时，由汇点向源点连边，下界 0 上界 inf 即可转化为无源无汇上下界流
33
34 对于每条边 <a->b cap[u,d]>, 建边 <ss->b cap(u)>、<a->st cap(u)>、
35     <a->b cap(d-u)>
36
37 Maximum flow: //好像也可以二分
38 //将流量还原至原图后，在残量网络上继续完成最大流
39 直接把 source 和 sink 设为原来的 st，此时输出的最大流即是答案
40 不需要删除或者调整 t->s 弧
41 Minimum flow: //好像也可以二分
42 建图时先不连汇点到源点的边，新图中完成最大流之后再连原汇至原源的边完成第二
43     次最大流，此时 t->s 这条弧的流量即为最小流
44 判断可行流存在还是必须连原汇 -> 原源的边之后查看满流
45 tips:
46 合并流量、减少边数来加速
47
48
49 Minimum cost feasible flow problem:
50 TODO
51 看起来像是在上面那样跑费用流就行了……
52
53
54 Minimum weighted vertex cover edge for bipartite graph:
55 for all vertex in X:
56     edge < s->x cap(weight(x)) >
57 for all vertex in Y:
58     edge < y->t cap(weight(y)) >
59 for original edges
60     edge < x->y cap(inf) >
61
62 ans={maximum flow}={minimum cut}
63
64 残量网络中的所有简单割 ( (源点可达 && 汇点不可达) || (源点不可达 && 汇点
65     可达) ) 对应着解
66
67
68
69 Maximum weighted vertex independent set for bipartite graph:
70 ans=Sum 点权 -valueMinimum weighted vertex cover edge
71 解应该就是最小覆盖集的补图吧……
72
73
74 方格取数: // refer: hdu 3820 golden eggs
75 取方格获得收益
76 当取了相邻方格时付出边的代价
77
78
79 必取的方格到源/汇的边的容量 inf
80 相邻方格之间的边的容量为 {代价}*2
81 ans=sum{方格收益}-{最大流}
82
83
84
85 最小割的唯一性: // refer: 关键边。有向边起点为 s 集，终点为 t 集
86 从源和汇分别能够到的点集是所有点时，最小割唯一
87 也就是每一条增广路径都仅有一条边满流
88 注意查看的是实际的网络，不是残量网络
89
90 具体来说
91

```

```

92 void rr(int now)
93 {
94     done[now]=true;
95     ++cnt;
96     for(int i=edge[now];i!=-1;i=nxt[i])
97         if(cap[i] && !done[v])
98             rr(v);
99 }
100
101 void dfs(int now)
102 {
103     done[now]=true;
104     ++cnt;
105     for(int i=edge[now];i!=-1;i=nxt[i])
106         if(cap[i^1] && !done[v])
107             dfs(v);
108 }
109
110 memset(done,0,sizeof done);
111 cnt=0;
112 rr(source);
113 dfs(sink);
114 puts(cnt==n?"UNIQUE":"AMBIGUOUS");
115
116
117 Tips:
118 两点间可以不止有一种边，也可以不止有一条边，无论有向无向；
119 两点间容量 inf 则可以设法化简为一个点；
120 点权始终要转化为边权；
121 不参与决策的边权设为 inf 来排除掉；
122 贪心一个初始不合法情况，然后通过可行流调整； // refer: 混合图欧拉回路存在
123 性、有向/无向图中国邮差问题（遍历所有边至少一次后回到原点）
124 按时间拆点（时间层……？）；

```

4.14 Hamiltonian circuit

```

1 //if every point connect with not less than [(N+1)/2] points
2 #include<stdio>
3 #include<algorithm>
4 #include<cstring>
5
6 #define MAXX 177
7 #define MAX (MAXX*MAXX)
8
9 int edge[MAXX],nxt[MAX],to[MAX],cnt;
10
11 inline void add(int a,int b)
12 {
13     nxt[++cnt]=edge[a];
14     edge[a]=cnt;
15     to[cnt]=b;
16 }
17
18 bool done[MAXX];
19 int n,m,i,j,k;
20
21 inline int find(int a)
22 {
23     static int i;
24     for(i=edge[a];i!=nxt[i])
25         if(!done[to[i]])
26         {
27             edge[a]=nxt[i];
28             return to[i];
29         }
30     return 0;
31 }
32
33 int a,b;
34 int next[MAXX],pre[MAXX];
35 bool mat[MAXX][MAXX];
36
37 int main()
38 {
39     while(scanf("%d%d",&n,&m)!=EOF)
40     {
41         for(i=1;i<=n;++i)
42             next[i]=done[i]=edge[i]=0;
43         memset(mat,0,sizeof mat);
44         cnt=0;
45         while(m--)
46         {
47             scanf("%d%d",&i,&j);
48             add(i,j);
49             add(j,i);
50             mat[i][j]=mat[j][i]=true;
51         }
52         a=1;
53         b=to[edge[a]];
54         cnt=2;
55         done[a]=done[b]=true;
56         next[a]=b;
57         while(cnt<n)

```

```

58     {
59         while(i=find(a))
60         {
61             next[i]=a;
62             done[a=i]=true;
63             ++cnt;
64         }
65         while(i=find(b))
66         {
67             next[b]=i;
68             done[b=i]=true;
69             ++cnt;
70         }
71         if(!mat[a][b])
72             for(i=next[a];next[i]!=b;i=next[i])
73                 if(mat[a][next[i]] && mat[i][b])
74                 {
75                     for(j=next[i];j!=b;j=next[j])
76                         pre[next[j]]=j;
77                     for(j=b;j!=next[i];j=pre[j])
78                         next[j]=pre[j];
79                     std::swap(next[i],b);
80                     break;
81                 }
82         next[b]=a;
83         for(i=a;i!=b;i=next[i])
84             if(find(i))
85             {
86                 a=next[b=i];
87                 break;
88             }
89     }
90     while(a!=b)
91     {
92         printf("%d_",a);
93         a=next[a];
94     }
95     printf("%d\n",b);
96 }
97 return 0;
98 }

```

4.15 Hopcroft-Karp algorithm

```

1 #include<stdio>
2 #include<string>
3
4 #define MAXX 50111
5 #define MAX 150111
6
7 int nx,p;
8 int i,j,k;
9 int x,y;
10 int ans;
11 bool flag;
12
13 int edge[MAXX],nxt[MAX],to[MAX],cnt;
14
15 int cx[MAXX],cy[MAXX];
16 int px[MAXX],py[MAXX];
17
18 int q[MAXX],*qf,*qb;
19
20 bool ag(int i)
21 {
22     int j,k;
23     for(k=edge[i];k!=nxt[k])
24         if(py[j=to[k]]!=px[i]+1)
25         {
26             py[j]=0;
27             if(cy[j]==-1 || ag(cy[j]))
28             {
29                 cx[i]=j;
30                 cy[j]=i;
31                 return true;
32             }
33         }
34     return false;
35 }
36
37 int main()
38 {
39     scanf("%d%d",&nx,&p);
40     while(p--)
41     {
42         scanf("%d",&i,&j);
43         nxt[++cnt]=edge[i];
44         edge[i]=cnt;
45         to[cnt]=j;
46     }
47     memset(cx,-1,sizeof cx);
48     memset(cy,-1,sizeof cy);
49     while(true)
50     {
51         memset(px,0,sizeof(px));

```

```

52     memset(py,0,sizeof(py));
53     qf=qb=q;
54     flag=false;
55
56     for(i=1;i<=nx;++i)
57         if(cx[i]==-1)
58             *qb++=i;
59     while(qf!=qb)
60         for(k=edge[i=*qf++];k=nxt[k])
61             if(!py[j=to[k]])
62                 {
63                     py[j]=px[i]+1;
64                     if(cy[j]==-1)
65                         flag=true;
66                     else
67                         {
68                             px[cy[j]]=py[j]+1;
69                             *qb++=cy[j];
70                         }
71                 }
72     if(!flag)
73         break;
74     for(i=1;i<=nx;++i)
75         if(cx[i]==-1 && ag(i))
76             ++ans;
77 }
78 printf("%d\n",ans);
79 return 0;
80 }

```

4.16 Improved Shortest Augmenting Path Algorithm

```

1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4
5  #define MAXX 5111
6  #define MAXM (30111*4)
7  #define inf 0x3f3f3f3f3f3f3f3f
8
9  int edge[MAXX],to[MAXM],nxt[MAXM],cnt;
10 #define v to[i]
11 long long cap[MAXM];
12
13 int n;
14 int h[MAXX],gap[MAXX],pre[MAXX],w[MAXX];
15
16 inline void add(int a,int b,long long c)
17 {
18     nxt[++cnt]=edge[a];
19     edge[a]=cnt;
20     to[cnt]=b;
21     cap[cnt]=c;
22 }
23
24 int source,sink;
25
26 inline long long go(const int N=sink)
27 {
28     static int now,i;
29     static long long min,mf;
30     memset(gap,0,sizeof gap);
31     memset(h,0,sizeof h);
32     memcpy(w,edge,sizeof w);
33     gap[0]=N;
34     mf=0;
35
36     pre[now=source]=-1;
37     while(h[source]<N)
38     {
39 rep:
40         if(now==sink)
41         {
42             min=inf;
43             for(i=pre[sink];i!=-1;i=pre[to[i^1]])
44                 if(min>cap[i])
45                 {
46                     min=cap[i];
47                     now=to[i^1];
48                 }
49             for(i=pre[sink];i!=-1;i=pre[to[i^1]])
50             {
51                 cap[i]-=min;
52                 cap[i^1]+=min;
53             }
54             mf+=min;
55         }
56         for(int &i(w[now]);i!=-1;i=nxt[i])
57             if(cap[i] && h[v]+1==h[now])
58             {
59                 pre[now=v]=i;
60                 goto rep;
61             }
62         if(!--gap[h[now]])

```

```

63         return mf;
64         min=N;
65         for(i=w[now]=edge[now];i!=-1;i=nxt[i])
66             if(cap[i])
67                 min=std::min(min,(long long)h[v]);
68         ++gap[h[now]=min+1];
69         if(now!=source)
70             now=to[pre[now]^1];
71     }
72     return mf;
73 }
74
75 int m,i,j,k;
76 long long ans;
77
78 int main()
79 {
80     scanf("%d%d",&n,&m);
81     source=1;
82     sink=n;
83     cnt=-1;
84     memset(edge,-1,sizeof edge);
85     while(m--)
86     {
87         scanf("%d%d%lld",&i,&j,&ans);
88         add(i,j,ans);
89         add(j,i,ans);
90     }
91     printf("%lld\n",go());
92     return 0;
93 }

```

4.17 k Shortest Path

```

1  #include<cstdio>
2  #include<cstring>
3  #include<queue>
4  #include<vector>
5
6  int K;
7
8  class states
9  {
10 public:
11     int cost,id;
12 };
13
14 int dist[1000];
15
16 class cmp
17 {
18 public:
19     bool operator()(const states &i,const states &j)
20     {
21         return i.cost>j.cost;
22     }
23 };
24
25 class cmp2
26 {
27 public:
28     bool operator()(const states &i,const states &j)
29     {
30         return i.cost+dist[i.id]>j.cost+dist[j.id];
31     }
32 };
33
34 struct edges
35 {
36     int to,next,cost;
37 } edger[100000],edge[100000];
38
39 int headr[1000],head[1000],Lr,L;
40
41 void dijkstra(int s)
42 {
43     states u;
44     u.id=s;
45     u.cost=0;
46     dist[s]=0;
47     std::priority_queue<states,std::vector<states>,cmp> q;
48     q.push(u);
49     while(!q.empty())
50     {
51         u=q.top();
52         q.pop();
53         if(u.cost!=dist[u.id])
54             continue;
55         for(int i=headr[u.id];i!=-1;i=edge[i].next)
56         {
57             states v=u;
58             v.id=edge[i].to;
59             if(dist[v.id]>dist[u.id]+edge[i].cost)
60             {
61                 v.cost=dist[v.id]=dist[u.id]+edge[i].cost;

```

```

62         q.push(v);
63     }
64 }
65 }
66 }
67
68 int num[1000];
69
70 inline void init(int n)
71 {
72     Lr=L=0;
73     memset(head,-1,4*n);
74     memset(headr,-1,4*n);
75     memset(dist,63,4*n);
76     memset(num,0,4*n);
77 }
78
79 void add_edge(int u,int v,int x)
80 {
81     edge[L].to=v;
82     edge[L].cost=x;
83     edge[L].next=head[u];
84     head[u]=L++;
85     edger[Lr].to=u;
86     edger[Lr].cost=x;
87     edger[Lr].next=headr[v];
88     headr[v]=Lr++;
89 }
90
91 inline int a_star(int s,int t)
92 {
93     if (dist[s]==0x3f3f3f3f)
94         return -1;
95     std::priority_queue<states,std::vector<states>,cmp2> q;
96     states tmp;
97     tmp.id=s;
98     tmp.cost=0;
99     q.push(tmp);
100     while (!q.empty())
101     {
102         states u=q.top();
103         q.pop();
104         num[u.id]++;
105         if (num[t]==K)
106             return u.cost;
107         for (int i=head[u.id]; i!=-1; i=edge[i].next)
108         {
109             int v=edge[i].to;
110             tmp.id=v;
111             tmp.cost=u.cost+edge[i].cost;
112             q.push(tmp);
113         }
114     }
115     return -1;
116 }
117
118 int main()
119 {
120     int n,m;
121     scanf("%d",&n,&m);
122     init(n);
123     for (int i=0; i<m; i++)
124     {
125         int u,v,x;
126         scanf("%d%d%d",&u,&v,&x);
127         add_edge(u-1,v-1,x);
128     }
129     int s,t;
130     scanf("%d%d",&s,&t,&K);
131     if (s==t)
132         ++K;
133     dijkstra(t-1);
134     printf("%d\n",a_star(s-1,t-1));
135     return 0;
136 }

```

4.18 Kariv-Hakimi Algorithm

```

1 //Absolute Center of a graph, not only a tree
2 #include<cstdio>
3 #include<algorithm>
4 #include<vector>
5 #include<cstring>
6 #include<set>
7
8 #define MAXX 211
9 #define inf 0x3f3f3f3f
10
11 int e[MAXX][MAXX],dist[MAXX][MAXX];
12 double dp[MAXX],ta;
13 int ans,d;
14 int n,m,a,b;
15 int i,j,k;
16 typedef std::pair<int,int> pii;
17 std::vector<pii>vt[2];

```

```

18 bool done[MAXX];
19 typedef std::pair<double,int> pdi;
20 std::multiset<pdi>q;
21 int pre[MAXX];
22
23 int main()
24 {
25     vt[0].reserve(MAXX);
26     vt[1].reserve(MAXX);
27     scanf("%d",&n,&m);
28     memset(e,0x3f,sizeof(e));
29     while(m--)
30     {
31         scanf("%d%d",&i,&j,&k);
32         e[i][j]=e[j][i]=std::min(e[i][j],k);
33     }
34     for(i=1;i<=n;++i)
35         e[i][i]=0;
36     memcpy(dist,e,sizeof(dist));
37     for(k=1;k<=n;++k)
38         for(i=1;i<=n;++i)
39             for(j=1;j<=n;++j)
40                 dist[i][j]=std::min(dist[i][j],dist[i][k]+dist[k][j]);
41
42     ans=inf;
43     for(i=1;i<=n;++i)
44         for(j=i;j<=n;++j)
45             if(e[i][j]!=inf)
46             {
47                 vt[0].resize(0);
48                 vt[1].resize(0);
49                 static int i;
50                 for(i=1;i<=n;++i)
51                     vt[0].push_back(pii(dist[i][i],dist[j][i]));
52                 std::sort(vt[0].begin(),vt[0].end());
53                 for(i=0;i<vt[0].size();++i)
54                 {
55                     while(!vt[1].empty() && vt[1].back().second
56                         <=vt[0][i].second)
57                         vt[1].pop_back();
58                     vt[1].push_back(vt[0][i]);
59                 }
60                 d=inf;
61                 if(vt[1].size()==1)
62                     if(vt[1][0].first<vt[1][0].second)
63                     {
64                         ta=0;
65                         d=(vt[1][0].first<<1);
66                     }
67                 else
68                 {
69                     ta=e[i][j];
70                     d=(vt[1][0].second<<1);
71                 }
72             }
73         else
74         for(i=1;i<vt[1].size();++i)
75             if(d>e[i][j]+vt[1][i-1].first+vt[1][i].second)
76             {
77                 ta=(e[i][j]+vt[1][i].second-vt[1][i-1].first)/(double)2.0f;
78                 d=e[i][j]+vt[1][i-1].first+vt[1][i].second;
79             }
80         if(d<ans)
81         {
82             ans=d;
83             a=i;
84             b=j;
85             dp[i]=ta;
86             dp[j]=e[i][j]-ta;
87         }
88     }
89     printf("%d\n",ans);
90     for(i=1;i<=n;++i)
91         if(i!=a && i!=b)
92             dp[i]=1e20;
93     q.insert(pdi(dp[a],a));
94     if(a!=b)
95         q.insert(pdi(dp[b],b));
96     if(a!=b)
97         pre[b]=a;
98     while(!q.empty())
99     {
100         k=q.begin()->second;
101         q.erase(q.begin());
102         if(done[k])
103             continue;
104         done[k]=true;
105         for(i=1;i<=n;++i)
106             if(e[k][i]!=inf && dp[k]+e[k][i]<dp[i])
107             {
108                 dp[i]=dp[k]+e[k][i];
109                 q.insert(pdi(dp[i],i));
110                 pre[i]=k;
111             }

```

```

108     }
109 }
110 vt[0].resize(0);
111 for(i=1;i<=n;++i)
112     if(pre[i])
113         if(i<pre[i])
114             printf("%d_%d\n",i,pre[i]);
115         else
116             printf("%d_%d\n",pre[i],i);
117 return 0;
118 }

```

4.19 Kuhn-Munkres algorithm

```

1 bool match(int u)//匈牙利
2 {
3     vx[u]=true;
4     for(int i=1;i<=n;++i)
5         if(lx[u]+ly[i]==g[u][i]&&!vy[i])
6         {
7             vy[i]=true;
8             if(!d[i]||match(d[i]))
9             {
10                 d[i]=u;
11                 return true;
12             }
13         }
14     return false;
15 }
16 inline void update()//
17 {
18     int i,j;
19     int a=1<<30;
20     for(i=1;i<=n;++i)if(vx[i])
21         for(j=1;j<=n;++j)if(!vy[j])
22             a=min(a,lx[i]+ly[j]-g[i][j]);
23     for(i=1;i<=n;++i)
24     {
25         if(vx[i])lx[i]-=a;
26         if(vy[i])ly[i]+=a;
27     }
28 }
29 void km()
30 {
31     int i,j;
32     for(i=1;i<=n;++i)
33     {
34         lx[i]=ly[i]=d[i]=0;
35         for(j=1;j<=n;++j)
36             lx[i]=max(lx[i],g[i][j]);
37     }
38     for(i=1;i<=n;++i)
39     {
40         while(true)
41         {
42             memset(vx,0,sizeof(vx));
43             memset(vy,0,sizeof(vy));
44             if(match(i))
45                 break;
46             update();
47         }
48     }
49     int ans=0;
50     for(i=1;i<=n;++i)
51         if(d[i]!=0)
52             ans+=g[d[i]][i];
53     printf("%d\n",ans);
54 }
55 int main()
56 {
57     while(scanf("%d\n",&n)!=EOF)
58     {
59         for(int i=1;i<=n;++i)gets(s[i]);
60         memset(g,0,sizeof(g));
61         for(int i=1;i<=n;++i)
62             for(int j=1;j<=n;++j)
63                 if(i!=j) g[i][j]=cal(s[i],s[j]);
64         km();
65     }
66     return 0;
67 }
68 //bupt
69 //算法：求二分图最佳匹配km n复杂度^3
70 //dfs(int u)//匈牙利求增广路
71 {
72     int v;
73     sx[u]=1;
74     for (v=1; v<=n; v++)
75         if (!sy[v] && lx[u]+ly[v]==map[u][v])
76         {
77             sy[v]=1;
78             if (match[v]==-1 || dfs(match[v]))

```

```

82     {
83         match[v]=u;
84         return 1;
85     }
86 }
87 return 0;
88 }
89
90 int bestmatch(void)//求最佳匹配km
91 {
92     int i,j,u;
93     for (i=1; i<=n; i++)//初始化顶标
94     {
95         lx[i]=-1;
96         ly[i]=0;
97         for (j=1; j<=n; j++)
98             if (lx[i]<map[i][j])
99                 lx[i]=map[i][j];
100     }
101     memset(match,-1,sizeof(match));
102     for (u=1; u<=n; u++)
103     {
104         while (true)
105         {
106             memset(sx,0,sizeof(sx));
107             memset(sy,0,sizeof(sy));
108             if (dfs(u))
109                 break;
110             int dx=Inf;//若找不到增广路，则修改顶标~~
111             for (i=1; i<=n; i++)
112             {
113                 if (sx[i])
114                     for (j=1; j<=n; j++)
115                         if(!sy[j] && dx>lx[i]+ly[j]-map[i][j])
116                             dx=lx[i]+ly[j]-map[i][j];
117             }
118             for (i=1; i<=n; i++)
119             {
120                 if (sx[i])
121                     lx[i]-=dx;
122                 if (sy[i])
123                     ly[i]+=dx;
124             }
125         }
126     }
127     int sum=0;
128     for (i=1; i<=n; i++)
129         sum+=map[match[i]][i];
130     return sum;
131 }

```

4.20 LCA - DA

```

1 int edge[MAXX],nxt[MAXX<<1],to[MAXX<<1],cnt;
2 int pre[MAXX][N],dg[MAXX];
3
4 inline void add(int j,int k)
5 {
6     nxt[++cnt]=edge[j];
7     edge[j]=cnt;
8     to[cnt]=k;
9 }
10
11 void rr(int now,int fa)
12 {
13     dg[now]=dg[fa]+1;
14     for(int i=edge[now];i;i=nxt[i])
15         if(to[i]!=fa)
16         {
17             static int j;
18             j=1;
19             for(pre[to[i]][0]=now;j<N;++j)
20                 pre[to[i]][j]=pre[pre[to[i]][j-1]][j-1];
21             rr(to[i],now);
22         }
23 }
24
25 inline int lca(int a,int b)
26 {
27     static int i,j;
28     j=0;
29     if(dg[a]<dg[b])
30         std::swap(a,b);
31     for(i=dg[a]-dg[b];i>=1;++j)
32         if(i&1)
33             a=pre[a][j];
34     if(a==b)
35         return a;
36     for(i=N-1;i>=0;--i)
37         if(pre[a][i]!=pre[b][i])
38         {
39             a=pre[a][i];
40             b=pre[b][i];
41         }
42     return pre[a][0];

```

```

43 // looks like above is a wrong version
44
45 static int i, log;
46 for(log=0; (1<<(log+1))<=dg[a]; ++log);
47 for(i=log; i>=0; --i)
48     if(dg[a]-(1<<i)>=dg[b])
49         a=pre[a][i];
50 if(a==b)
51     return a;
52 for(i=log; i>=0; --i)
53     if(pre[a][i]!=-1 && pre[a][i]!=pre[b][i])
54         a=pre[a][i], b=pre[b][i];
55 return pre[a][0];
56 }
57 }

```

4.21 LCA - tarjan - minmax

```

1 #include<cstdio>
2 #include<list>
3 #include<algorithm>
4 #include<cstring>
5
6 #define MAXX 100111
7 #define inf 0x5fffffff
8
9 short T, t;
10 int set[MAXX], min[MAXX], max[MAXX], ans[2][MAXX];
11 bool done[MAXX];
12 std::list<std::pair<int, int>> edge[MAXX];
13 std::list<std::pair<int, int>> q[MAXX];
14 int n, i, j, k, l, m;
15
16 struct node
17 {
18     int a, b, id;
19     node() {}
20     node(const int &aa, const int &bb, const int &idd): a(aa), b(bb), id(idd) {}
21 };
22
23 std::list<node> to[MAXX];
24
25 int find(const int &a)
26 {
27     if(set[a]==a)
28         return a;
29     int b(set[a]);
30     set[a]=find(set[a]);
31     max[a]=std::max(max[a], max[b]);
32     min[a]=std::min(min[a], min[b]);
33     return set[a];
34 }
35
36 void tarjan(const int &now)
37 {
38     done[now]=true;
39     for(std::list<std::pair<int, int>>::const_iterator it(q[now].begin()); it!=q[now].end(); ++it)
40         if(done[it->first])
41             if(it->second>0)
42                 to[find(it->first)].push_back(node(now, it->second, it->second));
43             else
44                 to[find(it->first)].push_back(node(it->first, now, -it->second));
45     for(std::list<std::pair<int, int>>::const_iterator it(edge[now].begin()); it!=edge[now].end(); ++it)
46         if(!done[it->first])
47         {
48             tarjan(it->first);
49             set[it->first]=now;
50             min[it->first]=it->second;
51             max[it->first]=it->second;
52         }
53     for(std::list<node>::const_iterator it(to[now].begin()); it!=to[now].end(); ++it)
54     {
55         find(it->a);
56         find(it->b);
57         ans[0][it->id]=std::min(min[it->b], min[it->a]);
58         ans[1][it->id]=std::max(max[it->a], max[it->b]);
59     }
60 }
61
62 int main()
63 {
64     scanf("%hd", &T);
65     for(t=1; t<=T; ++t)
66     {
67         scanf("%d", &n);
68         for(i=1; i<=n; ++i)
69         {
70             edge[i].clear();
71             q[i].clear();

```

```

72             to[i].clear();
73             done[i]=false;
74             set[i]=i;
75             min[i]=inf;
76             max[i]=0;
77         }
78         for(i=1; i<=n; ++i)
79         {
80             scanf("%d%d", &j, &k, &l);
81             edge[j].push_back(std::make_pair(k, l));
82             edge[k].push_back(std::make_pair(j, l));
83         }
84         scanf("%d", &m);
85         for(i=0; i<=m; ++i)
86         {
87             scanf("%d%d", &j, &k);
88             q[j].push_back(std::make_pair(k, i));
89             q[k].push_back(std::make_pair(j, i));
90         }
91         tarjan(1);
92         printf("Case_%hd:\n", t);
93         for(i=0; i<=m; ++i)
94             printf("%d_%d\n", ans[0][i], ans[1][i]);
95     }
96     return 0;
97 }

```

4.22 Minimum Ratio Spanning Tree

```

1 #include<cstdio>
2 #include<cstring>
3 #include<cmath>
4
5 #define MAXX 1111
6
7 struct
8 {
9     int x, y;
10     double z;
11 } node[MAXX];
12
13 struct
14 {
15     double l, c;
16 } map[MAXX][MAXX];
17
18 int n, l, f[MAXX], pre[MAXX];
19 double dis[MAXX];
20
21 double mst(double x)
22 {
23     int i, j, tmp;
24     double min, s=0, t=0;
25     memset(f, 0, sizeof(f));
26     f[1]=1;
27     for (i=2; i<=n; i++)
28     {
29         dis[i]=map[1][i].c-map[1][i].l*x;
30         pre[i]=1;
31     }
32     for (i=1; i<=n; i++)
33     {
34         min=1e10;
35         for (j=1; j<=n; j++)
36             if (!f[j] && min>dis[j])
37             {
38                 min=dis[j];
39                 tmp=j;
40             }
41         f[tmp]=1;
42         t+=map[pre[tmp]][tmp].l;
43         s+=map[pre[tmp]][tmp].c;
44         for (j=1; j<=n; j++)
45             if (!f[j] && map[tmp][j].c-map[tmp][j].l*x<dis[j])
46             {
47                 dis[j]=map[tmp][j].c-map[tmp][j].l*x;
48                 pre[j]=tmp;
49             }
50     }
51     return s/t;
52 }
53
54 int main()
55 {
56     int i, j;
57     double a, b;
58     while (scanf("%d", &n), n)
59     {
60         for (i=1; i<=n; i++)
61             scanf("%d%d%lf", &node[i].x, &node[i].y, &node[i].z);
62         for (i=1; i<=n; i++)
63             for (j=i+1; j<=n; j++)
64             {
65                 map[j][i].l=map[i][j].l=sqrt(1.0*(node[i].x-

```



```

66         y=node[j].y)*(node[i].y-node[j].y)); 78
        map[j][i].c=map[i][j].c=fabs(node[i].z-node[j].z); 79
    } 80
    a=0,b=mst(a); 81
    while (fabs(b-a)>1e-8) 82
    { 83
        a=b; 84
        b=mst(a); 85
    } 86
    printf("%.3lf\n",b); 87
} 88
return 0; 89
} 90
} 91
} 92
} 93
} 94
} 95
} 96
} 97
} 98
} 99
} 100
} 101
} 102
} 103
} 104
} 105
} 106
} 107
} 108
} 109
} 110
} 111
} 112
} 113
} 114
} 115
} 116
} 117
} 118
} 119
} 120
} 121
} 122
} 123
} 124
} 125
} 126
} 127
} 128
} 129
} 130
} 131
} 132
} 133
} 134
} 135
} 136
} 137
} 138
} 139
} 140
} 141
} 142
} 143
} 144
} 145
} 146
} 147
} 148
} 149
} 150
} 151
} 152
} 153
} 154
} 155
} 156

```

4.23 Minimum Steiner Tree

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 #include<queue>
5
6 #define MAXX 211
7 #define MAXE 10111
8 #define inf 0x3f3f3f3f
9
10 int edge[MAXX],nxt[MAXE],to[MAXE],wg[MAXE],cnt;
11 inline void add(int a,int b,int c)
12 {
13     nxt[++cnt]=edge[a];
14     edge[a]=cnt;
15     to[cnt]=b;
16     wg[cnt]=c;
17 }
18
19 int dp[1<<8];
20 int s[MAXX];
21 int d[1<<8][MAXX];
22 int S[MAXX],P[MAXX];
23 int fac[8];
24
25 struct node
26 {
27     int a,b,dist;
28     node(){}
29     node(int i,int j,int k):a(i),b(j),dist(k){}
30     bool operator<(const node &i)const
31     {
32         return dist>i.dist;
33     }
34     int &get()
35     {
36         return d[b][a];
37     }
38 }now;
39
40 std::priority_queue<node>q;
41
42 int n,m,nn,i,j,k;
43 int cs,cf,x,y;
44 int ans,cst;
45
46 inline bool check(int x)
47 {
48     static int re,i;
49     for(i=re=0;x>=1,++i)
50         re+=(x&1)*(i<cf?fac[i]:-1);
51     return re>=0;
52 }
53
54 inline int count(int x)
55 {
56     static int i,re;
57     x>=cf;
58     for(re=0;x>=1)
59         re+=(x&1);
60     return re;
61 }
62
63 int main()
64 {
65     while(scanf("%d",&n)!=EOF)
66     {
67         memset(s,0,sizeof s);
68         memset(d,0x3f,sizeof d);
69         memset(dp,0x3f,sizeof dp);
70         ans=cnt=cf=cs=0;
71         memset(edge,0,sizeof edge);
72         for(i=1;i<=n;++i)
73         {
74             scanf("%d%d",P+i,S+i);
75             if(S[i] && P[i])
76             {
77                 ++ans;

```

```

78         —P[i];
79         S[i]=0;
80     }
81     if(P[i])
82     {
83         s[i]=1<<cf;
84         fac[cf]=P[i];
85         d[s[i]][i]=0;
86         ++cf;
87     }
88 }
89 for(i=1;i<=n;++i)
90     if(S[i])
91     {
92         s[i]=1<<(cf+cs);
93         d[s[i]][i]=0;
94         ++cs;
95     }
96 nn=1<<(cf+cs);
97 scanf("%d",&m);
98 while(m—)
99 {
100     scanf("%d%d%d",&i,&j,&k);
101     add(i,j,k);
102     add(j,i,k);
103 }
104 for(y=1;y<nn;++y)
105 {
106     for(x=1;x<=n;++x)
107     {
108         if(s[x] && !s[x]&y))
109             continue;
110         for(i=(y-1)&y;i=(i-1)&y)
111             d[y][x]=std::min(d[y][x],d[i|s[x]][x]+d[(y^i)|s[x]][x]);
112         if(d[y][x]!=inf)
113             q.push(node(x,y,d[y][x]));
114     }
115     while(!q.empty())
116     {
117         now=q.top();
118         q.pop();
119         if(now.dist!=now.get())
120             continue;
121         static int x,y,a,b;
122         x=now.a;
123         y=now.b;
124         for(i=edge[x];i=nxt[i])
125         {
126             a=to[i];
127             b=y|s[a];
128             if(d[b][a]>now.get()+wg[i])
129             {
130                 d[b][a]=now.get()+wg[i];
131                 if(b==y)
132                     q.push(node(a,b,d[b][a]));
133             }
134         }
135     }
136 }
137 for(j=0;j<nn;++j)
138     dp[j]=*std::min_element(d[j]+1,d[j]+1+n);
139 cnt=cst=0;
140 for(i=1;i<nn;++i)
141     if(check(i))
142     {
143         for(j=(i-1)&i;j=(j-1)&i)
144             if(check(j) && check(i^j))
145                 dp[i]=std::min(dp[i],dp[j]+dp[i^j]);
146         k=count(i);
147         if(dp[i]!=inf && (k>cnt || (k==cnt && dp[i]<cst)))
148         {
149             cnt=k;
150             cst=dp[i];
151         }
152     }
153 printf("%d\n",ans+cnt,cst);
154 }
155 return 0;
156 }

```

4.24 Minimum-cost flow problem

```

1 // like Edmonds-Karp Algorithm
2 #include<cstdio>
3 #include<cstring>
4 #include<algorithm>
5 #include<queue>
6
7 #define MAXX 5011
8 #define MAXE (MAXX*10*2)
9 #define inf 0x3f3f3f3f
10
11 int edge[MAXX],nxt[MAXE],to[MAXE],cap[MAXE],cst[MAXE],cnt;

```

```

12 #define v to[i]
13 inline void adde(int a,int b,int c,int d)
14 {
15     nxt[++cnt]=edge[a];
16     edge[a]=cnt;
17     to[cnt]=b;
18     cap[cnt]=c;
19     cst[cnt]=d;
20 }
21 inline void add(int a,int b,int c,int d)
22 { adde(a,b,c,d);adde(b,a,0,-d);}
23
24 int dist[MAXX],pre[MAXX];
25 int source,sink;
26 std::queue<int>q;
27 bool in[MAXX];
28
29 inline bool go()
30 {
31     static int now,i;
32     memset(dist,0x3f,sizeof dist);
33     dist[source]=0;
34     pre[source]=-1;
35     q.push(source);
36     in[source]=true;
37     while(!q.empty())
38     {
39         in[now=q.front()]=false;
40         q.pop();
41         for(i=edge[now];i!=-1;i=nxt[i])
42             if(cap[i] && dist[v]>dist[now]+cst[i])
43             {
44                 dist[v]=dist[now]+cst[i];
45                 pre[v]=i;
46                 if(!in[v])
47                 {
48                     q.push(v);
49                     in[v]=true;
50                 }
51             }
52     }
53     return dist[sink]!=inf;
54 }
55
56 inline int mcmf(int &flow)
57 {
58     static int ans,i;
59     flow=ans=0;
60     while(go())
61     {
62         static int min;
63         min=inf;
64         for(i=pre[sink];i!=-1;i=pre[to[i^1]])
65             min=std::min(min,cap[i]);
66         flow+=min;
67         ans+=min*dist[sink];
68         for(i=pre[sink];i!=-1;i=pre[to[i^1]])
69         {
70             cap[i]-=min;
71             cap[i^1]+=min;
72         }
73     }
74     return ans;
75 }

```

```

29
30 int head[MAXN],to[MAXN<<1],nxt[MAXN<<1],wg[MAXN<<1],cnt;
31 inline void add(int a,int b,int c)
32 {
33     nxt[++cnt]=head[a];
34     head[a]=cnt;
35     to[cnt]=b;
36     wg[cnt]=c;
37 }
38
39 void dfs(const int now,const int fa)
40 {
41     done[now]=true;
42     for(int i(head[now]);i;i=nxt[i])
43         if(v!=fa)
44         {
45             for(int j(1);j<=n;++j)
46                 if(done[j])
47                     map[v][j]=map[j][v]=std::max(map[j][now],wg[j]);
48             dfs(v,now);
49         }
50 }
51
52 int main()
53 {
54     scanf("%d%d",&n,&m);
55     for(i=0;i<m;++i)
56         scanf("%d%d%d",&ed[i].a,&ed[i].b,&ed[i].c);
57     std::sort(ed,ed+m);
58     for(i=0;i<m;++i)
59         if(find(ed[i].a)!=find(ed[i].b))
60         {
61             j+=ed[i].c;
62             ++k;
63             set[find(ed[i].a)]=find(ed[i].b);
64             ed[i].in=true;
65             add(ed[i].a,ed[i].b,ed[i].c);
66             add(ed[i].b,ed[i].a,ed[i].c);
67         }
68     if(k+1!=n)
69         puts("Cost:∞\nCost:∞-1");
70     else
71     {
72         printf("Cost:∞%d\n",j);
73         if(m==n-1)
74         {
75             puts("Cost:∞-1");
76             return 0;
77         }
78         ans=0x3f3f3f3f;
79         memset(map,0x3f,sizeof map);
80         for(i=1;i<=n;++i)
81             map[i][i]=0;
82         dfs(1,0);
83         for(i=0;i<m;++i)
84             if(!ed[i].in)
85                 ans=std::min(ans,j+ed[i].c-map[ed[i].a][ed[i].b]);
86         printf("Cost:∞%d\n",ans);
87     }
88     return 0;
89 }

```

4.25 Second-best MST

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4
5 #define MAXN 511
6 #define MAXM 250011
7 #define v to[i]
8
9 int set[MAXN];
10 int find(int a)
11 {
12     return set[a]?set[a]=find(set[a]):a;
13 }
14
15 int n,m,i,j,k,ans;
16
17 struct edge
18 {
19     int a,b,c;
20     bool in;
21     bool operator<(const edge &i)const
22     {
23         return c<i.c;
24     }
25 }ed[MAXM];
26
27 int map[MAXN][MAXN];
28 bool done[MAXN];

```

4.26 Spanning tree

```

1 Minimum Bottleneck Spanning Tree:
2 Kruscal
3
4 All-pairs vertexes' Minimum Bottleneck Path:
5 DP in the Kruscal's MST
6  $O(n^2) * O(1)$ 
7
8 Minimum Diameter Spanning Tree:
9 Kariv-Hakimi Algorithm
10
11 Directed MST:-
12 ChuLiu/Edmonds' Algorithm
13
14 Second-best MST:
15 get All-pairs vertexes' Minimum Bottleneck Path, then enumerate
    all no-tree-edges to replace the longest edge between two
    vertexes to get a worse MST
16
17 Degree-constrained MST:
18 remove the vertex from the whole graph,then add edges to
    increase degrees and connect different connected
    components together (  $O(m \log m + n)$  with kruscal )
19 if we can't connect all connected components together, there
    exists no any spanning tree
20 next step is add edges to root vertex greedily, increase
    degrees, and decrease our answer (  $O(k * n)$  )
21 need all vertexes' minimum bottleneck path to root vertex
22
23 Minimum Ratio Spanning Tree:

```

```

24 Binary search
25
26 Manhattan MST:
27 combining line sweep with divide-and-conquer algorithm
28
29 Minimum Steiner Tree:
30 the MST contain all k vertexes
31 bit-mask with dijkstra  $O((1 \ll k) * (\text{dijkstra}))$ 
32 then run a bit-mask DP(  $O(n * (1 \ll k))$  )
33
34 Count Spanning Trees:
35 Kirchhoff's theorem
36 simply calculate the minor of (degree Matrix - edge Matrix)
37
38 k-best MST:
39 do like second-best MST for k times

```

4.27 Stable Marriage

```

1 //对于每个预备队列中的对象, 及被匹配对象, 先按照喜好程度排列匹配对象
2
3 while(!g.empty()) // 预备匹配队列
4 {
5     if(dfn[edge[g.front()].front()] == -1)
6         dfn[edge[g.front()].front()] = g.front(); // 如果目前还没尝
            试匹配过的对象没有被任何别的对象占据
7     else
8     {
9         for(it=edge[edge[g.front()].front()].begin(); it!=edge[
            edge[g.front()].front()].end(); ++it)
10            if(*it==dfn[edge[g.front()].front()] || *it==g.
                front()) //如果被匹配对象更喜欢正在被匹配的人或现在准
                    备匹配的对象
11                break;
12            if(*it==g.front()) //如果更喜欢新的
13            {
14                g.push_back(dfn[edge[g.front()].front()]);
15                dfn[edge[g.front()].front()] = g.front();
16            }
17            else
18                g.push_back(g.front()); //否则放到队尾, 重新等待匹配
19        }
20        edge[g.front()].pop_front(); //每组匹配最多只考虑一次
21        g.pop_front();
22    }

```

4.28 Stoer-Wagner Algorithm

```

1 #include<cstdio>
2 #include<cstring>
3
4 const int maxn=510;
5
6 int map[maxn][maxn];
7 int n;
8
9 void contract(int x,int y)//合并两个点
10 {
11     int i,j;
12     for (i=0; i<n; i++)
13         if (i!=x)
14         {
15             map[x][i] += map[y][i];
16             map[i][x] += map[i][y];
17         }
18     for (i=y+1; i<n; i++)
19         for (j=0; j<n; j++)
20         {
21             map[i-1][j] = map[i][j];
22             map[j][i-1] = map[j][i];
23         }
24     n--;
25 }
26
27 int w[maxn],c[maxn];
28 int sx,tx;
29
30 int mincut() //求最大生成树, 计算最后一个点的割, 并保存最后一条边的两个顶
    点
31 {
32     static int i,j,k,t;
33     memset(c,0,sizeof(c));
34     c[0]=1;
35     for (i=0; i<n; i++)
36         w[i]=map[0][i];
37     for (i=1; i+1<n; i++)
38     {
39         t=k=-1;
40         for (j=0; j<n; j++)
41             if (c[j]==0&&w[j]>k)
42                 k=w[t=j];
43         c[sx=t]=1;
44         for (j=0; j<n; j++)

```

```

45         w[j] += map[t][j];
46     }
47     for (i=0; i<n; i++)
48         if (c[i]==0)
49             return w[tx=i];
50 }
51 int main()
52 {
53     int i,j,k,m;
54     while (scanf("%d%d",&n,&m) != EOF)
55     {
56         memset(map,0,sizeof(map));
57         while (m--)
58         {
59             scanf("%d%d%d",&i,&j,&k);
60             map[i][j] += k;
61             map[j][i] += k;
62         }
63         int mint=999999999;
64         while (n>1)
65         {
66             k=mincut();
67             if (k<mint) mint=k;
68             contract(sx,tx);
69         }
70         printf("%d\n",mint);
71     }
72     return 0;
73 }

```

4.29 Strongly Connected Component

```

1 //缩点后注意自环
2 void dfs(const short &now)
3 {
4     dfn[now]=low[now]=cnt++;
5     st.push(now);
6     for(std::list<short>::const_iterator it(edge[now].begin());
7         it!=edge[now].end(); ++it)
8         if(dfn[*it]==-1)
9         {
10             dfs(*it);
11             low[now]=std::min(low[now],low[*it]);
12         }
13     else
14         if(sc[*it]==-1)
15             low[now]=std::min(low[now],dfn[*it]);
16     if(dfn[now]==low[now])
17     {
18         while(sc[now]==-1)
19         {
20             sc[st.top()]=p;
21             st.pop();
22             ++p;
23         }
24     }

```

4.30 ZKW's Minimum-cost flow

```

1 #include<cstdio>
2 #include<algorithm>
3 #include<cstring>
4 #include<vector>
5 #include<deque>
6
7 #define MAXX 111
8 #define MAXN 211
9 #define MAXE (MAXN*MAXN*3)
10 #define inf 0x3f3f3f3f
11
12 char buf[MAXX];
13
14 int edge[MAXN],nxt[MAXE],to[MAXE],cap[MAXE],cst[MAXE],cnt;
15
16 inline void adde(int a,int b,int c,int k)
17 {
18     nxt[cnt]=edge[a];
19     edge[a]=cnt;
20     to[cnt]=b;
21     cap[cnt]=c;
22     cst[cnt]=k;
23     ++cnt;
24 }
25
26 inline void add(int a,int b,int c,int k)
27 {
28     adde(a,b,c,k);
29     adde(b,a,0,-k);
30 }
31
32 int n,mf,cost,pil;
33 int source,sink;
34 bool done[MAXN];

```

```

35 int aug(int now,int maxcap)
36 {
37     if(now==sink)
38     {
39         mf+=maxcap;
40         cost+=maxcap*pil;
41         return maxcap;
42     }
43     done[now]=true;
44     int l=maxcap;
45     for(int i=edge[now];i!=-1;i=nxt[i])
46         if(cap[i] && !cst[i] && !done[to[i]])
47         {
48             int d(aug(to[i],std::min(l,cap[i])));
49             cap[i]-=d;
50             cap[i^1]+=d;
51             l-=d;
52             if(!l)
53                 return maxcap;
54         }
55     }
56     return maxcap-l;
57 }
58
59 inline bool label()
60 {
61     static int d,i,j;
62     d=inf;
63     for(i=1;i<=n;++i)
64         if(done[i])
65             for(j=edge[i];j!=-1;j=nxt[j])
66                 if(cap[j] && !done[to[j]] && cst[j]<d)
67                     d=cst[j];
68     if(d==inf)
69         return false;
70     for(i=1;i<=n;++i)
71         if(done[i])
72             for(j=edge[i];j!=-1;j=nxt[j])
73             {
74                 cst[j]-=d;
75                 cst[j^1]+=d;
76             }
77     pil+=d;
78     return true;
79     /* primal-dual approach
80     static int d[MAXN],i,j;
81     static std::deque<int>q;
82     memset(d,0x3f,sizeof d);
83     d[sink]=0;
84     q.push_back(sink);
85     while(!q.empty())
86     {
87         static int dt,now;
88         now=q.front();
89         q.pop_front();
90         for(i=edge[now];i!=-1;i=nxt[i])
91             if(cap[i^1] && (dt=d[now]-cst[i])<d[to[i]])
92                 if((d[to[i]]-dt)<=d[q.empty()?0:q.front()])
93                     q.push_front(to[i]);
94             else
95                 q.push_back(to[i]);
96     }
97     for(i=1;i<=n;++i)
98         for(j=edge[i];j!=-1;j=nxt[j])
99             cst[j]+=d[to[j]]-d[i];
100     pil+=d[source];
101     return d[source]!=inf;
102     */
103 }
104
105 int m,i,j,k;
106 typedef std::pair<int,int> pii;
107 std::vector<pii>M(MAXN),H(MAXN);
108
109 int main()
110 {
111     while(scanf("%d%d",&n,&m),(n|m))
112     {
113         M.resize(0);
114         H.resize(0);
115         for(i=0;i<n;++i)
116         {
117             scanf("%s",buf);
118             for(j=0;j<m;++j)
119                 if(buf[j]=='m')
120                     M.push_back(pii(i,j));
121             else
122                 if(buf[j]=='H')
123                     H.push_back(pii(i,j));
124         }
125         n=M.size()+H.size();
126         source=++n;
127         sink=++n;
128         memset(edge,-1,sizeof edge);
129         cnt=0;
130         for(i=0;i<M.size();++i)

```

```

131         for(j=0;j<H.size();++j)
132             add(i+1,j+1+M.size(),1,abs(M[i].first-H[j].
133                 first)+abs(M[i].second-H[j].second));
134         for(i=0;i<M.size();++i)
135             add(source,i+1,1,0);
136         for(i=0;i<H.size();++i)
137             add(i+1+M.size(),sink,1,0);
138         mf=cost=pil=0;
139         do
140             do
141                 memset(done,0,sizeof done);
142                 while(aug(source,inf));
143                 while(label());
144                 /* primal-dual approach
145                 while(label())
146                     do
147                         memset(done,0,sizeof done);
148                         while(aug(source,inf));
149                 */
150                 printf("%d\n",cost);
151             }
152         }
153     }
154     return 0;
155 }

```

5 Math

5.1 cantor

```

1 const int PermSize = 12;
2 int fac[PermSize] = {1, 1, 2, 6, 24, 120, 720, 5040, 40320,
3     362880, 3628800, 39916800};
4 inline int Cantor(int a[])
5 {
6     int i, j, cnt;
7     int res = 0;
8     for (i = 0; i < PermSize; ++i)
9     {
10         cnt = 0;
11         for (j = i + 1; j < PermSize; ++j)
12             if (a[i] > a[j])
13                 ++cnt;
14         res = res + cnt * fac[PermSize - i - 1];
15     }
16     return res;
17 }
18
19 bool h[13];
20
21 inline void UnCantor(int x, int res[])
22 {
23     int i, j, l, t;
24     for (i = 1; i <= 12; i++)
25         h[i] = false;
26     for (i = 1; i <= 12; i++)
27     {
28         t = x / fac[12 - i];
29         x -= t * fac[12 - i];
30         for (j = 1, l = 0; l <= t; j++)
31             if (!h[j])
32                 l++;
33         j--;
34         h[j] = true;
35         res[i - 1] = j;
36     }
37 }

```

5.2 discrete logarithms - BSGS

```

1 //The running time of BSGS and the space complexity is  $O(\sqrt{n})$ 
2 //Pollard's rho algorithm for logarithms' running time is
3 //approximately  $O(\sqrt{p})$  where p is n's largest prime factor.
4 #include<cstdio>
5 #include<cmath>
6 #include<cstring>
7
8 struct Hash // std::map is bad. clear() 时会付出巨大的代价
9 {
10     static const int mod=1000003; // prime is good
11     static const int MAXX=47111; // bigger than  $\sqrt{c}$ 
12     int hd[mod],nxt[MAXX],cnt;
13     long long v[MAXX],k[MAXX]; //  $a^k \equiv v \pmod{c}$ 
14     inline void init()
15     {
16         memset(hd,0,sizeof hd);
17         cnt=0;
18     }
19     inline long long find(long long v)
20     {
21         static int now;
22         for(now=hd[v%mod];now;now=nxt[now])
23             if(this->v[now]==v)
24                 return k[now];
25     }

```

```

24     return -1ll;
25 }
26 inline void insert(long long k, long long v)
27 {
28     if (find(v) != -1ll)
29         return;
30     nxt[++cnt] = hd[v%mod];
31     hd[v%mod] = cnt;
32     this->v[cnt] = v;
33     this->k[cnt] = k;
34 }
35 }hash;
36
37 long long gcd(long long a, long long b)
38 {
39     return b?gcd(b, a%b):a;
40 }
41
42 long long exgcd(long long a, long long b, long long &x, long long &y)
43 {
44     if (b)
45     {
46         long long re(exgcd(b, a%b, x, y)), tmp(x);
47         x = y;
48         y = tmp - (a/b)*y;
49         return re;
50     }
51     x = 1ll;
52     y = 0ll;
53     return a;
54 }
55
56 inline long long bsgs(long long a, long long b, long long c) //
57      $a^x \equiv b \pmod{c}$ 
58 {
59     static long long x, y, d, g, m, am, k;
60     static int i, cnt;
61     a%=c;
62     b%=c;
63     x=1ll%c; // if c==1....
64     for(i=0; i<100; ++i)
65     {
66         if (x==b)
67             return i;
68         x=(x*a)%c;
69     }
70     d=1ll%c;
71     cnt=0;
72     while((g=gcd(a, c))!=1ll)
73     {
74         if (b%g)
75             return -1ll;
76         ++cnt;
77         c/=g;
78         b/=g;
79         d=a/g*d%c;
80     }
81     hash.init();
82     m=sqrt((double)c); // maybe need a ceil
83     am=1ll%c;
84     hash.insert(0, am);
85     for(i=1; i<=m; ++i)
86     {
87         am=am*a%c;
88         hash.insert(i, am);
89     }
90     for(i=0; i<=m; ++i)
91     {
92         g=exgcd(d, c, x, y);
93         x=(x*b/g%c+c)%c;
94         k=hash.find(x);
95         if (k!=-1ll)
96             return i*m+k+cnt;
97         d=d*am%c;
98     }
99     return -1ll;
100 }
101
102 long long k, p, n;
103
104 int main()
105 {
106     while (scanf("%lld%lld%lld", &k, &p, &n) != EOF)
107     {
108         if (n>p || (k=bsgs(k, n, p))!=-1ll)
109             puts("0rZ, I_u' cant find u!");
110         else
111             printf("%lld\n", k);
112     }
113     return 0;
114 }

```

5.3 extended euclidean algorithm

```

1 //返回ax+by=gcd(a,b)的一组解
2 long long ex_gcd(long long a, long long b, long long &x, long long &y)
3 {
4     if (b)
5     {
6         long long ret = ex_gcd(b, a%b, x, y), tmp = x;
7         x = y;
8         y = tmp - (a/b)*y;
9         return ret;
10    }
11    else
12    {
13        x = 1;
14        y = 0;
15        return a;
16    }
17 }

```

5.4 Fast Fourier Transform

```

1 #include<cstdio>
2 #include<cstring>
3 #include<complex>
4 #include<vector>
5 #include<algorithm>
6
7 #define MAXX 100111
8 #define MAXN (MAXX<<2)
9
10 int T;
11 int n, i, j, k;
12
13 typedef std::complex<long double> com;
14 std::vector<com> x(MAXN);
15 int a[MAXX];
16 long long pre[MAXN], cnt[MAXN];
17 long long ans;
18
19 inline void fft(std::vector<com> &y, int sign)
20 {
21     static int i, j, k, h;
22     static com u, t, w, wn;
23     for(i=1, j=y.size()/2; i+1<y.size(); ++i)
24     {
25         if (i<j)
26             std::swap(y[i], y[j]);
27         k=y.size()/2;
28         while (j>=k)
29         {
30             j-=k;
31             k/=2;
32         }
33         if (j<k)
34             j+=k;
35     }
36     for(h=2; h<=y.size(); h<=<=1)
37     {
38         wn=com(cos(-sign*2*M_PI/h), sin(-sign*2*M_PI/h));
39         for(j=0; j<y.size(); j+=h)
40         {
41             w=com(1, 0);
42             for(k=j; k<j+h/2; ++k)
43             {
44                 u=y[k];
45                 t=w*y[k+h/2];
46                 y[k]=u+t;
47                 y[k+h/2]=u-t;
48                 w*=wn;
49             }
50         }
51     }
52     if (sign==1)
53         for(i=0; i<y.size(); ++i)
54             y[i]=com(y[i].real()/y.size(), y[i].imag());
55 }
56
57 int main()
58 {
59     scanf("%d", &T);
60     while (T--)
61     {
62         memset(cnt, 0, sizeof cnt);
63         scanf("%d", &n);
64         for(i=0; i<n; ++i)
65         {
66             scanf("%d", &a[i]);
67             ++cnt[a[i]];
68         }
69         std::sort(a, a+n);
70         k=a[n-1]+1;
71         for(j=1; j<(k<<1); j<=<=1); // size must be such many
72         x.resize(0);
73         for(i=0; i<k; ++i)
74             x.push_back(com(cnt[i], 0));
75     }
76 }

```

```

75     x.insert(x.end(),j-k,com(0,0));
76
77     fft(x,1);
78     for(i=0;i<x.size();++i)
79         x[i]=x[i]*x[i];
80     fft(x,-1);
81     /*
82     if we need to combine 2 arrays
83     fft(x,1);
84     fft(y,1);
85     for(i=0;i<x.size();++i)
86         x[i]=x[i]*y[i];
87     fft(x,-1);
88     */
89
90     for(i=0;i<x.size();++i)
91         cnt[i]=ceil(x[i].real()); // maybe we need (x[i].
92         real()+0.5f) or nearbyint(x[i].real())
93     x.resize(2*a[n-1]); // result here
94 }
95 }

```

5.5 Gaussian elimination

```

1  #define N
2
3  inline int ge(int a[N][N],int n) // 返回系数矩阵的秩
4  {
5      static int i,j,k,l;
6      for(j=i=0;j<n;++j) //第 i 行, 第 j 列
7      {
8          for(k=i;k<n;++k)
9              if(a[k][j])
10                 break;
11         if(k==n)
12             continue;
13         for(l=0;l<n;++l)
14             std::swap(a[i][l],a[k][l]);
15         for(l=0;l<n;++l)
16             if(l!=i && a[l][j])
17                 for(k=0;k<n;++k)
18                     a[l][k]^=a[i][k];
19         ++i;
20     }
21     for(j=i;j<n;++j)
22         if(a[j][n])
23             return -1; //无解
24     return i;
25 }
26 /*
27 */
28
29 void dfs(int v)
30 {
31     if(v==n)
32     {
33         static int x[MAXX],ta[MAXX][MAXX];
34         static int tmp;
35         memcpy(x,ans,sizeof(x));
36         memcpy(ta,a,sizeof(ta));
37         for(i=l-1;i>=0;--i)
38         {
39             for(j=i+1;j<n;++j)
40                 ta[i][n]^=(x[j]&&ta[i][j]); //迭代消元求解
41             x[i]=ta[i][n];
42         }
43         for(tmp=i=0;i<n;++i)
44             if(x[i])
45                 ++tmp;
46         cnt=std::min(cnt,tmp);
47         return;
48     }
49     ans[v]=0;
50     dfs(v+1);
51     ans[v]=1;
52     dfs(v+1);
53 }
54
55 inline int ge(int a[N][N],int n)
56 {
57     static int i,j,k,l;
58     for(i=j=0;j<n;++j)
59     {
60         for(k=i;k<n;++k)
61             if(a[k][j])
62                 break;
63         if(k<n)
64         {
65             for(l=0;l<n;++l)
66                 std::swap(a[i][l],a[k][l]);
67             for(k=0;k<n;++k)
68                 if(k!=i && a[k][j])
69                     for(l=0;l<n;++l)
70                         a[k][l]^=a[i][l];

```

```

71         ++i;
72     }
73     else //将不定元交换到后面去
74     {
75         l=n-1-j+i;
76         for(k=0;k<n;++k)
77             std::swap(a[k][l],a[k][i]);
78     }
79 }
80 if(i==n)
81 {
82     for(i=cnt=0;i<n;++i)
83         if(a[i][n])
84             ++cnt;
85     printf("%d\n",cnt);
86     continue;
87 }
88 for(j=i;j<n;++j)
89     if(a[j][n])
90         break;
91 if(j<n)
92     puts("impossible");
93 else
94 {
95     memset(ans,0,sizeof(ans));
96     cnt=111;
97     dfs(l=i);
98     printf("%d\n",cnt);
99 }
100 }
101
102 /*
103 */
104
105 inline void ge(int a[N][N],int m,int n) // m*n
106 {
107     static int i,j,k,l,b,c;
108     for(i=j=0;i<m && j<n;++j)
109     {
110         for(k=i;k<m;++k)
111             if(a[k][j])
112                 break;
113         if(k==m)
114             continue;
115         for(l=0;l<n;++l)
116             std::swap(a[i][l],a[k][l]);
117         for(k=0;k<m;++k)
118             if(k!=i && a[k][j])
119             {
120                 b=a[k][j];
121                 c=a[i][j];
122                 for(l=0;l<n;++l)
123                     a[k][l]=((a[k][l]*c-a[i][l]*b)%7+7)%7;
124             }
125         ++i;
126     }
127     for(j=i;j<m;++j)
128         if(a[j][n])
129             break;
130     if(j<m)
131     {
132         puts("Inconsistent_data.");
133         return;
134     }
135     if(i<n)
136         puts("Multiple_solutions.");
137     else
138     {
139         memset(ans,0,sizeof(ans));
140         for(i=n-1;i>=0;--i)
141         {
142             k=a[i][n];
143             for(j=i+1;j<n;++j)
144                 k=((k-a[i][j]*ans[j])%7+7)%7;
145             while(k%a[i][i])
146                 k+=7;
147             ans[i]=(k/a[i][i])%7;
148         }
149         for(i=0;i<n;++i)
150             printf("%d%c",ans[i],i+1==n?' \n':' ');
151     }
152 }

```

5.6 Integration

```

1 // simpson 公式用到的函数
2 double F(double x) {
3     return sqrt(1 + 4*a*x*x);
4 }
5
6 // 三点 simpson 法。这里要求 F 是一个全局函数
7 double simpson(double a, double b) {
8     double c = a + (b-a)/2;
9     return (F(a)+4*F(c)+F(b))*(b-a)/6;
10 }

```

```

11 |
12 | // 自适应 Simpson 公式 (递归过程)。已知整个区间 [a,b] 上的三点 simpson
    值 A
13 | double asr(double a, double b, double eps, double A) {
14 |     double c = a + (b-a)/2;
15 |     double L = simpson(a, c), R = simpson(c, b);
16 |     if(fabs(L+R-A) <= 15*eps)
17 |         return L+R+(L+R-A)/15.0;
18 |     return asr(a, c, eps/2, L) + asr(c, b, eps/2, R);
19 | }
20 |
21 | // 自适应 Simpson 公式 (主过程)
22 | double asr(double a, double b, double eps)
23 | {
24 |     return asr(a, b, eps, simpson(a, b));
25 | }
26 |
27 | // 用自适应 Simpson 公式计算宽度为 w, 高度为 h 的抛物线长
28 | double parabola_arc_length(double w, double h)
29 | {
30 |     a = 4.0*h/(w*w); // 修改全局变量 a, 从而改变全局函数 F 的行为
31 |     return asr(0, w/2, 1e-5)*2;
32 | }
33 |
34 | // thx for mzry
35 | inline double f(double)
36 | {
37 |     /*
38 |     define the function
39 |     */
40 | }
41 |
42 | inline double simp(double l, double r)
43 | {
44 |     double h = (r-l)/2.0;
45 |     return h*(f(l)+4*f((l+r)/2.0)+f(r))/3.0;
46 | }
47 |
48 | inline double rsimp(double l, double r) // call here
49 | {
50 |     double mid = (l+r)/2.0;
51 |     if(fabs((simp(l,r)-simp(l,mid)-simp(mid,r)))/15 < eps)
52 |         return simp(l,r);
53 |     else
54 |         return rsimp(l,mid)+rsimp(mid,r);
55 | }
56 |
57 | //Romberg
58 |
59 | /* Romberg 求定积分
60 | * 输入: 积分区间 [a,b], 被积函数 f(x,y,z)
61 | * 输出: 积分结果
62 | * f(x,y,z) 示例:
63 | * double f0( double x, double l, double t )
64 | * {
65 | *     return sqrt(1.0+l*t*t*cos(t*x)*cos(t*x));
66 | * }
67 | */
68 | double Integral(double a, double b, double (*f)(double x,
    double y, double z), double eps, double l, double t);
69 |
70 | inline double Romberg (double a, double b, double (*f)(double x,
    double y, double z), double eps, double l, double t)
71 | {
72 | #define MAX_N 1000
73 |     int i, j, temp2, min;
74 |     double h, R[2][MAX_N], temp4;
75 |     for (i=0; i<MAX_N; i++)
76 |     {
77 |         R[0][i] = 0.0;
78 |         R[1][i] = 0.0;
79 |     }
80 |     h = b-a;
81 |     min = (int)(log(h*10.0)/log(2.0)); //h should be at most
        0.1
82 |     R[0][0] = ((*f)(a, l, t)+(*f)(b, l, t))*h*0.50;
83 |     i = 1;
84 |     temp2 = 1;
85 |     while (i<MAX_N)
86 |     {
87 |         i++;
88 |         R[1][0] = 0.0;
89 |         for (j=1; j<=temp2; j++)
90 |             R[1][j] += (*f)(a+h*((double)j-0.50), l, t);
91 |         R[1][0] = (R[0][0] + h*R[1][0])*0.50;
92 |         temp4 = 4.0;
93 |         for (j=1; j<i; j++)
94 |         {
95 |             R[1][j] = R[1][j-1] + (R[1][j-1]-R[0][j-1])/(temp4
                -1.0);
96 |             temp4 *= 4.0;
97 |         }
98 |         if ((fabs(R[1][i-1]-R[0][i-2])<eps) && (i>min))
99 |             return R[1][i-1];
100 |         h *= 0.50;
101 |         temp2 *= 2;
102 |         for (j=0; j<i; j++)
103 |             R[0][j] = R[1][j];
104 |     }
105 |     return R[1][MAX_N-1];
106 | }
107 |
108 | inline double Integral(double a, double b, double (*f)(double x
    , double y, double z), double eps, double l, double t)
109 | {
110 |     const double pi(acos(-1.0f));
111 |     int n;
112 |     double R, p, res;
113 |     n = (int)(floor)(b * t * 0.50 / pi);
114 |     p = 2.0 * pi / t;
115 |     res = b - (double)n * p;
116 |     if (n)
117 |         R = Romberg (a, p, f0, eps/((double)n, l, t);
118 |     R = R * (double)n + Romberg( 0.0, res, f0, eps, l, t );
119 |     return R/100.0;
120 | }
121 |
122 | //
123 | inline double romberg(double a, double b)
124 | {
125 | #define MAXN 111
126 |     double t[MAXN][MAXN];
127 |     int n,k,i,m;
128 |     double h,g,p;
129 |     h=(double)(b-a)/2;
130 |     t[0][0]=h*(func(a)+func(b));
131 |     k=n=1;
132 |     do
133 |     {
134 |         g=0;
135 |         for(i=1;i<=n;i++)
136 |             g+=func((a+((2*i-1)*h)));
137 |         t[k][0]=(t[k-1][0]/2)+(h*g);
138 |         p = 1.0;
139 |         for(m=1;m<=k;m++)
140 |         {
141 |             p=p*4.0f;
142 |             t[k-m][m]=(p*t[k-m+1][m-1]-t[k-m][m-1])/(p-1);
143 |         }
144 |         m-=1;
145 |         h/=2;
146 |         n*=2;
147 |         k+=1;
148 |     }
149 |     while (fabs(t[0][m]-t[0][m-1])>eps);
150 |     return t[0][m];
151 | }
152 |

```

5.7 inverse element

```

1 | inline void getInv2(int x,int mod)
2 | {
3 |     inv[1]=1;
4 |     for (int i=2; i<=x; i++)
5 |         inv[i]=(mod-(mod/i)*inv[mod%i]%mod)%mod;
6 | }
7 |
8 | long long inv(long long x)// likes above one
9 | {
10 |     return x <= 1ll ? x : (mod - mod / x) * inv(mod % x) % mod;
11 | }
12 |
13 | inline long long power(long long x,long long y,int mod)
14 | {
15 |     long long ret=1;
16 |     for (long long a=x%mod; y;>=1,a=a*a%mod)
17 |         if (y&1)
18 |             ret=ret*a%mod;
19 |     return ret;
20 | }
21 |
22 | inline int getInv(int x,int mod)//mod 为素数
23 | {
24 |     return power(x,mod-2);
25 | }

```

5.8 Linear programming

```

1 | #include<cstdio>
2 | #include<cstring>
3 | #include<cmath>
4 | #include<algorithm>
5 |
6 | #define MAXN 33
7 | #define MAXM 33
8 | #define eps 1e-8
9 |
10 | double a[MAXN][MAXM],b[MAXN],c[MAXM];

```

```

11 double x[MAXM],d[MAXN][MAXM];
12 int ix[MAXN+MAXM];
13 double ans;
14 int n,m;
15 int i,j,k,r,s;
16 double D;
17
18 inline bool simplex()
19 {
20     r=n;
21     s=m++;
22     for(i=0;i<n+m;++i)
23         ix[i]=i;
24     memset(d,0,sizeof d);
25     for(i=0;i<n;++i)
26     {
27         for(j=0;j+1<m;++j)
28             d[i][j]=-a[i][j];
29         d[i][m-1]=1;
30         d[i][m]=b[i];
31         if(d[r][m]>d[i][m])
32             r=i;
33     }
34     for(j=0;j+1<m;++j)
35         d[n][j]=c[j];
36     d[n+1][m-1]=-1;
37     while(true)
38     {
39         if(r<n)
40         {
41             std::swap(ix[s],ix[r+m]);
42             d[r][s]=1./d[r][s];
43             for(j=0;j<m;++j)
44                 if(j!=s)
45                     d[r][j]*=-d[r][s];
46             for(i=0;i<n+1;++i)
47                 if(i!=r)
48                 {
49                     for(j=0;j<m;++j)
50                         if(j!=s)
51                             d[i][j]+=d[r][j]*d[i][s];
52                     d[i][s]=d[r][s];
53                 }
54             }
55             r=-1;
56             s=-1;
57             for(j=0;j<m;++j)
58                 if((s<0 || ix[s]>ix[j]) && (d[n+1][j]>eps || (d[n+1][j]>-eps && d[n][j]>eps)))
59                     s=j;
60             if(s<0)
61                 break;
62             for(i=0;i<n;++i)
63                 if(d[i][s]<=-eps && (r<0 || (D=(d[r][m]/d[r][s]-d[i][m]/d[i][s]))<=-eps || (D<eps && ix[r+m]>ix[i+m])))
64                     r=i;
65             if(r<0)
66                 return false;
67         }
68         if(d[n+1][m]<=-eps)
69             return false;
70         for(i=m;i<n+m;++i)
71             if(ix[i]+1<m)
72                 x[ix[i]]=d[i-m][m]; // answer
73         ans=d[n][m]; // maxium value
74         return true;
75     }
76
77 int main()
78 {
79     while(scanf("%d%d",&m,&n)!=EOF)
80     {
81         for(i=0;i<m;++i)
82             scanf("%lf",c+i); // max{ sum{c[i]*x[i]} }
83         for(i=0;i<n;++i)
84         {
85             for(j=0;j<m;++j)
86                 scanf("%lf",a[i][j]); // sum{ a[i]*x[i] } <= b
87             scanf("%lf",b+i);
88             b[i]*=n;
89         }
90         simplex();
91         printf("Nasa can spend %.0lf taka.\n",ceil(ans));
92     }
93     return 0;
94 }
95
96 /*
97 Simplex C(n+m)(n)
98 maximize:
99     sum_{i=1}^n (c[i] * x[i])
100 subject to
101     forall i in [1,m]

```

```

102     sum_{j=1}^m (a[i][j] * x[j]) <= rhs[i]
103 限制:
104     传入的矩阵必须是标准形式的.
105 sample:
106 3 3
107 15 17 20
108 0 1 -1 2
109 3 3 5 15
110 3 2 1 8
111 out:
112 OPTIMAL
113 76.000000
114 x[ 1 ] = 0.333333
115 x[ 2 ] = 3.000000
116 x[ 3 ] = 1.000000
117 */
118
119 #include <stdio>
120 #include <cstring>
121 #include <cmath>
122
123 #define eps 1e-8
124 #define inf 1e15
125 #define OPTIMAL -1 //最优解
126 #define UNBOUNDED -2 //无边界的
127 #define FEASIBLE -3 //可行的
128 #define INFEASIBLE -4 //无解
129 #define PIVOT_OK 1 //还可以松弛
130
131 #define N 45 //变量个数
132 #define M 45 //约束个数
133
134 int basic[N],row[M],col[N];
135 double c0[N];
136
137 inline double dcmp(double x)
138 {
139     if(x>eps)
140         return 1;
141     if(x<=-eps)
142         return -1;
143     return 0;
144 }
145
146 inline int Pivot(int n,int m,double *c,double a[M][N],double *
147     rhs,int &i,int &j)
148 {
149     double min=inf;
150     int k=-1;
151     for(j=0;j<=n;j++)
152         if(!basic[j] && dcmp(c[j])>0)
153             if(k<0 || dcmp(c[j]-c[k])>0)
154                 k=j;
155     j=k;
156     if(k<0)
157         return OPTIMAL;
158     for(k=-1,i=1;i<=m;i++)
159         if(dcmp(a[i][j])>0 && dcmp(rhs[i]/a[i][j]-min)<0)
160         {
161             min=rhs[i]/a[i][j];
162             k=i;
163         }
164     i=k;
165     if(k<0)
166         return UNBOUNDED;
167     return PIVOT_OK;
168 }
169
170 inline int PhaseII(int n,int m,double *c,double a[M][N],double
171     *rhs,double &ans,int PivotIndex)
172 {
173     static int i,j,k,l;
174     static double tmp;
175     while((k=Pivot(n,m,c,a,rhs,i,j))==PIVOT_OK || PivotIndex)
176     {
177         if(PivotIndex)
178         {
179             i=PivotIndex;
180             j=PivotIndex=0;
181         }
182         basic[row[i]]=0;
183         col[row[i]]=0;
184         basic[j]=1;
185         col[j]=i;
186         row[i]=j;
187         tmp=a[i][j];
188         for(k=0;k<=n;k++)
189             a[i][k]/=tmp;
190         rhs[i]/=tmp;
191         for(k=1;k<=m;k++)
192             if(k!=i && dcmp(a[k][j]))
193             {
194                 tmp=-a[k][j];
195                 for(l=0;l<=n;l++)

```



```

194         a[k][l]+=tmp*a[i][l];
195         rhs[k]+=tmp*rhs[i];
196     }
197     tmp=-c[j];
198     for(l=0;l<n;l++)
199         c[l]+=a[i][l]*tmp;
200     ans-=tmp*rhs[i];
201 }
202 return k;
203 }
204
205 inline int PhaseI(int n,int m,double *c,double a[M][N],double
    rhs,double &ans)
206 {
207     int i,j,k=-1;
208     double tmp,min=0,ans0=0;
209     for(i=1;i<=m;i++)
210         if(dcmp(rhs[i]-min)<0)
211         {
212             min=rhs[i];
213             k=i;
214         }
215     if(k<0)
216         return FEASIBLE;
217     for(i=1;i<=m;i++)
218         a[i][0]=-1;
219     for(j=1;j<=n;j++)
220         c0[j]=0;
221     c0[0]=-1;
222     PhaseII(n,m,c0,a, rhs,ans0,k);
223     if(dcmp(ans0)<0)
224         return INFEASIBLE;
225     for(i=1;i<=m;i++)
226         a[i][0]=0;
227     for(j=1;j<=n;j++)
228         if(dcmp(c[j]) && basic[j])
229         {
230             tmp=c[j];
231             ans+=rhs[col[j]]*tmp;
232             for(i=0;i<=n;i++)
233                 c[i]-=tmp*a[col[j]][i];
234         }
235     return FEASIBLE;
236 }
237 inline int simplex(int n,int m,double *c,double a[M][N],double
    *rhs,double &ans,double *x)
238 {
239     int i,j,k;
240     for(i=1;i<=m;i++)
241     {
242         for(j=n+1;j<=n+m;j++)
243             a[i][j]=0;
244         a[i][n+1]=1;
245         a[i][0]=0;
246         row[i]=n+i;
247         col[n+i]=i;
248     }
249     k=PhaseI(n+m,m,c,a, rhs,ans);
250     if(k==INFEASIBLE)
251         return k; //无解
252     k=PhaseII(n+m,m,c,a, rhs,ans,0);
253     for(j=0;j<=n+m;j++)
254         x[j] = 0;
255     for(i=1;i<=m;i++)
256         x[row[i]] = rhs[i];
257     return k;
258 }
259
260 double c[M],ans,a[M][N],rhs[M],x[N];
261
262 int main()
263 {
264     int i,j,n,m;
265     while(scanf("%d%d",&n,&m)!=EOF)
266     {
267         for(int i=0;i<=n+m;i++)
268         {
269             for(int j=0;j<=n+m;j++)
270                 a[i][j]=0;
271             basic[i]=0;
272             row[i]=0;
273             col[i]=0;
274             c[i]=0;
275             rhs[i]=0;
276         }
277         ans=0;
278
279         for(j=1;j<=n;j++)
280             scanf("%lf",c+j);
281         for(i=1;i<=m;i++)
282         {
283             for(j=1;j<=n;j++)
284                 scanf("%lf",a[i]+j);
285             scanf("%lf",rhs+i);
286         }
287
288         switch(simplex(n,m,c,a, rhs,ans,x))
289         {
290             case OPTIMAL:
291                 printf("Nasa can spend %.0f taka.\n",ceil(m*ans));
292                 //for(j=1;j<=n;j++)
293                 //    printf("x[ %2d ] = %10lf\n",j,x[j]);
294                 break;
295             case UNBOUNDED:
296                 puts("UNBOUNDED");
297                 break;
298             case INFEASIBLE:
299                 puts("INFEASIBLE");
300                 break;
301         }
302     }
303     return 0;
304 }

```

5.9 Lucas' theorem(2)

```

1 #include<stdio>
2 #include<cstring>
3 #include<iostream>
4
5 int mod;
6 long long num[100000];
7 int ni[100],mi[100];
8 int len;
9
10 void init(int p)
11 {
12     mod=p;
13     num[0]=1;
14     for (int i=1; i<p; i++)
15         num[i]=i*num[i-1]%p;
16 }
17
18 void get(int n,int ni[],int p)
19 {
20     for (int i = 0; i < 100; i++)
21         ni[i] = 0;
22     int tlen = 0;
23     while (n != 0)
24     {
25         ni[tlen++] = n%p;
26         n /= p;
27     }
28     len = tlen;
29 }
30
31 long long power(long long x,long long y)
32 {
33     long long ret=1;
34     for (long long a=x%mod; y; y>=1,a=a*a%mod)
35         if (y&1)
36             ret=ret*a%mod;
37     return ret;
38 }
39
40 long long getInv(long long x)//mod 为素数
41 {
42     return power(x,mod-2);
43 }
44
45 long long calc(int n,int m,int p)//C(n,m)%p
46 {
47     init(p);
48     long long ans=1;
49     for (; n && m && ans; n/=p,m/=p)
50     {
51         if (n%p>=m%p)
52             ans = ans*num[n%p]%p *getInv(num[m%p]%p)%p *getInv(
                num[n%p-m%p]%p)%p;
53         else
54             ans=0;
55     }
56     return ans;
57 }
58
59 int main()
60 {
61     int t;
62     scanf("%d",&t);
63     while (t--)
64     {
65         int n,m,p;
66         scanf("%d%d%d",&n,&m,&p);
67         printf("%lld\n",calc(n+m,m,p));
68     }
69     return 0;
70 }

```

5.10 Lucas' theorem

```

1 #include <cstdio>
2 /*
3 Lucas 快速求解C(n,m)%p
4 */
5 void gcd(int n,int k,int &x,int &y)
6 {
7     if(k)
8     {
9         gcd(k,n%k,x,y);
10        int t=x;
11        x=y;
12        y=t-(n/k)*y;
13        return;
14    }
15    x=1;
16    y=0;
17 }
18
19 int CmodP(int n,int k,int p)
20 {
21     if(k>n)
22         return 0;
23     int a,b,flag=0,x,y;
24     a=b=1;
25     for(int i=1;i<=k;i++)
26     {
27         x=n-i+1;
28         y=i;
29         while(x%p==0)
30         {
31             x/=p;
32             ++flag;
33         }
34         while(y%p==0)
35         {
36             y/=p;
37             --flag;
38         }
39         x%=p;
40         y%=p;
41
42         a*=x;
43         b*=y;
44
45         b%=p;
46         a%=p;
47     }
48     if(flag)
49         return 0;
50     gcd(b,p,x,y);
51     if(x<0)
52         x+=p;
53     a*=x;
54     a%=p;
55     return a;
56 }
57
58 //用Lucas 定理求解 C(n,m) % p ,p 是素数
59 long long Lucas(long long n, long long m, long long p)
60 {
61     long long ans=1;
62     while(m && n && ans)
63     {
64         ans*=(CmodP(n%p,m%p,p));
65         ans=ans%p;
66         n=n/p;
67         m=m/p;
68     }
69     return ans;
70 }
71
72 int main()
73 {
74     long long n,k,p,ans;
75     int cas=0;
76     while(scanf("%I64d%I64d%I64d",&n,&k,&p)!=EOF)
77     {
78         if(k>n-k)
79             k=n-k;
80         ans=Lucas(n+1,k,p)+n-k;
81         printf("Case_#%d: %I64d\n",++cas,ans%p);
82     }
83     return 0;
84 }

```

5.11 matrix

```

1 template<int n>class Matrix
2 {
3     long long a[n][n];
4     inline Matrix<n> operator*(const Matrix<n> &b)const //比照
5     {
6         //别忘了矩阵乘法虽然满足结合律但是不满足交换律……
7         static Matrix<n> re;
8         static int i,j,k;

```

```

9         for(i=0;i<n;++i)
10            for(j=0;j<n;++j)
11                re.a[i][j]=0;
12        for(k=0;k<n;++k)
13            for(i=0;i<n;++i)
14                if(a[i][k])
15                    for(j=0;j<n;++j)
16                        if(b.a[k][j])
17                            re.a[i][j]=(re.a[i][j]+a[i][k]*b.a[k][j])%mod;
18
19        return re;
20    }
21    inline Matrix<n> operator^(int y)const
22    {
23        static Matrix<n> re,x;
24        static int i,j;
25        for(i=0;i<n;++i)
26        {
27            for(j=0;j<n;++j)
28            {
29                re.a[i][j]=0;
30                x.a[i][j]=a[i][j];
31            }
32            re.a[i][i]=1;
33        }
34        for(;y>=1,x=x*x)
35            if(y&1)
36                re=re*x;
37        return re;
38    }
39    long long det()
40    {
41        static int i,j,k;
42        static long long ret,t;
43        ret=1ll;
44        for(i=0;i<n;++i)
45            for(j=0;j<n;++j)
46                a[i][j]%=mod;
47        for(i=0;i<n;++i)
48        {
49            for(j=i+1;j<n;++j)
50                while(a[j][i])
51                {
52                    t=a[i][i]/a[j][i];
53                    for(k=i;k<n;++k)
54                        a[i][k]=(a[i][k]-a[j][k]*t)%mod;
55                    for(k=i;k<n;++k)
56                        std::swap(a[i][k],a[j][k]);
57                    ret=-ret;
58                }
59            if(!a[i][i])
60                return 0ll;
61            ret=ret*a[i][i]%mod;
62        }
63        return (ret+mod)%mod;
64    }
65 };
66
67 /*
68 1 1
69 1 0
70 org[0][j], trans[i][j]
71 means
72 transform(org,1 times) -> org[0][j]= $\sum_{i=0}^n org[0][i] \times trans[i][j]$ 
73 */

```

5.12 Pell's equation

```

1 /*
2 find the (x,y) pair that  $x^2 - n \times y^2 = 1$ 
3 these is not solution if and only if n is a square number.
4
5 solution:
6 simply brute-force search the integer y, get (x1,y1). ( toooo
7 slow in some situation )
8 or we can enumerate the continued fraction of  $\sqrt{n}$ , as  $\frac{x}{y}$ , it will
9 be much more faster
10
11 other solution pairs' matrix:
12  $\begin{matrix} x1 & n \times y1 \\ y1 & x1 \end{matrix}$ 
13 k-th solution is {matrix}k
14 */
15
16 import java.util.*;
17 import java.math.*;
18
19 public class Main
20 {
21     static BigInteger p,q,p1,p2,p3,q1,q2,q3,a1,a2,a0,h1,h2,g1,
22         g2,n0;

```

```

20 static int n,t;
21 static void solve()
22 {
23     p2=BigInteger.ONE;
24     p1=BigInteger.ZERO;
25     q2=BigInteger.ZERO;
26     q1=BigInteger.ONE;
27     a0=a1=BigInteger.valueOf((long)Math.sqrt(n));
28     g1=BigInteger.ZERO;
29     h1=BigInteger.ONE;
30     n0=BigInteger.valueOf(n);
31     while(true)
32     {
33         g2=a1.multiply(h1).subtract(g1);
34         h2=(n0.subtract(g2.multiply(g2))).divide(h1);
35         a2=(g2.add(a0)).divide(h2);
36         p=p2.multiply(a1).add(p1);
37         q=q2.multiply(a1).add(q1);
38         if(p.multiply(p).subtract(n0.multiply(q.multiply(q)
39             )),equals(BigInteger.ONE))
40             return ;
41         a1=a2;
42         g1=g2;
43         h1=h2;
44         p1=p2;
45         p2=p;
46         q1=q2;
47         q2=q;
48     }
49 }
50 public static void main(String[] args)
51 {
52     Scanner in=new Scanner(System.in);
53     t=in.nextInt();
54     for(int i=0;i<t;++i)
55     {
56         n=in.nextInt();
57         solve();
58         System.out.println(p+"u"+q);
59     }
60 }

```

5.13 Pollard's rho algorithm

```

1 #include<stdio>
2 #include<stdlib>
3 #include<list>
4
5 short T;
6 unsigned long long a;
7 std::list<unsigned long long> fac;
8
9 inline unsigned long long multi_mod(const unsigned long long &a,
10     unsigned long long b,const unsigned long long &n)
11 {
12     unsigned long long exp(a%n),tmp(0);
13     while(b)
14     {
15         if(b&1)
16         {
17             tmp+=exp;
18             if(tmp>n)
19                 tmp-=n;
20         }
21         exp<<=1;
22         if(exp>n)
23             exp-=n;
24         b>>=1;
25     }
26     return tmp;
27 }
28 inline unsigned long long exp_mod(unsigned long long a,unsigned
29     long long b,const unsigned long long &c)
30 {
31     unsigned long long tmp(1);
32     while(b)
33     {
34         if(b&1)
35             tmp=multi_mod(tmp,a,c);
36         a=multi_mod(a,a,c);
37         b>>=1;
38     }
39     return tmp;
40 }
41 inline bool miller_rabbin(const unsigned long long &n,short T)
42 {
43     if(n==2)
44         return true;
45     if(n<2 || !(n&1))
46         return false;
47     unsigned long long a,u(n-1),x,y;
48     short t(0),i;

```

```

49 while(!(u&1))
50 {
51     ++t;
52     u>>=1;
53 }
54 while(T—)
55 {
56     a=rand()%(n-1)+1;
57     x=exp_mod(a,u,n);
58     for(i=0;i<t;++i)
59     {
60         y=multi_mod(x,x,n);
61         if(y==1 && x!=1 && x!=n-1)
62             return false;
63         x=y;
64     }
65     if(y!=1)
66         return false;
67 }
68 return true;
69 }
70
71 unsigned long long gcd(const unsigned long long &a,const
72     unsigned long long &b)
73 {
74     return b?gcd(b,a%b):a;
75 }
76 inline unsigned long long pollar_rho(const unsigned long long n
77     ,const unsigned long long &c)
78 {
79     unsigned long long x(rand()%(n-1)+1),y,d,i(1),k(2);
80     y=x;
81     while(true)
82     {
83         ++i;
84         x=(multi_mod(x,x,n)+c)%n;
85         d=gcd((x-y+n)%n,n);
86         if(d>1 && d<n)
87             return d;
88         if(x==y)
89             return n;
90         if(i==k)
91         {
92             k<<=1;
93             y=x;
94         }
95     }
96 }
97 void find(const unsigned long long &n,short c)
98 {
99     if(n==1)
100         return;
101     if(miller_rabbin(n,6))
102     {
103         fac.push_back(n);
104         return;
105     }
106     unsigned long long p(n);
107     short k(c);
108     while(p>n)
109         p=pollar_rho(p,c—);
110     find(p,k);
111     find(n/p,k);
112 }
113
114 int main()
115 {
116     scanf("%hd",&T);
117     while(T—)
118     {
119         scanf("%llu",&a);
120         fac.clear();
121         find(a,120);
122         if(fac.size()==1)
123             puts("Prime");
124         else
125         {
126             fac.sort();
127             printf("%llu\n",fac.front());
128         }
129     }
130     return 0;
131 }

```

5.14 System of linear congruences

```

1 // minimal val that for all (m,a) , val%m == a
2 #include<stdio>
3
4 #define MAXX 11
5
6 int T,t;
7 int m[MAXX],a[MAXX];

```

```

8 int n,i,j,k;
9 int x,y,c,d;
10 int lcm;
11
12 int exgcd(int a,int b,int &x,int &y)
13 {
14     if(b)
15     {
16         int re(exgcd(b,a%b,x,y)),tmp(x);
17         x=y;
18         y=tmp-(a/b)*y;
19         return re;
20     }
21     x=1;
22     y=0;
23     return a;
24 }
25
26 int main()
27 {
28     scanf("%d",&T);
29     for(t=1;t<=T;++t)
30     {
31         scanf("%d",&n);
32         lcm=1;
33         for(i=0;i<n;++i)
34         {
35             scanf("%d",m+i);
36             lcm*=m[i]/exgcd(lcm,m[i],x,y);
37         }
38         for(i=0;i<n;++i)
39             scanf("%d",a+i);
40         for(i=1;i<n;++i)
41         {
42             c=a[i]-a[0];
43             d=exgcd(m[0],m[i],x,y);
44             if(c%d)
45                 break;
46             y=m[i]/d;
47             c/=d;
48             x=(x*c%y+y)%y;
49             a[0]+=m[0]*x;
50             m[0]*=y;
51         }
52         //标程用的步长可能是最终的 m[0] 而不是 lcm。枚举一下标程
53         printf("Case %d: %d\n",t,i<n?-1:(a[0]?a[0]:lcm));
54     }
55     return 0;
56 }

```

5.15 Combinatorics

5.15.1 Subfactorial

$!n$ = number of permutations of n elements with no fixed points

from !0:

1, 0, 1, 2, 9, 44, 265, 1854, 14833, 133496, 1334961, 14684570

$!n = (n-1)(!(n-1) + !(n-2))$

PS: $n! = (n-1)((n-1)! + (n-2)!)$

$!n = n \times n! + (-1)^n$

Rencontres numbers:

$D_{n,k}$ is the number of permutations of $\{1, \dots, n\}$ that have exactly k fixed points.

$D_{n,0} = !n$

$D_{n,k} = \binom{n}{k} \times !(n-k)$

5.15.2 Ménage numbers

Ménage numbers:

number of permutations s of $[0, \dots, n-1]$ such that.

$\forall i, s(i) \neq i$ and $s(i) \not\equiv i+1 \pmod{n}$.

from A(0):

1, 0, 0, 1, 2, 13, 80, 579, 4738, 43387, 439792, 4890741

$$A_n = \sum_{k=0}^n (-1)^k \frac{2n}{2n-k} \binom{2n-k}{k} (n-k)!$$

$$A_n = nA_{n-1} + \frac{n}{n-2}A_{n-2} + \frac{4(-1)^{n-1}}{n-2}$$

$$A_n = nA_{n-1} + 2A_{n-2} - (n-4)A_{n-3} - A_{n-4}$$

5.15.3 Multiset

Permutation:

MultiSet $S = \{1 \text{ m}, 4 \text{ s}, 4 \text{ i}, 2 \text{ p}\}$

$$P(S) = \frac{(1+4+4+2)!}{1!4!4!2!}$$

Combination:

MultiSet $S = \{\infty a1, \infty a2, \dots, \infty ak\}$

$$\binom{S}{r} = \frac{(r+k-1)!}{r!(k-1)!} = \binom{r+k-1}{r}$$

if $r > \min\{\text{count}(\text{element}[i])\}$

you have to resolve this problem with inclusion-exclusion principle.

MS $T = \{3 \text{ a}, 4 \text{ b}, 5 \text{ c}\}$

MS $T_* = \{\infty a, \infty b, \infty c\}$

$$A1 = \left\{ \binom{T_*}{10} \mid \text{count}(a) > 3 \right\} // \binom{8}{6}$$

$$A2 = \left\{ \binom{T_*}{10} \mid \text{count}(b) > 4 \right\} // \binom{7}{5}$$

$$A3 = \left\{ \binom{T_*}{10} \mid \text{count}(c) > 5 \right\} // \binom{6}{4}$$

$$\binom{T}{10} = \binom{T_*}{10} - (|A1| + |A2| + |A3|) + (|A1 \cap A2| + |A1 \cap A3| + |A2 \cap A3|) - |A1 \cap A2 \cap A3|$$

$$\text{ans} = C(10,12) - (C(6,8) + C(5,7) + C(4,6)) + (C(1,3) + C(0,2) + 0) - 0 = 6$$

5.15.4 Distributing Balls into Boxes

Distributing m Balls into n Boxes.

balls	boxes	boxes empty	counts
diff	diff	empty	n^m
diff	diff	full	$n! \times S(m, n) = \sum_{i=0}^n (-1)^i \binom{n}{i} (n-i)^m$
diff	same	empty	$\sum_{k=1}^{\min\{n,m\}} S(m, k) = \frac{1}{n!} \sum_{k=1}^{\min\{n,m\}} \sum_{i=0}^k (-1)^i \binom{k}{i} (k-i)^m$
diff	same	full	$S(m, n)$ (Stirling numbers of the second kind)
same	diff	empty	$\binom{n+m-1}{n-1}$
same	diff	full	$\binom{m-1}{n-1}$
same	same	empty	$\text{dp}[0][0..n] = \text{dp}[1..m][1] = 1;$ if $m \geq n$ $\text{dp}[m][n] = \text{dp}[m][n-1] + \text{dp}[m-n][n];$ else $\text{dp}[m][n] = \text{dp}[m][n-1];$
same	same	full	$g[m][n] = \text{dp}[m-n][n];$

5.15.5 Combinatorial Game Theory

Wythoff's game:

- There are two piles of counters.
- Players take turns removing counters (at least 1 counter) from one or both piles; in the latter case, the numbers of counters removed from each pile must be equal.
- The player who removes the last counter wins.

consider the counters of status as pair (a, b) ($a \leq b$)

$$\{\text{first player loses}\} \iff a = \lfloor (b-a) \times \phi \rfloor, \phi = \frac{\sqrt{5}+1}{2}$$

Fibonacci Nim:

- There is one pile of n counters.
- The first player may remove any positive number of counters, but not the whole pile.
- Thereafter, each player may remove at most twice the number of counters his opponent took on the previous move.
- The player who removes the last counter wins.

{first player wins} $\iff n \notin \{\text{Fibonacci number}\}$

poj 1740:

- There are n piles of stones.
- At each step of the game, the player choose a pile, remove at least one stones, then freely move stones from this pile to any other pile that still has stones.
- The player who removes the last counter wins.

{first player lose} $\iff n$ is even && $(a_1, a_2, \dots, a_k) (a_1 \leq a_2 \leq \dots \leq a_{2k})$ satisfy $a_{2i-1} = a_{2i} \{ \forall i \in [1, k] \}$

Staircase Nim:

- A staircase of n steps contains coins on some of the steps.
- A move of staircase nim consists of moving any positive number of coins from any step j , to the next lower step, $j - 1$.
- Coins reaching the ground (step 0) are removed from play.
- The player who removes the last counter wins.

Even steps are unusefull.

$SG = x_1 \oplus x_3 \oplus x_5 \dots$

Anti-SG:

- Everything is likes SG.
- The player who removes the last counter loses.

{first player wins} \iff

$SG_{\text{sum}}=0$, && {all piles is 1}

$SG_{\text{sum}} \neq 0$, && {some piles are larger than 1}

Every-SG:

- Everything is likes SG.
- For each turns, player have to move all of sub-games if the sub-game was not ended yet.

{first player wins} $\iff \max(\text{steps of all sub-games})$ is odd.

Coin Game:

- Given a horizontal line of N coins with some coins showing heads and some tails.
- Each turn, a player have to follow some rules, flip some coins. But the most right coin he flipped has to be flipped from head to tail.
- The player who can not flip coin loses.

$\text{game}\{\text{THHTTH}\} = \text{game}\{\text{TH}\} \oplus \text{game}\{\text{TTH}\} \oplus \text{game}\{\text{TTTTTH}\}$

Tree Game:

- There is a rooted tree.
- Each turn, a player has to remove an edge from the tree. The parts can not connect with root with also are removed.
- The player who removes the last edge wins.

$\forall \text{node}(x),$

$SG(x) = (SG(i_1) + 1) \oplus (SG(i_2) + 1) \oplus \dots (\forall i \text{ are childnodes of } x)$

Undirectional Graph Game:

- There is a rooted undirectional graph.
- Other rules are likes Tree Game.

Odd Circle's SG value is 1.

Even Circle's SG value is 0.

turn the graph to a tree.

5.16 Number theory

5.16.1 Divisor Function

$n = p_1^{a_1} \times p_2^{a_2} \times \dots \times p_s^{a_s}$

sum of positive divisors function

$$\sigma(n) = \prod_{j=1}^s \frac{p_j^{a_j+1} - 1}{p_j - 1}$$

number of positive divisors function

$$\tau(n) = \prod_{j=1}^s (a_j + 1)$$

5.16.2 Reduced Residue System

Euler's totient function:

对正整数 n , 欧拉函数 φ 是小于或等于 n 的数中与 n 互质的数的数目, 也就是对 n 的简化剩余系的大小。

$\varphi(2)=1$ (唯一和 1 互质的数就是 1 本身)。

若 m, n 互质, $\varphi(m \times n) = \varphi(m) \times \varphi(n)$ 。

对于 n 来说, 所有这样的数的和为 $\frac{n \times \varphi(n)}{2}$ 。

$\gcd(k, n) = d, k \in [1, n]$, 这样的 k 有 $\varphi(\frac{n}{d})$

```

1 inline int phi(int n)
2 {
3     static int i;
4     static int re;
5     re=n;
6     for(i=0; prm[i]*prm[i]<=n; ++i)
7         if(n%prm[i]==0)
8         {
9             re=re/prm[i];
10            do
11                n/=prm[i];
12            while(n%prm[i]==0);
13        }
14    if(n!=1)
15        re=re/n;
16    return re;
17 }
18
19 inline void Euler()
20 {
21     static int i, j;
22     phi[1]=1;
23     for(i=2; i<MAXX; ++i)
24         if(!phi[i])
25             for(j=i; j<MAXX; j+=i)

```

```

26 |         {
27 |             if(!phi[j])
28 |                 phi[j]=j;
29 |             phi[j]=phi[j]/i*(i-1);
30 |         }
31 | }

```

Multiplicative order:

the multiplicative order of a modulo n is the smallest positive integer k with

$$a^k \equiv 1 \pmod{n}$$

对 m 的简化剩余系中的所有 x , $\text{ord}(x)$ 都一定是 $\varphi(m)$ 的一个约数 (aka. Euler's totient theorem)

求:

method 1、根据定义, 对 $\varphi(m)$ 分解素因子之后暴力寻找最小的一个 $d \{d|\varphi(m)\}$, 满足 $x^d \equiv 1 \pmod{m}$;

method 2、

```

1 | inline long long ord(long long x, long long m)
2 | {
3 |     static long long ans;
4 |     static int i, j;
5 |     ans = phi(m);
6 |     for(i=0; i<fac.size(); ++i)
7 |         for(j=0; j<fac[i].second && pow(x, ans/fac[i].first, m) == 1; ++j)
8 |             ans /= fac[i].first;
9 |     return ans;
10 | }

```

Primitive root:

若 $\text{ord}(x) = \varphi(m)$, 则 x 为 m 的一个原根
因此只需检查所有 $x^d \{d|\varphi(m)\}$ 找到使 $x^d \equiv 1 \pmod{m}$ 的所有 d , 当且仅当这样的 d 只有一个, 并且为 $\varphi(m)$ 的时候, x 是 m 的一个原根

当且仅当 $m = 1, 2, 4, p^n, 2 \times p^n$ $\{p$ 为奇质数, n 为正整数 $\}$ 时, m 存在原根 // 应该是指存在对于完全剩余系的原根
.... ?

当 m 存在原根时, 原根数目为 $\varphi(\varphi(m))$

求:

枚举每一个简化剩余系中的数 i , 若对于 i 的每一个质因子 $p[j], i^{\frac{\varphi(m)}{p[j]}} \not\equiv 1 \pmod{m}$, 那么 i 为 m 的一个原根。也就是说, $\text{ord}(i) = \varphi(m)$ 。
最小原根通常极小。

Carmichael function:

$\lambda(n)$ is defined as the smallest positive integer m such that

$$a^m \equiv 1 \pmod{n} \{ \forall a \mid \gcd(a, n) = 1 \}$$

也就是简化剩余系 (完全剩余系中存在乘法群中无法得到的数) 中所有 x 的 $\text{lcm}\{\text{ord}(x)\}$

$$\text{if } n = p[0]^{a[0]} \times p[1]^{a[1]} \times \dots \times p[m-1]^{a[m-1]} \\ \text{then } \lambda(n) = \text{lcm}(\lambda(p[0]^{a[0]}), \lambda(p[1]^{a[1]}), \dots, \lambda(p[m-1]^{a[m-1]}));$$

$$\text{if } n = 2^c \times p[0]^{a[0]} \times p[1]^{a[1]} \times \dots \times p[m-1]^{a[m-1]} \\ \text{then } \lambda(n) = \text{lcm}(2^c, \varphi(p[0]^{a[0]}), \varphi(p[1]^{a[1]}), \dots, \varphi(p[m-1]^{a[m-1]}));$$

$$c=0 \text{ if } a<2; c=1 \text{ if } a==2; c=a-2 \text{ if } a>3;$$

Carmichael's theorem:

if $\gcd(a, n) == 1$
then $\lambda(n) \equiv 1 \pmod{n}$

5.16.3 Prime

Prime number theorem:

Let $\pi(x)$ be the prime-counting function that gives the number of primes less than or equal to x , for any real number x .

$$\lim_{x \rightarrow \infty} \frac{\pi(x)}{x/\ln(x)} = 1$$

known as the asymptotic law of distribution of prime numbers.

$$\pi(x) \sim \frac{x}{\ln x}.$$

```

1 | #include<vector>
2 |
3 | std::vector<int> prm;
4 | bool flag[MAXX];
5 |
6 | int main()
7 | {
8 |     prm.reserve(MAXX); // pi(x)=x/ln(x);
9 |     for(i=2; i<MAXX; ++i)
10 |     {
11 |         if(!flag[i])
12 |             prm.push_back(i);
13 |         for(j=0; j<prm.size() && i*prm[j]<MAXX; ++j)
14 |         {
15 |             flag[i*prm[j]] = true;
16 |             if(i%prm[j]==0)
17 |                 break;
18 |         }
19 |     }
20 |     return 0;
21 | }

```

5.16.4 Euler–Mascheroni constant

$$\gamma = \lim_{n \rightarrow \infty} \left(\sum_{k=1}^n \frac{1}{k} - \ln(n) \right) = \int_1^{\infty} \left(\frac{1}{[x]} - \frac{1}{x} \right) dx$$

0.57721566490153286060651209008240243104215933593992...

6 String

6.1 Aho–Corasick Algorithm

```

1 | //trie graph
2 | #include<cstring>
3 | #include<queue>
4 |
5 | #define MAX 1000111
6 | #define N 26
7 |
8 | int nxt[MAX][N], fal[MAX], cnt;
9 | bool ed[MAX];
10 | char buf[MAX];
11 |
12 | inline void init(int a)
13 | {
14 |     memset(nxt[a], 0, sizeof(nxt[0]));
15 |     fal[a] = 0;
16 |     ed[a] = false;
17 | }
18 |
19 | inline void insert()
20 | {
21 |     static int i, p;
22 |     for(i=p=0; buf[i]; ++i)
23 |     {
24 |         if(!nxt[p][map[buf[i]]])
25 |             init(nxt[p][map[buf[i]]] = ++cnt);
26 |         p = nxt[p][map[buf[i]]];
27 |     }
28 |     ed[p] = true;
29 | }
30 |
31 | inline void make()
32 | {
33 |     static std::queue<int> q;
34 |     int i, now, p;
35 |     q.push(0);

```

```

36 while(!q.empty())
37 {
38     now=q.front();
39     q.pop();
40     for(i=0;i<N;++i)
41         if(nxt[now][i])
42         {
43             q.push(p=nxt[now][i]);
44             if(now)
45                 fal[p]=nxt[fal[now]][i];
46             ed[p]=ed[fal[p]];
47         }
48     else
49         nxt[now][i]=nxt[fal[now]][i]; // 使用本身的 trie
50     }
51 }
52 // normal version
53 #define N 128
54 char buf[MAXX];
55 int cnt[1111];
56 struct node
57 {
58     node *fal,*nxt[N];
59     int idx;
60     node() { memset(this,0,sizeof node); }
61 }*rt;
62 std::queue<node*>Q;
63 void free(node *p)
64 {
65     for(int i(0);i<N;++i)
66         if(p->nxt[i])
67             free(p->nxt[i]);
68     delete p;
69 }
70 inline void add(char *s,int idx)
71 {
72     static node *p;
73     for(p=rt;*s;++s)
74     {
75         if(!p->nxt[*s])
76             p->nxt[*s]=new node();
77         p=p->nxt[*s];
78     }
79     p->idx=idx;
80 }
81 inline void make()
82 {
83     Q.push(rt);
84     static node *p,*q;
85     static int i;
86     while(!Q.empty())
87     {
88         p=Q.front();
89         Q.pop();
90         for(i=0;i<N;++i)
91             if(p->nxt[i])
92             {
93                 q=p->fal;
94                 while(q)
95                 {
96                     if(q->nxt[i])
97                     {
98                         p->nxt[i]->fal=q->nxt[i];
99                         break;
100                     }
101                     q=q->fal;
102                 }
103                 if(!q)
104                     p->nxt[i]->fal=rt;
105                 Q.push(p->nxt[i]);
106             }
107     }
108 }
109 inline void match(const char *s)
110 {
111     static node *p,*q;
112     for(p=rt;*s;++s)
113     {
114         while(p!=rt && !p->nxt[*s])
115             p=p->fal;
116         p=p->nxt[*s];
117         if(!p)
118             p=rt;
119         for(q=p;q!=rt && q->idx;q=q->fal) // why q->idx ? looks
120             like not necessary at all, I delete it in an
121             other solution
122             ++cnt[q->idx];
123     }
124 }

```

```

129     }
130 }
131 //可以考虑 dfs 一下，拉直 fal 指针来跳过无效的匹配
132 //在线调整关键字存在性的时候，可以考虑欧拉序压扁之后使用 BIT 或者线段树进
133     行区间修改
134 //fal 指针构成的是一颗树，从匹配到的节点到树根都数一次

```

6.2 Gusfield's Z Algorithm

```

1 inline void make(int *z,char *buf)
2 {
3     int i,j,l,r;
4     l=0;
5     r=1;
6     z[0]=strlen(buf);
7     for(i=1;i<z[0];++i)
8         if(r<=i || z[i-l]>=r-i)
9         {
10             j=std::max(i,r);
11             while(j<z[0] && buf[j]==buf[j-i])
12                 ++j;
13             z[i]=j-i;
14             if(i<j)
15             {
16                 l=i;
17                 r=j;
18             }
19         }
20     else
21         z[i]=z[i-l];
22 }
23 for(i=1;i<len && i+z[i]<len;++i); //i= 可能最小循环节长度

```

6.3 Manacher's Algorithm

```

1 inline int match(const int a,const int b,const std::vector<int>
2     &str)
3 {
4     static int i;
5     i=0;
6     while(a-i>=0 && b+i<str.size() && str[a-i]==str[b+i])//注意
7         ++i;
8     return i;
9 }
10 inline void go(int *z,const std::vector<int> &str)
11 {
12     static int c,l,r,i,ii,n;
13     z[0]=1;
14     c=l=r=0;
15     for(i=1;i<str.size();++i)
16     {
17         ii=(l<<1)-i;
18         n=r+1-i;
19         if(i>r)
20         {
21             z[i]=match(i,i,str);
22             l=i;
23             r=i+z[i]-1;
24         }
25         else
26             if(z[ii]==n)
27             {
28                 z[i]=n+match(i-n,i+n,str);
29                 l=i;
30                 r=i+z[i]-1;
31             }
32             else
33                 z[i]=std::min(z[ii],n);
34             if(z[i]>z[c])
35                 c=i;
36     }
37 }
38 }
39 inline bool check(int *z,int a,int b) //检查子串 [a,b] 是否回文
40 {
41     a=a*2-1;
42     b=b*2-1;
43     int m=(a+b)/2;
44     return z[m]>=b-m+1;
45 }
46 }

```

6.4 Morris-Pratt Algorithm

```

1 inline void make(char *buf,int *fal)
2 {
3     static int i,j;
4     fal[0]=-1;

```

```

5   for(i=1,j=-1;buf[i];++i)
6   {
7       while(j>=0 && buf[j+1]!=buf[i])
8           j=fal[j];
9       if(buf[j+1]==buf[i])
10          ++j;
11          fal[i]=j;
12  }
13 }
14
15 inline int match(char *p,char *t,int* fal)
16 {
17     static int i,j,re;
18     re=0;
19     for(i=0,j=-1;t[i];++i)
20     {
21         while(j>=0 && p[j+1]!=t[i])
22             j=fal[j];
23         if(p[j+1]==t[i])
24             ++j;
25         if(!p[j+1])
26         {
27             ++re;
28             j=fal[j];
29         }
30     }
31     return re;
32 }
33
34 inline void make(char *buf,int *fal) // knuth-morris-pratt, not
35     tested yet
36 {
37     static int i,j;
38     fal[0]=-1;
39     for(i=1,j=-1;buf[i];++i)
40     {
41         while(j>=0 && buf[j+1]!=buf[i])
42             j=fal[j];
43         if(buf[j+1]==buf[i])
44             ++j;
45         fal[i]=j;
46     }
47     for(i=-2;i>=0;--i)
48     {
49         for(j=fal[i];j!=-1 && buf[j+1]!=buf[i+1];j=fal[j]);
50         fal[i]=j;
51     }

```

6.5 smallest representation

```

1  int min(char a[],int len)
2  {
3      int i = 0,j = 1,k = 0;
4      while (i < len && j < len && k < len)
5      {
6          int cmp = a[(j+k)%len]-a[(i+k)%len];
7          if (cmp == 0)
8              k++;
9          else
10         {
11             if (cmp > 0)
12                 j += k+1;
13             else
14                 i += k+1;
15             if (i == j) j++;
16             k = 0;
17         }
18     }
19     return std::min(i,j);
20 }

```

6.6 Suffix Array - DC3 Algorithm

```

1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4
5  #define MAXX 1111
6  #define F(x) ((x)/3+((x)%3==1?0:tb))
7  #define G(x) ((x)<tb?(x)*3+1:((x)-tb)*3+2)
8
9  int wa[MAXX],wb[MAXX],wv[MAXX],ws[MAXX];
10
11 inline bool c0(const int *str,const int &a,const int &b)
12 {
13     return str[a]==str[b] && str[a+1]==str[b+1] && str[a+2]==
14         str[b+2];
15 }
16
17 inline bool c12(const int *str,const int &k,const int &a,const
18     int &b)
19 {
20     if(k==2)

```

```

19     return str[a]<str[b] || str[a]==str[b] && c12(str,1,a
20         +1,b+1);
21     else
22         return str[a]<str[b] || str[a]==str[b] && wv[a+1]<wv[b
23         +1];
24 }
25
26 inline void sort(int *str,int *a,int *b,const int &n,const int
27     &m)
28 {
29     memset(ws,0,sizeof(ws));
30     int i;
31     for(i=0;i<n;++i)
32         ++ws[wv[i]=str[a[i]]];
33     for(i=1;i<m;++i)
34         ws[i]+=ws[i-1];
35     for(i=n-1;i>=0;--i)
36         b[--ws[wv[i]]]=a[i];
37 }
38
39 inline void dc3(int *str,int *sa,const int &n,const int &m)
40 {
41     int *strn(str+n);
42     int *san(sa+n),tb((n+1)/3),ta(0),tbc(0),i,j,k;
43     str[n]=str[n+1]=0;
44     for(i=0;i<n;++i)
45     {
46         if(i%3)
47             wa[tbc++]=i;
48         sort(str+2,wa,wb,tbc,m);
49         sort(str+1,wb,wa,tbc,m);
50         sort(str,wa,wb,tbc,m);
51         for(i=j=1,strn[F(wb[0])]=0;i<tbc;++i)
52             strn[F(wb[i])]=c0(str,wb[i-1],wb[i])?j-1:j++;
53         if(j<tbc)
54             dc3(strn,san,tbc,j);
55     }
56     else
57         for(i=0;i<tbc;++i)
58             san[strn[i]]=i;
59     for(i=0;i<tbc;++i)
60     {
61         if(san[i]<tbc)
62             wb[ta++]=san[i]*3;
63     }
64     if(n%3==1)
65         wb[ta++]=n-1;
66     sort(str,wb,wa,ta,m);
67     for(i=0;i<tbc;++i)
68         wv[wb[i]]=G(san[i])=i;
69     for(i=j=k=0;i<ta && j<tbc;)
70         sa[k++]=c12(str,wb[j]%3,wa[i],wb[j])?wa[i++]:wb[j++];
71     while(i<ta)
72         sa[k++]=wa[i++];
73     while(j<tbc)
74         sa[k++]=wb[j++];
75 }
76
77 int rk[MAXX],lcpa[MAXX],sa[MAXX*3];
78 int str[MAXX*3]; //必须int
79
80 int main()
81 {
82     scanf("%d",&n,&j);
83     for(i=0;i<n;++i)
84     {
85         scanf("%d",&k);
86         num[i]=k-j+100;
87         j=k;
88     }
89     num[n]=0;
90
91     dc3(num,sa,n+1,191); //191: str 中取值范围,桶排序
92
93     for(i=1;i<=n;++i) // rank 数组
94         rk[sa[i]]=i;
95     for(i=k=0;i<n;++i) // lcp 数组
96     {
97         if(!rk[i])
98             lcpa[0]=0;
99         else
100         {
101             j=sa[rk[i]-1];
102             if(k>0)
103                 --k;
104             while(num[i+k]==num[j+k])
105                 ++k;
106             lcpa[rk[i]]=k;
107         }
108     }
109
110     for(i=1;i<=n;++i)
111         sptb[0][i]=i;
112     for(i=1;i<=lg[n];++i) //sparse table RMQ
113     {
114         k=n+1-(1<<i);
115         for(j=1;j<=k;++j)
116         {
117             a=sptb[i-1][j];
118             b=sptb[i-1][j+(1<<(i-1))];
119             sptb[i][j]=lcpa[a]<lcpa[b]?a:b;

```



```

112     }
113 }
114 }
115
116 inline int ask(int l,int r)
117 {
118     a=lg[r-l+1];
119     r--=(1<a)-1;
120     l=sptb[a][l];
121     r=sptb[a][r];
122     return lcpa[l]<lcpa[r]?l:r;
123 }
124
125 inline int lcp(int l,int r) // 字符串上 [l,r] 区间的 rmq
126 {
127     l=rk[l];
128     r=rk[r];
129     if(l>r)
130         std::swap(l,r);
131     return lcpa[ask(l+1,r)];
132 }

```

6.7 Suffix Array - Prefix-doubling Algorithm

```

1 int wx[maxn],wy[maxn],*x,*y,wss[maxn],wv[maxn];
2
3 bool cmp(int *r,int n,int a,int b,int l)
4 {
5     return a+l<n && b+l<n && r[a]==r[b]&&r[a+l]==r[b+l];
6 }
7 void da(int str[],int sa[],int rank[],int height[],int n,int m)
8 {
9     int *s = str;
10    int *x=wx,*y=wy,*t,p;
11    int i,j;
12    for(i=0; i<m; i++)
13        wss[i]=0;
14    for(i=0; i<n; i++)
15        wss[x[i]=s[i]]++;
16    for(i=1; i<m; i++)
17        wss[i]=wss[i-1];
18    for(i=n-1; i>=0; i--)
19        sa[--wss[x[i]]]=i;
20    for(j=1,p=1; p<n && j<n; j*=2,m=p)
21    {
22        for(i=n-j,p=0; i<n; i++)
23            y[p++]=i;
24        for(i=0; i<n; i++)
25            if(sa[i]-j>=0)
26                y[p++]=sa[i]-j;
27        for(i=0; i<n; i++)
28            wv[i]=x[y[i]];
29        for(i=0; i<m; i++)
30            wss[i]=0;
31        for(i=0; i<n; i++)
32            wss[wv[i]]++;
33        for(i=1; i<m; i++)
34            wss[i]=wss[i-1];
35        for(i=n-1; i>=0; i--)
36            sa[--wss[wv[i]]]=y[i];
37        for(t=x,x=y,y=t,p=1,i=1,x[sa[0]]=0; i<n; i++)
38            x[sa[i]]=cmp(y,n,sa[i-1],sa[i],j)?p-1:p++;
39    }
40    for(int i=0; i<n; i++)
41        rank[sa[i]]=i;
42    for(int i=0,j=0,k=0; i<n; height[rank[i++]]=k)
43        if(rank[i]>0)
44            for(k?k--:0,j=sa[rank[i]-1]; i+k < n && j+k < n &&
45                str[i+k]==str[j+k]; ++k);

```

6.8 Suffix Automaton

```

1 /*
2 length(s) ∈ [ min(s), max(s) ] = [ val[fal[s]]+1, val[s] ]
3 */
4 #define MAXX 90111
5 #define MAXN (MAXX<<1)
6
7 int fal[MAXN],nxt[MAXN][26],val[MAXN],cnt,rt,last;
8
9 inline int neww(int v=0)
10 {
11     val[++cnt]=v;
12     fal[cnt]=0;
13     memset(nxt[cnt],0,sizeof nxt[0]);
14     return cnt;
15 }
16
17 inline void add(int w)
18 {
19     static int p,np,q,nq;
20     p=last;
21     last=np=neww(val[p]+1);

```

```

22 while(p && !nxt[p][w])
23 {
24     nxt[p][w]=np;
25     p=fal[p];
26 }
27 if(!p)
28     fal[np]=rt;
29 else
30 {
31     q=nxt[p][w];
32     if(val[p]+1==val[q])
33         fal[np]=q;
34     else
35     {
36         nq=neww(val[p]+1);
37         memcpy(nxt[nq],nxt[q],sizeof nxt[0]);
38         fal[nq]=fal[q];
39
40         fal[q]=fal[np]=nq;
41         while(p && nxt[p][w]==q)
42         {
43             nxt[p][w]=nq;
44             p=fal[p];
45         }
46     }
47 }
48 }
49
50 int v[MAXN],the[MAXN];
51
52 inline void make(char *str)
53 {
54     cnt=0;
55     rt=last=neww();
56     static int i,len,now;
57     for(i=0;str[i];++i)
58         add(str[i]-'a');
59     len=i;
60     memset(v,0,sizeof v);
61     for(i=1;i<=cnt;++i)
62         ++v[val[i]];
63     for(i=1;i<=len;++i)
64         v[i]=v[i-1];
65     for(i=1;i<=cnt;++i)
66         the[v[val[i]]--]=i;
67     for(i=cnt;i-->0)
68     {
69         now=the[i];
70         // topsort already
71     }
72 }
73 /*
74 sizeof right(s):
75 init:
76     for all np:
77         count[np]=1;
78 process:
79     for all status s:
80         count[fal[s]]+=count[s];
81 */

```

7 Dynamic Programming

7.1 knapsack problem

```

1 multiple-choice knapsack problem:
2
3 for 所有的组k
4     for v=V..0
5         for 所有的 i 属于组 k
6             f[v]=max{f[v],f[v-c[i]]+w[i]}

```

7.2 LCIS

```

1 #include<cstdio>
2 #include<cstring>
3 #include<vector>
4
5 #define MAXX 1111
6
7 int T;
8 int n,m,p,i,j,k;
9 std::vector<int>the[2];
10 int dp[MAXX],path[MAXX];
11 int ans[MAXX];
12
13 int main()
14 {
15     the[0].reserve(MAXX);
16     the[1].reserve(MAXX);
17     {
18         scanf("%d",&n);
19         the[0].resize(n);

```

```

20     for(i=0;i<n;++i)
21         scanf("%d",&the[0][i]);
22     scanf("%d",&m);
23     the[1].resize(m);
24     for(i=0;i<m;++i)
25         scanf("%d",&the[1][i]);
26     memset(dp,0,sizeof dp);
27     for(i=0;i<the[0].size();++i)
28     {
29         n=0;
30         p=-1;
31         for(j=0;j<the[1].size();++j)
32         {
33             if(the[0][i]==the[1][j] && n+1>dp[j])
34             {
35                 dp[j]=n+1;
36                 path[j]=p;
37             }
38             if(the[1][j]<the[0][i] && n<dp[j])
39             {
40                 n=dp[j];
41                 p=j;
42             }
43         }
44         n=0;
45         p=-1;
46         for(i=0;i<the[1].size();++i)
47             if(dp[i]>n)
48                 n=dp[p=i];
49         printf("%d\n",n);
50         for(i=n-1;i>=0;--i)
51         {
52             ans[i]=the[1][p];
53             p=path[p];
54         }
55         for(i=0;i<n;++i)
56             printf("%d_",ans[i]);
57         puts("");
58     }
59     return 0;
60 }
61 }

```

7.3 LCS

```

1 #include<cstdio>
2 #include<algorithm>
3 #include<vector>
4
5 #define MAXX 111
6 #define N 128
7
8 std::vector<char>the[2];
9 std::vector<int>dp(MAXX),p[N];
10
11 int i,j,k;
12 char buf[MAXX];
13 int t;
14
15 int main()
16 {
17     the[0].reserve(MAXX);
18     the[1].reserve(MAXX);
19     while(gets(buf),buf[0]!='#')
20     {
21         the[0].resize(0);
22         for(i=0;buf[i];++i)
23             the[0].push_back(buf[i]);
24         the[1].resize(0);
25         gets(buf);
26         for(i=0;buf[i];++i)
27             the[1].push_back(buf[i]);
28         for(i=0;i<N;++i)
29             p[i].resize(0);
30         for(i=0;i<the[1].size();++i)
31             p[the[1][i]].push_back(i);
32         dp.resize(1);
33         dp[0]=-1;
34         for(i=0;i<the[0].size();++i)
35             for(j=p[the[0][i]].size()-1;j>=0;--j)
36             {
37                 k=p[the[0][i]][j];
38                 if(k>dp.back())
39                     dp.push_back(k);
40                 else
41                     *std::lower_bound(dp.begin(),dp.end(),k)=k;
42             }
43         printf("Case_%d: you can visit at most %ld cities.\n",
44             ++t,dp.size()-1);
45     }
46     return 0;
47 }

```

7.4 sequence partitioning

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 #include<set>
5
6 #define MAXX 40111
7
8 int a[MAXX],b[MAXX];
9 int n,R;
10 std::multiset<int>set;
11
12 inline bool check(const int g)
13 {
14     static int i,j,k;
15     static long long sum;
16     static int l,r,q[MAXX],dp[MAXX];
17     set.clear();
18     q[0]=dp[0]=l=r=sum=0;
19     for(j=i=1;i<n;++i)
20     {
21         sum+=b[i];
22         while(sum>g)
23             sum-=b[j++];
24         if(j>i)
25             return false;
26         while(l<r && q[l]<j)
27         {
28             ++l;
29             if(l<r && set.count(dp[q[l-1]]+a[q[l]]))
30                 set.erase(set.find(dp[q[l-1]]+a[q[l]]));
31         }
32         while(l<r && a[q[r-1]]<=a[i])
33         {
34             --r;
35             if(l<r && set.count(dp[q[r-1]]+a[q[r]]))
36                 set.erase(set.find(dp[q[r-1]]+a[q[r]]));
37         }
38         if(l<r)
39             set.insert(dp[q[r-1]]+a[i]);
40         q[r++]=i;
41         dp[i]=dp[j-1]+a[q[l]];
42         if(r-l>1)
43             dp[i]=std::min(dp[i],*set.begin());
44     }
45     return dp[n]<=R;
46 }
47
48 int i,j,k;
49 long long l,r,mid,ans;
50
51 int main()
52 {
53     while(scanf("%d%d",&n,&R)!=EOF)
54     {
55         l=r=0;
56         for(i=1;i<n;++i)
57         {
58             scanf("%d%d",&a[i],&b[i]);
59             r+=b[i];
60         }
61         ans=-1;
62         while(l<r)
63         {
64             mid=l+r>>1;
65             if(check(mid))
66             {
67                 ans=mid;
68                 r=mid-1;
69             }
70             else
71                 l=mid+1;
72         }
73         printf("%lld\n",ans);
74     }
75     return 0;
76 }

```

8 Search

8.1 dlx

1. 精确覆盖：给定一个 01 矩阵，现在要选择一些行，使得每一列有且仅有一个 1。
2. 每次选定一个元素个数最少的列，从该列中选择一行加入答案，删除该行所有的列以及该行冲突的行。
3. 重复覆盖：给定一个 01 矩阵，现在要选择一些行，使得每一列至少有一个 1。
4. 每次选定一个元素个数最少的列，从该列中选择一行加入答案，删除该行所有的列。与该行冲突的行可能满足重复覆盖。

8.2 dlx - exact cover

```

1 #include<cstdio>
2 #include<cstring>

```

```

3 #include<algorithm>
4 #include<vector>
5
6 #define N 256
7 #define MAXN N*22
8 #define MAXM N*5
9 #define inf 0x3f3f3f3f
10 const int MAXX(MAXN*MAXM);
11
12 bool mat[MAXN][MAXM];
13
14 int u[MAXX],d[MAXX],l[MAXX],r[MAXX],ch[MAXX],rh[MAXX];
15 int sz[MAXM];
16 std::vector<int>ans(MAXX);
17 int hd,cnt;
18
19 inline int node(int up,int down,int left,int right)
20 {
21     u[cnt]=up;
22     d[cnt]=down;
23     l[cnt]=left;
24     r[cnt]=right;
25     u[down]=d[up]=l[right]=r[left]=cnt;
26     return cnt++;
27 }
28
29 inline void init(int n,int m)
30 {
31     cnt=0;
32     hd=node(0,0,0,0);
33     static int i,j,k,r;
34     for(j=1;j<=m;++j)
35     {
36         ch[j]=node(cnt,cnt,l[hd],hd);
37         sz[j]=0;
38     }
39     for(i=1;i<=n;++i)
40     {
41         r=-1;
42         for(j=1;j<=m;++j)
43             if(mat[i][j])
44             {
45                 if(r==-1)
46                 {
47                     r=node(u[ch[j]],ch[j],cnt,cnt);
48                     rh[r]=i;
49                     ch[r]=ch[j];
50                 }
51                 else
52                 {
53                     k=node(u[ch[j]],ch[j],l[r],r);
54                     rh[k]=i;
55                     ch[k]=ch[j];
56                 }
57                 ++sz[j];
58             }
59     }
60 }
61
62 inline void rm(int c)
63 {
64     l[r[c]]=l[c];
65     r[l[c]]=r[c];
66     static int i,j;
67     for(i=d[c];i!=c;i=d[i])
68         for(j=r[i];j!=i;j=r[j])
69         {
70             u[d[j]]=u[j];
71             d[u[j]]=d[j];
72             --sz[ch[j]];
73         }
74 }
75
76 inline void add(int c)
77 {
78     static int i,j;
79     for(i=u[c];i!=c;i=u[i])
80         for(j=l[i];j!=i;j=l[j])
81         {
82             ++sz[ch[j]];
83             u[d[j]]=d[u[j]]=j;
84         }
85     l[r[c]]=r[l[c]]=c;
86 }
87
88 bool dlx(int k)
89 {
90     if(hd==r[hd])
91     {
92         ans.resize(k);
93         return true;
94     }
95     int s=inf,c;
96     int i,j;
97     for(i=r[hd];i!=hd;i=r[i])
98         if(sz[i]<s)
99             {
100                 s=sz[i];
101                 c=i;
102             }
103     rm(c);
104     for(i=d[c];i!=c;i=d[i])
105     {
106         ans[k]=rh[i];
107         for(j=r[i];j!=i;j=r[j])
108             rm(ch[j]);
109         if(dlx(k+1))
110             return true;
111         for(j=l[i];j!=i;j=l[j])
112             add(ch[j]);
113     }
114     add(c);
115     return false;
116 }
117
118 #include <cstdio>
119 #include <cstring>
120
121 #define N 1024
122 #define M 1024*110
123 using namespace std;
124
125 int l[M], r[M], d[M], u[M], col[M], row[M], h[M], res[N],
126     cntcol[N];
127 int dcnt = 0;
128 //初始化一个节点
129 inline void addnode(int &x)
130 {
131     ++x;
132     r[x] = l[x] = u[x] = d[x] = x;
133 }
134 //将加入到后xrowx
135 inline void insert_row(int rowx, int x)
136 {
137     r[l[rowx]] = x;
138     l[x] = l[rowx];
139     r[x] = rowx;
140     l[rowx] = x;
141 }
142 //将加入到后xcolx
143 inline void insert_col(int colx, int x)
144 {
145     d[u[colx]] = x;
146     u[x] = u[colx];
147     d[x] = colx;
148     u[colx] = x;
149 }
150 //全局初始化
151 inline void dlx_init(int cols)
152 {
153     memset(h, -1, sizeof(h));
154     memset(cntcol, 0, sizeof(cntcol));
155     dcnt = -1;
156     addnode(dcnt);
157     for (int i = 1; i <= cols; ++i)
158     {
159         addnode(dcnt);
160         insert_row(0, dcnt);
161     }
162 }
163 //删除一列以及相关的所有行
164 inline void remove(int c)
165 {
166     l[r[c]] = l[c];
167     r[l[c]] = r[c];
168     for (int i = d[c]; i != c; i = d[i])
169         for (int j = r[i]; j != i; j = r[j])
170         {
171             u[d[j]] = u[j];
172             d[u[j]] = d[j];
173             cntcol[col[j]]--;
174         }
175 }
176 //恢复一列以及相关的所有行
177 inline void resume(int c)
178 {
179     for (int i = u[c]; i != c; i = u[i])
180         for (int j = l[i]; j != i; j = l[j])
181         {
182             u[d[j]] = j;
183             d[u[j]] = j;
184             cntcol[col[j]]++;
185         }
186     l[r[c]] = c;
187     r[l[c]] = c;
188 }
189 //搜索部分
190 bool DLX(int deep)
191 {
192     if (r[0] == 0)
193         {

```

```

193 //Do anything you want to do here
194 printf("%d", deep);
195 for (int i = 0; i < deep; ++i) printf("%d", res[i]);
196 puts("");
197 return true;
198 }
199 int min = INT_MAX, tempc;
200 for (int i = r[0]; i != 0; i = r[i])
201     if (cntcol[i] < min)
202     {
203         min = cntcol[i];
204         tempc = i;
205     }
206 remove(tempc);
207 for (int i = d[tempc]; i != tempc; i = d[i])
208 {
209     res[deep] = row[i];
210     for (int j = r[i]; j != i; j = r[j]) remove(col[j]);
211     if (DLX(deep + 1)) return true;
212     for (int j = l[i]; j != i; j = l[j]) resume(col[j]);
213 }
214 resume(tempc);
215 return false;
216 }
217 //插入矩阵中的节点"1"
218 inline void insert_node(int x, int y)
219 {
220     cntcol[y]++;
221     addnode(dcnt);
222     row[dcnt] = x;
223     col[dcnt] = y;
224     insert_col(y, dcnt);
225     if (h[x] == -1) h[x] = dcnt;
226     else insert_row(h[x], dcnt);
227 }
228 int main()
229 {
230     int n, m;
231     while (~scanf("%d%d", &n, &m))
232     {
233         dlx_init(m);
234         for (int i = 1; i <= n; ++i)
235         {
236             int k, x;
237             scanf("%d", &k);
238             while (k--)
239             {
240                 scanf("%d", &x);
241                 insert_node(i, x);
242             }
243         }
244         if (!DLX(0))
245             puts("NO");
246     }
247     return 0;
248 }

```

8.3 dlx - repeat cover

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4
5 #define MAXN 110
6 #define MAXM 1000000
7 #define INF 0x7FFFFFFF
8
9 using namespace std;
10
11 int G[MAXN][MAXN];
12 int L[MAXM], R[MAXM], U[MAXM], D[MAXM];
13 int size, ans, S[MAXM], H[MAXM], C[MAXM];
14 bool vis[MAXN * 100];
15 void Link(int r, int c)
16 {
17     U[size] = c;
18     D[size] = D[c];
19     U[D[c]] = size;
20     D[c] = size;
21     if (H[r] < 0)
22         H[r] = L[size] = R[size] = size;
23     else
24     {
25         L[size] = H[r];
26         R[size] = R[H[r]];
27         L[R[H[r]]] = size;
28         R[H[r]] = size;
29     }
30     S[c]++;
31     C[size++] = c;
32 }
33 void Remove(int c)
34 {
35     int i;
36     for (i = D[c]; i != c; i = D[i])

```

```

37 {
38     L[R[i]] = L[i];
39     R[L[i]] = R[i];
40 }
41 }
42 void Resume(int c)
43 {
44     int i;
45     for (i = D[c]; i != c; i = D[i])
46         L[R[i]] = R[L[i]] = i;
47 }
48 int A()
49 {
50     int i, j, k, res;
51     memset(vis, false, sizeof(vis));
52     for (res = 0, i = R[0]; i; i = R[i])
53     {
54         if (!vis[i])
55         {
56             res++;
57             for (j = D[i]; j != i; j = D[j])
58             {
59                 for (k = R[j]; k != j; k = R[k])
60                     vis[C[k]] = true;
61             }
62         }
63     }
64     return res;
65 }
66 void Dance(int now)
67 {
68     if (R[0] == 0)
69         ans = min(ans, now);
70     else if (now + A() < ans)
71     {
72         int i, j, temp, c;
73         for (temp = INF, i = R[0]; i; i = R[i])
74         {
75             if (temp > S[i])
76             {
77                 temp = S[i];
78                 c = i;
79             }
80         }
81         for (i = D[c]; i != c; i = D[i])
82         {
83             Remove(i);
84             for (j = R[i]; j != i; j = R[j])
85                 Remove(j);
86             Dance(now + 1);
87             for (j = L[i]; j != i; j = L[j])
88                 Resume(j);
89             Resume(i);
90         }
91     }
92 }
93 void Init(int m)
94 {
95     int i;
96     for (i = 0; i <= m; i++)
97     {
98         R[i] = i + 1;
99         L[i + 1] = i;
100         U[i] = D[i] = i;
101         S[i] = 0;
102     }
103     R[m] = 0;
104     size = m + 1;
105 }

```

8.4 fibonacci knapsack

```

1 #include<stdio.h>
2 #include<stdlib.h>
3 #include<algorithm>
4
5 #define MAXX 71
6
7 struct mono
8 {
9     long long weig, cost;
10 } goods[MAXX];
11
12 int n, T, t, i;
13 long long carry, sumw, sumc;
14 long long ans, las[MAXX];
15
16 bool comp(const struct mono a, const struct mono b)
17 {
18     if (a.weig != b.weig)
19         return a.weig < b.weig;
20     return b.cost < a.cost;
21 }
22
23 void dfs(int i, long long cost_n, long long carry_n, int last)

```

```

24 {
25     if(ans<cost_n)
26         ans=cost_n;
27     if(i==n || goods[i].weig>carry_n || cost_n+las[i]<=ans)
28         return;
29     if(last || (goods[i].weig!=goods[i-1].weig && goods[i].cost>
30         >goods[i-1].cost))
31         dfs(i+1,cost_n+goods[i].cost,carry_n-goods[i].weig,1);
32     dfs(i+1,cost_n,carry_n,0);
33 }
34 int main()
35 {
36     scanf("%d",&T);
37     for(t=1;t<=T;++t)
38     {
39         scanf("%d%lld",&n,&carry);
40         sumw=0;
41         sumc=0;
42         ans=0;
43         for(i=0;i<n;++i)
44         {
45             scanf("%lld%lld",&goods[i].weig,&goods[i].cost);
46             sumw+=goods[i].weig;
47             sumc+=goods[i].cost;
48         }
49         if(sumw<=carry)
50         {
51             printf("Case_%d: %lld\n",t,sumc);
52             continue;
53         }
54         std::sort(goods,goods+n,comp);
55         for(i=0;i<n;++i)
56         {
57             las[i]=sumc;
58             sumc-=goods[i].cost;
59         }
60         dfs(0,0,carry,1);
61         printf("Case_%d: %lld\n",t,ans);
62     }
63     return 0;
64 }

```

9 Others

9.1 .vimrc

```

1 set number
2 set history=1000000
3 set autoindent
4 set smartindent
5 set tabstop=4
6 set shiftwidth=4
7 set expandtab
8 set showmatch
9
10 set nocomp
11 filetype plugin indent on
12
13 filetype on
14 syntax on

```

9.2 bigint

```

1 // header files
2 #include <cstdio>
3 #include <string>
4 #include <algorithm>
5 #include <iostream>
6
7 struct Bigint
8 {
9     // representations and structures
10     std::string a; // to store the digits
11     int sign; // sign = -1 for negative numbers, sign = 1
12                 otherwise
13     // constructors
14     Bigint() {} // default constructor
15     Bigint( std::string b ) { (*this) = b; } // constructor for
16         std::string
17     // some helpful methods
18     int size() // returns number of digits
19     {
20         return a.size();
21     }
22     Bigint inverseSign() // changes the sign
23     {
24         sign *= -1;
25         return (*this);
26     }
27     Bigint normalize( int newSign ) // removes leading 0, fixes
28         sign
29     {
30         for( int i = a.size() - 1; i > 0 && a[i] == '0'; i-- )
31             a.erase(a.begin() + i);
32         sign = ( a.size() == 1 && a[0] == '0' ) ? 1 : newSign;
33         return (*this);
34     }
35     // assignment operator
36     void operator = ( std::string b ) // assigns a std::string
37         to Bigint
38     {
39         a = b[0] == '-' ? b.substr(1) : b;
40         reverse( a.begin(), a.end() );
41         this->normalize( b[0] == '-' ? -1 : 1 );
42     }
43     // conditional operators
44     bool operator < ( const Bigint &b ) const // less than
45         operator
46     {
47         if( sign != b.sign )
48             return sign < b.sign;
49         if( a.size() != b.a.size() )
50             return sign == 1 ? a.size() < b.a.size() : a.size()
51                 > b.a.size();
52         for( int i = a.size() - 1; i >= 0; i-- )
53             if( a[i] != b.a[i] )
54                 return sign == 1 ? a[i] < b.a[i] : a[i] > b.a[i];
55         return false;
56     }
57     bool operator == ( const Bigint &b ) const // operator for
58         equality
59     {
60         return a == b.a && sign == b.sign;
61     }
62     // mathematical operators
63     Bigint operator + ( Bigint b ) // addition operator
64         overloading
65     {
66         if( sign != b.sign )
67             return (*this) - b.inverseSign();
68         Bigint c;
69         for( int i = 0, carry = 0; i < a.size() || i < b.size() ||
70             carry; i++ )
71         {
72             carry += (i < a.size() ? a[i] - 48 : 0) + (i < b.a.size() ? b
73                 .a[i] - 48 : 0);
74             c.a += (carry % 10 + 48);
75             carry /= 10;
76         }
77         return c.normalize(sign);
78     }
79     Bigint operator - ( Bigint b ) // subtraction operator
80         overloading
81     {
82         if( sign != b.sign )
83             return (*this) + b.inverseSign();
84         int s = sign; sign = b.sign = 1;
85         if( (*this) < b )
86             return ((b - (*this)).inverseSign()).normalize(-s);
87         Bigint c;
88         for( int i = 0, borrow = 0; i < a.size(); i++ )
89         {
90             borrow = a[i] - borrow - (i < b.size() ? b.a[i] :
91                 48);
92             c.a += borrow >= 0 ? borrow + 48 : borrow + 58;
93             borrow = borrow >= 0 ? 0 : 1;
94         }
95         return c.normalize(s);
96     }
97     Bigint operator * ( Bigint b ) // multiplication operator
98         overloading
99     {
100         Bigint c("0");
101         for( int i = 0, k = a[i] - 48; i < a.size(); i++, k = a
102             [i] - 48 )
103         {
104             while(k-->0)
105                 c = c + b; // ith digit is k, so, we add k
106                 times
107             b.a.insert(b.a.begin(), '0'); // multiplied by 10
108         }
109         return c.normalize(sign * b.sign);
110     }
111     Bigint operator / ( Bigint b ) // division operator
112         overloading
113     {
114         if( b.size() == 1 && b.a[0] == '0' )
115             b.a[0] /= ( b.a[0] - 48 );
116         Bigint c("0"), d;
117         for( int j = 0; j < a.size(); j++ )
118             d.a += "0";
119         int dSign = sign * b.sign;
120         b.sign = 1;
121         for( int i = a.size() - 1; i >= 0; i-- )
122         {

```

```

109         c.a.insert( c.a.begin(), '0');
110         c = c + a.substr( i, 1 );
111         while( !( c < b ) )
112         {
113             c = c - b;
114             d.a[i]++;
115         }
116     }
117     return d.normalize(dSign);
118 }
119 Bigint operator % ( Bigint b ) // modulo operator
120     overloading
121 {
122     if( b.size() == 1 && b.a[0] == '0' )
123         b.a[0] /= ( b.a[0] - 48 );
124     Bigint c("0");
125     b.sign = 1;
126     for( int i = a.size() - 1; i >= 0; i-- )
127     {
128         c.a.insert( c.a.begin(), '0');
129         c = c + a.substr( i, 1 );
130         while( !( c < b ) )
131             c = c - b;
132     }
133     return c.normalize(sign);
134 }
135 // output method
136 void print()
137 {
138     if( sign == -1 )
139         putchar('-');
140     for( int i = a.size() - 1; i >= 0; i-- )
141         putchar(a[i]);
142 }
143 };
144
145 int main()
146 {
147     Bigint a, b, c; // declared some Bigint variables
148     ///////////////////////////////////////////////////
149     // taking Bigint input //
150     ///////////////////////////////////////////////////
151
152     std::string input; // std::string to take input
153     std::cin >> input; // take the Big integer as std::string
154     a = input; // assign the std::string to Bigint a
155
156     std::cin >> input; // take the Big integer as std::string
157     b = input; // assign the std::string to Bigint b
158
159     ///////////////////////////////////////////////////
160     // Using mathematical operators //
161     ///////////////////////////////////////////////////
162
163     c = a + b; // adding a and b
164     c.print(); // printing the Bigint
165     puts(""); // newline
166
167     c = a - b; // subtracting b from a
168     c.print(); // printing the Bigint
169     puts(""); // newline
170
171     c = a * b; // multiplying a and b
172     c.print(); // printing the Bigint
173     puts(""); // newline
174
175     c = a / b; // dividing a by b
176     c.print(); // printing the Bigint
177     puts(""); // newline
178
179     c = a % b; // a modulo b
180     c.print(); // printing the Bigint
181     puts(""); // newline
182
183     ///////////////////////////////////////////////////
184     // Using conditional operators //
185     ///////////////////////////////////////////////////
186
187     if( a == b )
188         puts("equal"); // checking equality
189     else
190         puts("not equal");
191
192     if( a < b )
193         puts("a is smaller than b"); // checking less than
194         operator
195
196     return 0;
197 }
198 }

```

```

1 // [0,n)
2 inline int go(int A[],int n,int x) // return the least i that
3     make A[i]==x;
4 {
5     static int l,r,mid,re;
6     l=0;
7     r=n-1;
8     re=-1;
9     while(l<=r)
10     {
11         mid=l+r>>1;
12         if(A[mid]<x)
13             l=mid+1;
14         else
15         {
16             r=mid-1;
17             if(A[mid]==x)
18                 re=mid;
19         }
20     }
21     return re;
22 }
23 inline int go(int A[],int n,int x) // return the largest i that
24     make A[i]==x;
25 {
26     static int l,r,mid,re;
27     l=0;
28     r=n-1;
29     re=-1;
30     while(l<=r)
31     {
32         mid=l+r>>1;
33         if(A[mid]<=x)
34         {
35             l=mid+1;
36             if(A[mid]==x)
37                 re=mid;
38         }
39         else
40             r=mid-1;
41     }
42     return re;
43 }
44 inline int go(int A[],int n,int x) // retrun the largest i that
45     make A[i]<x;
46 {
47     static int l,r,mid,re;
48     l=0;
49     r=n-1;
50     re=-1;
51     while(l<=r)
52     {
53         mid=l+r>>1;
54         if(A[mid]<x)
55         {
56             l=mid+1;
57             re=mid;
58         }
59         else
60             r=mid-1;
61     }
62     return re;
63 }
64 inline int go(int A[],int n,int x)// return the largest i that
65     make A[i]<=x;
66 {
67     static int l,r,mid,re;
68     l=0;
69     r=n-1;
70     re=-1;
71     while(l<=r)
72     {
73         mid=l+r>>1;
74         if(A[mid]<=x)
75         {
76             l=mid+1;
77             re=mid;
78         }
79         else
80             r=mid-1;
81     }
82     return re;
83 }
84 inline int go(int A[],int n,int x)// return the least i that
85     make A[i]>x;
86 {
87     static int l,r,mid,re;
88     l=0;
89     r=n-1;
90     re=-1;
91     while(l<=r)
92     {

```

9.3 Binary Search

```

92         mid=l+r>>1;
93         if(A[mid]<=x)
94             l=mid+1;
95         else
96         {
97             r=mid-1;
98             re=mid;
99         }
100     }
101     return re;
102 }
103
104 inline int go(int A[],int n,int x)// upper_bound();
105 {
106     static int l,r,mid;
107     l=0;
108     r=n-1;
109     while(l<r)
110     {
111         mid=l+r>>1;
112         if(A[mid]<=x)
113             l=mid+1;
114         else
115             r=mid;
116     }
117     return r;
118 }
119
120 inline int go(int A[],int n,int x)// lower_bound();
121 {
122     static int l,r,mid;;
123     l=0;
124     r=n-1;
125     while(l<r)
126     {
127         mid=l+r>>1;
128         if(A[mid]<x)
129             l=mid+1;
130         else
131             r=mid;
132     }
133     return r;
134 }

```

9.4 java

```

1 //Scanner
2
3 Scanner in=new Scanner(new FileReader("asdf"));
4 PrintWriter pw=new PrintWriter(new FileWriter("out"));
5 boolean    in.hasNext();
6 String      in.next();
7 BigDecimal  in.nextBigDecimal();
8 BigInteger  in.nextBigInteger();
9 BigInteger  in.nextBigInteger(int radix);
10 double      in.nextDouble();
11 int         in.nextInt();
12 int         in.nextInt(int radix);
13 String      in.nextLine();
14 long        in.nextLong();
15 long        in.nextLong(int radix);
16 short       in.nextShort();
17 short       in.nextShort(int radix);
18 int         in radix(); //Returns this scanner's default
    radix.
19 Scanner    in.useRadix(int radix);// Sets this scanner's
    default radix to the specified radix.
20 void        in.close();//Closes this scanner.
21
22 //String
23
24 char        str.charAt(int index);
25 int         str.compareTo(String anotherString); // <0 if
    less. ==0 if equal. >0 if greater.
26 int         str.compareToIgnoreCase(String str);
27 String      str.concat(String str);
28 boolean     str.contains(CharSequence s);
29 boolean     str.endsWith(String suffix);
30 boolean     str.startsWith(String prefix);
31 boolean     str.startsWith(String prefix,int toffset);
32 int         str.hashCode();
33 int         str.indexOf(int ch);
34 int         str.indexOf(int ch,int fromIndex);
35 int         str.indexOf(String str);
36 int         str.indexOf(String str,int fromIndex);
37 int         str.lastIndexOf(int ch);
38 int         str.lastIndexOf(int ch,int fromIndex);
39 // (ry
40 int         str.length();
41 String      str.substring(int beginIndex);
42 String      str.substring(int beginIndex,int endIndex);
43 String      str.toLowerCase();
44 String      str.toUpperCase();
45 String      str.trim();// Returns a copy of the string, with
    leading and trailing whitespace omitted.

```

```

46 //StringBuilder
47
48 StringBuilder str.insert(int offset,...);
49 StringBuilder str.reverse();
50 void          str.setCharAt(int index,int ch);
51
52 //BigInteger
53 compareTo(); equals(); doubleValue(); longValue(); hashCode();
    toString(); toString(int radix); max(); min(); mod();
    modPow(BigInteger exp,BigInteger m); nextProbablePrime();
    pow();
54 andNot(); and(); xor(); not(); or(); getLowestSetBit();
    bitCount(); bitLength(); setBit(int n); shiftLeft(int n);
    shiftRight(int n);
55 add(); divide(); divideAndRemainder(); remainder(); multiply();
    subtract(); gcd(); abs(); signum(); negate();
56
57 //BigDecimal
58 movePointLeft(); movePointRight(); precision();
    stripTrailingZeros(); toBigInteger(); toPlainString();
59
60 import java.util.*;
61
62 //sort
63 class pii implements Comparable
64 {
65     public int a,b;
66     public int compareTo(Object i)
67     {
68         pii c=(pii)i;
69         return a==c.a?c.b-b:c.a-a;
70     }
71 }
72
73 class Main
74 {
75     public static void main(String[] args)
76     {
77         pii[] the=new pii[2];
78         the[0]=new pii();
79         the[1]=new pii();
80         the[0].a=1;
81         the[0].b=1;
82         the[1].a=1;
83         the[1].b=2;
84         Arrays.sort(the);
85         for(int i=0;i<2;++i)
86             System.out.printf("%d,%d\n",the[i].a,the[i].b);
87     }
88 }
89
90 //fraction
91 class frac
92 {
93     public BigInteger a,b;
94     public frac(long aa,long bb)
95     {
96         a=BigInteger.valueOf(aa);
97         b=BigInteger.valueOf(bb);
98         BigInteger c=a.gcd(b);
99         a=a.divide(c);
100        b=b.divide(c);
101    }
102    public frac(BigInteger aa,BigInteger bb)
103    {
104        BigInteger c=aa.gcd(bb);
105        a=aa.divide(c);
106        b=bb.divide(c);
107    }
108    public frac mul(frac i)
109    {
110        return new frac(a.multiply(i.a),b.multiply(i.b));
111    }
112    public frac mul(long i)
113    {
114        return new frac(a.multiply(BigInteger.valueOf(i)),b);
115    }
116    public frac div(long i)
117    {
118        return new frac(a,b.multiply(BigInteger.valueOf(i)));
119    }
120    public frac add(frac i)
121    {
122        return new frac((a.multiply(i.b)).add(i.a.multiply(b)),
            b.multiply(i.b));
123    }
124    public void print()
125    {
126        System.out.println(a+"/"+b); //printf 会 PE 啊尼玛死.....
127    }
128 }

```

9.5 others

```

1| god damn it windows:

```

```

2 | #pragma comment(linker, "/STACK:16777216")
3 | #pragma comment(linker, "/STACK:102400000,102400000")
4 |
5 |
6 | chmod +x [filename]
7 |
8 | while true; do
9 | ./gen > input
10 | ./sol < input > output.sol
11 | ./bf < input > output.bf
12 |
13 | diff output.sol output.bf
14 | if[ $? -ne 0];then break; fi
15 | done
16 |
17 |
18 |

```

1. nothing to be afraid of, 'cause you love it. isn't it?
2. calm_down();calm_down();calm_down();
3. 读完题目读完题目读完题目
 - (a) 认真读题、认真读题、认真读题、认真读题、
 - (b) 不盲目跟版
 - (c) 换题/换想法
4. 对数/离线/hash/观察问题本身/点 \leftrightarrow 区间互转
 - (a) 对数调整精度 or 将乘法转换成加法
 - (b) 点化区间, 区间化点
5. 数组大小……
6. 写解释器/编译器的时候别忘了负数
 - (a) 还有 istringstream in <sstream>
 - (b) 指令/函数名也可能是变量名
7. vector 比 array 慢很多
8. modPow 比手写快速幂慢很多
9. 对于 bool 数组, memset 快 8 倍