

# Code Library



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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",
111             ++cas, ans);
112     }
113     return 0;
114 }
```

## 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
27 inline int update(int id,int pos)
28 {
29     int re(++cnt);
30     l=1;
31     r=m;
32     int nid(re);
33     sz[nid]=sz[id]+1;
34     while(l<r)
35     {
36         mid=(l+r)>>1;
37         if(pos<=mid)
38         {
39             lson[nid]=++cnt;
40             rson[nid]=rson[id];
41             nid=lson[nid];
42             id=lson[id];
43             r=mid;
44         }
45         else
46         {
47             lson[nid]=lson[id];
48             rson[nid]=++cnt;
49             nid=rson[nid];
50             id=rson[id];
51             l=mid+1;
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         if(to[i]!=fa)
64         {
65             j=1;
66             for(pre[to[i]][0]=now;j<N;j++)
67                 pre[to[i]][j]=pre[pre[to[i]][j-1]][j-1];
68             rr(to[i],now);
69         }
70 }
71
72 inline int query(int a,int b,int n,int k)
73 {
74     static int tmp,t;
75     l=1;
76     r=m;
77     a=head[a];
78     b=head[b];
79     t=num[n];
80     n=head[n];
81     while(l<r)
82     {
83         mid=(l+r)>>1;
84         tmp=sz[lson[a]]+sz[lson[b]]-2*sz[lson[n]]+(1<=t && t<=mid);
85         if(tmp>=k)
86         {
87             a=lson[a];
88             b=lson[b];
89             n=lson[n];
90             r=mid;
91         }
92         else
93         {
94             k-=tmp;
95             a=rson[a];
96             b=rson[b];
97             n=rson[n];
98             l=mid+1;
99         }
100     }
101     return l;
102 }
103
104 inline int lca(int a,int b)
105 {
106     static int i,j;
107     j=0;
108     if(dg[a]<dg[b])
109         std::swap(a,b);
110     for(i=dg[a]-dg[b];i;i>>=1,++j)
111         if(i&1)
112             a=pre[a][j];
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_%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<=n;++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
8  int set[MAXX];
9
10 int merge(int a,int b)
11 {
12     if(!a)
13         return b;
14     if(!b)
15         return a;
16     if(val[a]<val[b]) // max-heap
17         std::swap(a,b);
18     r[a]=merge(r[a],b);
19     if(d[l[a]]<d[r[a]])
20         std::swap(l[a],r[a]);
21     d[a]=d[r[a]]+1;
22     set[l[a]]=set[r[a]]=a; // set a as father of its sons
23     return a;
24 }
25
26 inline int find(int &a)
27 {
28     while(set[a]) //brute-force to get the index of root
29         a=set[a];
30     return a;
31 }
32
33 inline void reset(int i)
34 {
35     l[i]=r[i]=d[i]=set[i]=0;
36 }
37
38 int n,i,j,k;
39
40 int main()
41 {
42     while(scanf("%d",&n)!=EOF)
43     {
44         for(i=1;i<=n;++i)
45         {
46             scanf("%d",&val[i]);
47             reset(i);
48         }
49         scanf("%d",&n);
50         while(n--)
51         {
52             scanf("%d%d",&i,&j);
53             if(find(i)==find(j))
54                 puts("-1");
55             else
56             {
57                 k=merge(l[i],r[i]);
58                 val[i]>>=1;
59                 reset(i);
60                 set[i]=merge(i,k)=0;
61
62                 k=merge(l[j],r[j]);
63                 val[j]>>=1;
64                 reset(j);
65                 set[j]=merge(j,k)=0;
66
67                 set[k=merge(i,j)]=0;
68                 printf("%d\n",val[k]);
69             }
70         }
71     }
72     return 0;
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 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
150 int head[MAXX],root[MAXX],len[MAXX],pos[MAXX];
151
152 #define MAX (MAXX*6)
153 #define mid (l+r>>1)
154 #define lc lson[id],l,mid
155 #define rc rson[id],mid+1,r
156
157 int lson[MAX],rson[MAX];
158 int treap[MAX];
159
160 void make(int &id,int l,int r,int *the)
161 {
162     id=++cnt;
163     static int k;
164     for(k=l;k<=r;++k)
165         Treap::insert(treap[id],the[k]);
166     if(l!=r)
167     {
168         make(lc,the);
169         make(rc,the);
170     }
171 }
172
173 int query(int id,int l,int r,int a,int b,int q)
174 {
175     if(a<=l && r<=b)
176         return Treap::rank(treap[id],q);
177     int re(0);
178     if(a<=mid)
179         re=query(lc,a,b,q);
180     if(b>mid)
181         re+=query(rc,a,b,q);
182     return re;
183 }
184
185 inline int query(int a,int b,int v)
186 {
187     static int re;
188     for(re=0;root[a]!=root[b];a=fa[root[a]][0])
189         re+=query(head[root[a]],1,len[root[a]],1,pos[a],v);
190     re+=query(head[root[a]],1,len[root[a]],pos[b],pos[a],v);
191
192     return re;
193 }
194
195 inline void update(int id,int l,int r,int pos,int val,int n)
196 {
197     while(l<=r)
198     {
199         Treap::del(treap[id],val);
200         Treap::insert(treap[id],n);
201         if(l==r)
202             return;
203         if(pos<=mid)
204         {
205             id=lson[id];
206             r=mid;
207         }
208         else
209         {
210             id=rson[id];
211             l=mid+1;
212         }
213     }
214 }
215
216 int n,q,i,j,k;
217 int val[MAXX];
218
219 int main()
220 {
221     srand(1e9+7);
222     scanf("%d%d",&n,&q);
223     for(i=1;i<=n;++i)
224         scanf("%d",&val[i]);
225     for(k=1;k<=n;++k)
226     {
227         scanf("%d%d",&i,&j);
228         add(i,j);
229         add(j,i);
230     }
231     rr(rand()%n+1);
232     for(j=1;j<=n;++j)
233         for(i=1;i<=n;++i)
234             fa[i][j]=fa[i][j-1][j-1];
235
236     Treap::init();
237     cnt=0;
238     for(i=1;i<=n;++i)
239         if(!pre[i])
240         {
241             static int tmp[MAXX];
242             for(k=1,j=i;j;j=next[j],++k)
243             {
244                 pos[j]=k;
245                 root[j]=i;
246                 tmp[k]=val[j];
247             }
248             len[i]=k;
249             make(head[i],1,k,tmp);
250         }
251     while(q-->0)
252     {
253         scanf("%d",&k);
254         if(k)
255         {
256             static int a,b,c,d,l,r,ans,m;
257             scanf("%d%d",&a,&b);
258             c=lca(a,b);
259             if(dg[a]+dg[b]-2*dg[c]+1<k)
260             {
261                 puts("invalid request!");
262                 continue;
263             }
264             k=dg[a]+dg[b]-2*dg[c]+1-k+1;
265             if(dg[a]<dg[b])
266                 std::swap(a,b);
267             l=-1e9;
268             r=1e9;
269             if(b!=c)
270             {
271                 d=a;
272                 for(i=0,j=dg[a]-dg[c]-1;j>=1;++i)
273                     if(j&1)
274                         d=fa[d][i];
275                 while(l<=r)
276                 {
277                     m=l+r>>1;
278                     if(query(a,d,m)+query(b,c,m)>=k)
279                     {
280                         ans=m;
281                         r=m-1;
282                     }
283                     else
284                         l=m+1;
285                 }
286             }
287         }
288     }

```

```
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]);
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
8 int nxt[MAXX][2],fa[MAXX],pre[MAXX],val[MAXX],sum[MAXX];
9 bool rev[MAXX];
10
11 inline void up(int id)
12 {
13     static int i;
14     sum[id]=val[id];
15     for(i=0;i<2;++i)
16         if(nxt[id][i])
17             sum[id]+=sum[nxt[id][i]];
18 }
19
20 inline void rot(int id,int tp)
21 {
22     static int k;
23     k=pre[id];
24     nxt[k][tp^1]=nxt[id][tp];
25     if(nxt[id][tp])
26         pre[nxt[id][tp]]=k;
27     if(pre[k])
28         nxt[pre[k]][k==nxt[pre[k]][1]]=id;
29     pre[id]=pre[k];
30     nxt[id][tp]=k;
31     pre[k]=id;
32     up(k);
33     up(id);
34 }
35
36 inline void down(int id) //记得随手 down 啊.....亲.....
37 {
38     static int i;
39     if(rev[id])
40     {
41         rev[id]=false;
42         std::swap(nxt[id][0],nxt[id][1]);
43         for(i=0;i<2;++i)
44             if(nxt[id][i])
45                 rev[nxt[id][i]]^=true;
46     }
47 }
48
49 int freshen(int id)
50 {
51     int re(id);
52     if(pre[id])
53         re=freshen(pre[id]);
54     down(id);
55     return re;
56 }
57
58 inline void splay(int id)//记得随手 down 啊.....亲.....
59 {
60     static int rt;
61     if(id!=(rt=freshen(id)))
62         for(std::swap(fa[id],fa[rt]);pre[id];rot(id,id==nxt[pre[id]][0]));
63     /* another faster method:
64     if(id!=rt)
65     {
```

```
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
87 inline void access(int id)
88 {
89     static int to;
90     for(to=0;id;id=fa[id])
91     {
92         splay(id);
93         if(nxt[id][1])
94         {
95             pre[nxt[id][1]]=0;
96             fa[nxt[id][1]]=id;
97         }
98         nxt[id][1]=to;
99         if(to)
100         {
101             pre[to]=id;
102             fa[to]=0;
103         }
104         up(to=id);
105     }
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         rev[id]^=true;
126 }
127
128 int n,i,j,k,q;
129 char buf[11];
130
131 int main()
132 {
133     scanf("%d",&n);
134     for(i=1;i<=n;++i)
135         scanf("%d",&val[i]);
136     scanf("%d",&q);
137     while(q--)
138     {
139         scanf("%s%d%d",buf,&i,&j);
140         switch(buf[0])
141         {
142             case 'b':
143                 if(getrt(i)==getrt(j))
144                     puts("no");
145                 else
146                 {
147                     puts("yes");
148                     makert(i);
149                     fa[i]=j;
150                 }
151                 break;
152             case 'p':
153                 access(i);
154                 splay(i);
155                 val[i]=j;
156                 up(i);
157                 break;
158             case 'e':
159                 if(getrt(i)!=getrt(j))
160                     puts("impossible");
161                 else
```

```

162         {
163             makert(i);
164             access(j);
165             splay(j);
166             printf("%d\n",sum[j]);
167         }
168         break;
169     }
170 }
171 return 0;
172 }

```

# 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 if(mid[id]>=r)
62     update(id<<1,ll,mid[id],l,r,val);
63 else
64     if(mid[id]<l)
65         update(id<<1|1,mid[id]+1,rr,l,r,val);
66     else
67     {
68         update(id<<1,ll,mid[id],l,mid[id],val);
69         update(id<<1|1,mid[id]+1,rr,mid[id]+1,r,val);
70     }
71 if(!cnt[id])
72 {
73     len[id]=len[id<<1]+len[id<<1|1];
74     seg[id]=seg[id<<1]+seg[id<<1|1];
75     if(rt[id<<1] && lf[id<<1|1])
76         seg[id];
77     rt[id]=rt[id<<1|1];
78     lf[id]=lf[id<<1];
79 }
80 }
81
82 struct node
83 {
84     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 dsel(int a)
53 {
54     return dsel(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         {
130             Tp ret(val[pos]);
131             if(!l[pos] || !r[pos])
132                 pos = l[pos] + r[pos];
133             else
134                 val[pos] = del(l[pos], val[pos] + 1);

```

```

135     return ret;
136 }
137 else
138     if(a < val[pos])
139         return del(l[pos], a);
140     else
141         return del(r[pos], a);
142 }
143 bool find(int &pos, const Tp &a)
144 {
145     if(!pos)
146         return false;
147     if(a < val[pos])
148         return find(l[pos], a);
149     else
150         return (val[pos] == a || find(r[pos], a));
151 }
152 Tp pred(int &pos, const Tp &a)
153 {
154     if(!pos)
155         return a;
156     if(a > val[pos])
157     {
158         Tp ret(pred(r[pos], a));
159         if(ret == a)
160             return val[pos];
161         else
162             return ret;
163     }
164     return pred(l[pos], a);
165 }
166 Tp succ(int &pos, const Tp &a)
167 {
168     if(!pos)
169         return a;
170     if(a < val[pos])
171     {
172         Tp ret(succ(l[pos], a));
173         if(ret == a)
174             return val[pos];
175         else
176             return ret;
177     }
178     return succ(r[pos], a);
179 }
180 Tp min(int &pos)
181 {
182     if(l[pos])
183         return min(l[pos]);
184     else
185         return val[pos];
186 }
187 Tp max(int &pos)
188 {
189     if(r[pos])
190         return max(r[pos]);
191     else
192         return val[pos];
193 }
194 void dels(int &pos, const Tp &v)
195 {
196     if(!pos)
197         return;
198     if(val[pos] < v)
199     {
200         pos = r[pos];
201         dels(pos, v);
202         return;
203     }
204     dels(l[pos], v);
205     sz[pos] = 1 + sz[l[pos]] + sz[r[pos]];
206 }
207 int rank(const int &pos, const Tp &v)
208 {
209     if(val[pos] == v)
210         return sz[l[pos]] + 1;
211     if(v < val[pos])
212         return rank(l[pos], v);
213     return rank(r[pos], v) + sz[l[pos]] + 1;
214 }
215 Tp sel(const int &pos, const int &v)
216 {
217     if(sz[l[pos]] + 1 == v)
218         return val[pos];
219     if(v > sz[l[pos]] + 1)
220         return sel(r[pos], v - sz[l[pos]] - 1);
221     return sel(l[pos], v);
222 }
223 Tp dsel(int &pos, int k)
224 {
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(1[pos],val[pos]+1);
233         return re;
234     }
235     if(k>sz[1[pos]])
236         return delse1(r[pos],k-1-sz[1[pos]]);
237     return delse1(1[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-1][j][ii][jj],table[i][j-1][ii][jj],table[i-1][j-1][ii][jj]);
39                         else
40                             table[i][j][ii][jj]=std::min(table[i-1][j][ii][jj],table[i][j-1][ii][jj],table[i-1][j-1][ii][jj+(1<<(i-1))]);
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%hd",&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],
21                                                         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]));
22         }
23         printf("Case_%hd:\n",t);
24         while(q-->0)
25         {
26             scanf("%hd%hd%hd",&i,&j,&l);
27             --i;
28             --j;
29             k=lg[l];
30             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])));
31         }
32     }
33 }

```

## 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-->0)
24     {
25         scanf("%d",&i,&j);
26         k=lg[j-i+1];
27         printf("%d\n",std::min(min[i][k],min[j-(1<<k)+1][k]));
28     }
29 }

```

## 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
13 node::node(int a):sz(1),val(a),key(rand()-1){ch[0]=ch[1]=null;}
14
15 class Treap
16 {
17     inline void up(node *pos)
18     {
19         pos->sz=pos->ch[0]->sz+pos->ch[1]->sz+1;
20     }
21     inline void rot(node *&pos,int tp)
22     {
23         node *k(pos->ch[tp]);
24         pos->ch[tp]=k->ch[tp^1];
25         k->ch[tp^1]=pos;
26         up(pos);
27         up(k);
28         pos=k;
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*sin ()*cos ();
50 y=r*sin ()*sin ();
51 z=r*cos ();
52
53 r=sqrt(x*2+y*2+z*2);//??
54 r=sqrt(x^2+y^2+z^2);//??
55
56 =atan(y/x);
57 =acos(z/r);
58
59 r∞[0,]
60 [0,2]
61 [0,]
62
63 lat1 [-/2,/2]
64 lng1 [-,]
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)
89     {
90         gets(buf);
91     }
92 }

```

```
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))*180;
119    printf("The distance to the iceberg: %.2f miles.\n",
120        ans);
121    if(ans+0.005<100)
122        puts("DANGER!");
123
124    gets(buf);
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 //范围值为 0, pi 之间的弧度 [0, pi]
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 }
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```

78     {
79         pla add(b,a,p);
80         add.set();
81         fac.push_back(add);
82     }
83 }
84
85 void dfs(const short &p,const short &nw)
86 {
87     fac[now].ok=false;
88     deal(p,fac[now].b,fac[now].a);
89     deal(p,fac[now].c,fac[now].b);
90     deal(p,fac[now].a,fac[now].c);
91 }
92
93 inline void make()
94 {
95     fac.resize(0);
96     if(n<4)
97         return;
98
99     for(i=1;i<n;++i)
100         if((pnt[0]-pnt[i]).len(>eps)
101         {
102             std::swap(pnt[i],pnt[1]);
103             break;
104         }
105     if(i==n)
106         return;
107
108     for(i=2;i<n;++i)
109         if(((pnt[0]-pnt[1])*(pnt[1]-pnt[i]).len(>eps)
110         {
111             std::swap(pnt[i],pnt[2]);
112             break;
113         }
114     if(i==n)
115         return;
116
117     for(i=3;i<n;++i)
118         if(fabs((pnt[0]-pnt[1])*(pnt[1]-pnt[2])^(pnt[2]-pnt[i]).len(>eps)
119         {
120             std::swap(pnt[3],pnt[i]);
121             break;
122         }
123     if(i==n)
124         return;
125
126     for(i=0;i<4;++i)
127     {
128         pla add((i+1)%4,(i+2)%4,(i+3)%4);
129         if(ptof(pnt[i],add)>0)
130             std::swap(add.c,add.b);
131         add.set();
132         fac.push_back(add);
133     }
134     for(;i<n;++i)
135         for(j=0;j<fac.size();++j)
136             if(fac[j].ok && ptof(pnt[i],fac[j])>eps)
137             {
138                 dfs(i,j);
139                 break;
140             }
141
142     short tmp(fac.size());
143     fac.resize(0);
144     for(i=0;i<tmp;++i)
145         if(fac[i].ok)
146             fac.push_back(fac[i]);
147 }
148
149 inline pv gc() //重心
150 {
151     pv re(0,0,0),o(0,0,0);
152     double all(0),v;
153     for(i=0;i<fac.size();++i)
154     {
155         v=vol(o,pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
156         re+=(pnt[fac[i].a]+pnt[fac[i].b]+pnt[fac[i].c])*0.25*v;
157         all+=v;
158     }
159     return re*(1/all);
160 }
161
162 inline bool same(const short &s,const short &t) //两面是否相等
163 {
164     pv &a=pnt[fac[s].a],&b=pnt[fac[s].b],&c=pnt[fac[s].c];
165     return fabs(vol(a,b,c,pnt[fac[t].a])<eps && fabs(vol(a,b,c,pnt[fac[t].b])<eps && fabs(vol(a,b,c,pnt[fac[t].c])<eps;
166 }
167
168 //表面多边形数目
169 inline short facetcnt()
170 {
171     short ans=0;
172     for(short i=0;i<fac.size();++i)
173     {
174         for(j=0;j<i;++j)
175             if(same(i,j))
176                 break;
177         if(j==i)
178             ++ans;
179     }
180     return ans;
181 }
182
183 //表面三角形数目
184 inline short trianglecnt()
185 {
186     return fac.size();
187 }
188
189 //三点构成的三角形面积*2
190 inline double area(const pv &a,const pv &b,const pv &c)
191 {
192     return (b-a)*(c-a).len();
193 }
194
195 //表面积
196 inline double area()
197 {
198     double ret(0);
199     for(i=0;i<fac.size();++i)
200         ret+=area(pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
201     return ret/2;
202 }
203
204 //体积
205 inline double volume()
206 {
207     pv o(0,0,0);
208     double ret(0);
209     for(short i(0);i<fac.size();++i)
210         ret+=vol(o,pnt[fac[i].a],pnt[fac[i].b],pnt[fac[i].c]);
211     return fabs(ret/6);
212 }
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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].r,c[j].r) <= 0)
17                             del[i] = true;
18         }
19     tn = n;
20     n = 0;
21     for (int i = 0; i < tn; i++)
22         if (del[i] == false)
23             c[n++] = c[i];
24 }
25
26 //ans[i]表示被覆盖i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	<b>double</b> tim;	143	)),
51	<b>int</b> typ;		Point(c[i].c.x+c[i].r*cos(e[j].tim)
52	Event(){} Event( <b>double</b> _tim, <b>int</b> _typ)		,c[i].c.y+c[i].r*sin(e[j].tim)
53	{	144	))/2.0;
54	{	145	}
55	tim = _tim;	146	cur += e[j].typ;
56	typ = _typ;	147	pre[cur] = e[j].tim;
57	}	148	}
58	};	149	for ( <b>int</b> i = 1;i < n;i++)
59		150	ans[i] -= ans[i+1];
60	<b>int</b> cmp( <b>const double</b> & a, <b>const double</b> & b)	151	for ( <b>int</b> i = 1;i <= n;i++)
61	{	152	printf("%d]_=%f\n",i,ans[i]);
62	if (fabs(a-b) < eps) return 0;	153	}
63	if (a < b) return -1;	154	return 0;
64	return 1;	155	}
65	}		
66			
67	<b>bool</b> Eventcmp( <b>const</b> Event& a, <b>const</b> Event& b)	2.4 circle	
68	{	1	//单位圆覆盖
69	return cmp(a.tim,b.tim) < 0;	2	#include<cstdio>
70	}	3	#include<cmath>
71		4	#include<vector>
72	<b>double</b> Area( <b>double</b> theta, <b>double</b> r)	5	#include<algorithm>
73	{	6	
74	return 0.5*r*r*(theta-sin(theta));	7	#define MAXX 333
75	}	8	#define eps 1e-8
76		9	
77	<b>double</b> xmult(Point a,Point b)	10	<b>struct</b> pv
78	{	11	{
79	return a.x*b.y-a.y*b.x;	12	double x,y;
80	}	13	pv(){} pv( <b>const double</b> &xx, <b>const double</b> &yy):x(xx),y(yy){}
81		14	<b>inline</b> pv operator-( <b>const</b> pv &i) <b>const</b>
82	<b>int</b> n,cur,tote;	15	{
83	Circle c[1000];	16	return pv(x-i.x,y-i.y);
84	<b>double</b> ans[1001],pre[1001],AB,AC,BC,theta,fai,a0,a1;	17	}
85	Event e[4000];	18	<b>inline double</b> cross( <b>const</b> pv &i) <b>const</b>
86	Point lab;	19	{
87		20	return x*i.y-y*i.x;
88	<b>int</b> main()	21	}
89	{	22	<b>inline void</b> print()
90	while (scanf("%d",&n) != EOF)	23	{
91	{	24	printf("%lf_\\n",x,y);
92	for ( <b>int</b> i = 0;i < n;i++)	25	}
93	scanf("%lf%lf%lf",&c[i].c.x,&c[i].c.y,&c[i].r);	26	<b>inline double</b> len()
94	for ( <b>int</b> i = 1;i <= n;i++)	27	{
95	ans[i] = 0.0;	28	return sqrt(x*x+y*y);
96	for ( <b>int</b> i = 0;i < n;i++)	29	}
97	{	30	}
98	tote = 0;	31	}pnt[MAXX];
99	e[tote++] = Event(-pi,1);	32	
100	e[tote++] = Event(pi,-1);	33	<b>struct</b> node
101	for ( <b>int</b> j = 0;j < n;j++)	34	{
102	if (j != i)	35	double k;
103	{	36	<b>bool</b> flag;
104	lab = Point(c[j].c.x-c[i].c.x,c[j].c.y-c[i].c.y);	37	node(){} node( <b>const double</b> &kk, <b>const bool</b> &ff):k(kk),flag(ff){}
105	AB = lab.Length();	38	<b>inline bool</b> operator<( <b>const</b> node &i) <b>const</b>
106	AC = c[i].r;	39	{
107	BC = c[j].r;	40	return k<i.k;
108	if (cmp(AB+AC,BC) <= 0)	41	}
109	{	42	}
110	e[tote++] = Event(-pi,1);	43	};
111	e[tote++] = Event(pi,-1);	44	
112	continue;	45	std::vector<node>alpha;
113	}	46	
114	if (cmp(AB+BC,AC) <= 0) continue;	47	<b>short</b> n,i,j,k,l;
115	if (cmp(AB,AC+BC) > 0) continue;	48	<b>short</b> ans,sum;
116	theta = atan2(lab.y,lab.x);	49	<b>double</b> R=2;
117	fai = acos((AC*AC+AB*AB-BC*BC)/(2.0*AC*AB));	50	<b>double</b> theta,phi,d;
118		51	<b>const</b> theta pi(acos(-1.0));
119	a0 = theta-fai;	52	
120	if (cmp(a0,-pi) < 0) a0 += 2*pi;	53	<b>int</b> main()
121	a1 = theta+fai;	54	{
122	if (cmp(a1,pi) > 0) a1 -= 2*pi;	55	alpha.reserve(MAXX<1);
123	if (cmp(a0,a1) > 0)	56	while(scanf("%d",&n),n)
124	{	57	{
125	e[tote++] = Event(a0,1);	58	for (i=0;i<n;++i)
126	e[tote++] = Event(pi,-1);	59	scanf("%lf_\\n",&pnt[i].x,&pnt[i].y);
127	e[tote++] = Event(-pi,1);	60	ans=0;
128	e[tote++] = Event(a1,-1);	61	for (i=0;i<n;++i)
129		62	{
130	else	63	alpha.resize(0);
131	{	64	for (j=0;j<n;++j)
132	e[tote++] = Event(a0,1);	65	if (i!=j)
133	e[tote++] = Event(a1,-1);	66	{
134	}	67	if ((d=(pnt[i]-pnt[j]).len())>R)
135	}	68	continue;
136	sort(e,e+tote,Eventcmp);	69	if ((theta=atan2(pnt[j].y-pnt[i].y,pnt[j].x-pnt[i].x))<0)
137	cur = 0;	70	theta+=2*pi;
138	for ( <b>int</b> j = 0;j < tote;j++)	71	phi=acos(d/R);
139	{	72	alpha.push_back(node(theta-phi,true));
140	if (cur != 0 && cmp(e[j].tim,pre[cur]) != 0)	73	alpha.push_back(node(theta+phi,false));
141	{	74	}
142	ans[cur] += Area(e[j].tim-pre[cur],c[i].r);	75	std::sort(alpha.begin(),alpha.end());
	ans[cur] += xmult(Point(c[i].c.x+c[i].r*cos(pre[cur]),c[i].c.y+c[i].r*sin(pre[cur]),		

```

76         for(j=0;j<alpha.size();++j)
77         {
78             if(alpha[j].flag)
79                 ++sum;
80             else
81                 --sum;
82             ans=std::max(ans,sum);
83         }
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,t1,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     t1=a2-a1;
135     lt=b2-b1;
136     u=(b1-a1).cross(lt)/(t1).cross(lt);
137     return a1+t1*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("%.21f_%.21f_%.21f\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*tr/tr,tv.y*tr/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 }
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```

## 2.5 closest point pair

```

1 //演算法笔记1
2
3 struct Point {double x, y;} p[10], t[10];
4 bool cmpx(const Point& i, const Point& j) {return i.x < j.x;}
5 bool cmpy(const Point& i, const Point& j) {return i.y < j.y;}
6
7 double DnC(int L, int R)
8 {
9     if (L >= R) return 1e9; // 沒有點、只有一個點。
10
11     /* : 把所有點分成左右兩側，點數盡量一樣多。Divide */
12
13     int M = (L + R) / 2;
14
15     /* : 左側、右側分別遞迴求解。Conquer */
16
17     double d = min(DnC(L,M), DnC(M+1,R));
18     // if (d == 0.0) return d; // 提早結束
19
20     /* : 尋找靠近中線的點，並依座標排序。Merge YO(NlogN)。 */
21
22     int N = 0; // 靠近中線的點數目
23     for (int i=M; i>=L && p[M].x - p[i].x < d; --i) t[N++] = p[i];

```

```

24   for (int i=M+1; i<=R && p[i].x - p[M].x < d; ++i) t[N++] =
25       p[i];
26   sort(t, t+N, cmpy); // Quicksort O(NlogN)
27
28   /* : 尋找橫跨兩側的最近點對。MergeO(N)。 */
29   for (int i=0; i<N-1; ++i)
30       for (int j=1; j<=2 && i+j<N; ++j)
31           d = min(d, distance(t[i], t[i+j]));
32
33   return d;
34 }
35
36 double closest_pair()
37 {
38     sort(p, p+10, cmpx);
39     return DnC(0, N-1);
40 }
41
42 //演算法筆記2
43
44 struct Point {double x, y;} p[10], t[10];
45 bool cmpx(const Point& i, const Point& j) {return i.x < j.x;}
46 bool cmpy(const Point& i, const Point& j) {return i.y < j.y;}
47
48 double DnC(int L, int R)
49 {
50     if (L >= R) return 1e9; // 沒有點、只有一個點。
51
52     /* : 把所有點分成左右兩側，點數盡量一樣多。Divide */
53
54     int M = (L + R) / 2;
55
56     // 先把中線的座標記起來，因為待會重新排序之後會跑掉。X
57     double x = p[M].x;
58
59     /* : 左側、右側分別遞迴求解。Conquer */
60
61     // 遞迴求解，並且依照座標重新排序。Y
62     double d = min(DnC(L, M), DnC(M+1, R));
63     // if (d == 0.0) return d; // 提早結束
64
65     /* : 尋找靠近中線的點，並依座標排序。MergeYO(N)。 */
66
67     // 尋找靠近中線的點，先找左側。各點已照座標排序了。Y
68     int N = 0; // 靠近中線的點數目
69     for (int i=0; i<=M; ++i)
70         if (x - p[i].x < d)
71             t[N++] = p[i];
72
73     // 尋找靠近中線的點，再找右側。各點已照座標排序了。Y
74     int P = N; // 為分隔位置P
75     for (int i=M+1; i<=R; ++i)
76         if (p[i].x - x < d)
77             t[N++] = p[i];
78
79     // 以座標排序。使用YMerge方式，合併已排序的兩陣列。Sort
80     inplace_merge(t, t+P, t+N, cmpy);
81
82     /* : 尋找橫跨兩側的最近點對。MergeO(N)。 */
83
84     for (int i=0; i<N; ++i)
85         for (int j=1; j<=2 && i+j<N; ++j)
86             d = min(d, distance(t[i], t[i+j]));
87
88     /* : 重新以座標排序所有點。MergeYO(N)。 */
89
90     // 如此一來，更大的子問題就可以直接使用Merge。Sort
91     inplace_merge(p+L, p+M+1, p+R+1, cmpy);
92
93     return d;
94 }
95
96 double closest_pair()
97 {
98     sort(p, p+10, cmpx);
99     return DnC(0, N-1);
100 }
101
102 //mzry
103 //分治
104 double calc_dis(Point &a, Point &b) {
105     return sqrt((a.x-b.x)*(a.x-b.x) + (a.y-b.y)*(a.y-b.y));
106 }
107
108 //別忘了排序
109 bool operator<(const Point &a, const Point &b) {
110     if (a.y != b.y) return a.x < b.x;
111     return a.x < b.x;
112 }
113 double Gao(int l, int r, Point pnts[]) {
114     double ret = inf;
115     if (l == r) return ret;
116
117     if (l+1 == r) {
118         ret = min(calc_dis(pnts[l], pnts[l+1]), ret);
119         return ret;
120     }
121     if (l+2 == r) {
122         ret = min(calc_dis(pnts[l], pnts[l+1]), ret);
123         ret = min(calc_dis(pnts[l], pnts[l+2]), ret);
124         ret = min(calc_dis(pnts[l+1], pnts[l+2]), ret);
125         return ret;
126     }
127
128     int mid = l+r>>1;
129     ret = min (ret, Gao(l, mid, pnts));
130     ret = min (ret, Gao(mid+1, r, pnts));
131
132     for (int c = l; c<=r; c++)
133         for (int d = c+1; d<=c+7 && d<=r; d++) {
134             ret = min(ret, calc_dis(pnts[c], pnts[d]));
135         }
136     return ret;
137 }
138
139 //增量
140 #include <iostream>
141 #include <cstdio>
142 #include <cstring>
143 #include <map>
144 #include <vector>
145 #include <cmath>
146 #include <algorithm>
147 #define Point pair<double, double>
148 using namespace std;
149
150 const int step[9][2] =
151     {{-1, -1}, {-1, 0}, {-1, 1}, {0, -1}, {0, 0}, {0, 1}, {1, -1}, {1, 0}, {1, 1}};
152
153 int n, x, y, nx, ny;
154 map<pair<int, int>, vector<Point>> g;
155 vector<Point> tmp;
156 Point p[20000];
157 double tx, ty, ans, nowans;
158 vector<Point>::iterator it, op, ed;
159 pair<int, int> gird;
160 bool flag;
161
162 double Dis(Point p0, Point p1)
163 {
164     return sqrt((p0.first-p1.first)*(p0.first-p1.first)+
165                 (p0.second-p1.second)*(p0.second-p1.second));
166 }
167
168 double CalcDis(Point p0, Point p1, Point p2)
169 {
170     return Dis(p0, p1)+Dis(p0, p2)+Dis(p1, p2);
171 }
172
173 void build(int n, double w)
174 {
175     g.clear();
176     for (int i = 0; i < n; i++)
177         g[make_pair((int)floor(p[i].first/w), (int)floor(p[i].second/w))].push_back(p[i]);
178 }
179
180 int main()
181 {
182     int t;
183     scanf("%d", &t);
184     for (int ft = 1; ft <= t; ft++)
185     {
186         scanf("%d", &n);
187         for (int i = 0; i < n; i++)
188         {
189             scanf("%lf%lf", &tx, &ty);
190             p[i] = make_pair(tx, ty);
191         }
192         random_shuffle(p, p+n);
193         ans = CalcDis(p[0], p[1], p[2]);
194         build(3, ans/2.0);
195         for (int i = 3; i < n; i++)
196         {
197             x = (int)floor(2.0*p[i].first/ans);
198             y = (int)floor(2.0*p[i].second/ans);
199             tmp.clear();
200             for (int k = 0; k < 9; k++)
201             {
202                 nx = x+step[k][0];
203                 ny = y+step[k][1];
204                 gird = make_pair(nx, ny);
205                 if (g.find(gird) != g.end())
206                 {
207                     op = g[gird].begin();
208                     ed = g[gird].end();
209                     for (it = op; it != ed; it++)
210                         tmp.push_back(*it);
211                 }
212             }
213         }
214     }
215 }

```



```

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(
225             (2.0*p[i].second/ans)))] .push_back(p[i]);
226     printf("%.3f\n", ans);
227 }
228 }

```

## 2.6 ellipse

```

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

```

## 2.7 Graham's scan

```

1  | pv pnt[1000];
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.
29 |             size()-2])<eps)
30 |             ch.pop_back();
31 |         ch.push_back(pnt[i]);
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 |     t1=b-a;
64 |     return pv(u*t1.x/v+a.x, u*t1.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(ins(p[j][k], 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(ins(p[j][k], 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[tot++] = 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 bool InCircle(Point a, double r)
2 {
3     return cmp(a.x*a.x+a.y*a.y, r*r) <= 0;
4     //这里判断的时候 EPS 一定不要太小!!
5 }
6
7 double CalcArea(Point a, Point b, double r)
8 {
9     Point p[4];
10    int tot = 0;
11    p[tot++] = a;
12
13    Point tv = Point(a, b);
14    Line tmp = Line(Point(0, 0), Point(tv.y, -tv.x));
15    Point near = LineToLine(Line(a, b), tmp);
16    if (cmp(near.x*near.x+near.y*near.y, r*r) <= 0)
17    {
18        double A, B, C;
19        A = near.x*near.x+near.y*near.y;
20        C = r;
21        B = C*C-A;
22        double tvl = tv.x*tv.x+tv.y*tv.y;
23        double tmp = sqrt(B/tvl); //这样做只用一次开根
24        p[tot] = Point(near.x+tmp*tv.x, near.y+tmp*tv.y);
25        if (OnSeg(Line(a, b), p[tot]) == true) tot++;
26        p[tot] = Point(near.x-tmp*tv.x, near.y-tmp*tv.y);
27        if (OnSeg(Line(a, b), p[tot]) == true) tot++;
28    }
29    if (tot == 3)
30    {
31        if (cmp(Point(p[0], p[1]).Length(), Point(p[0], p[2]).Length()) > 0)
32            swap(p[1], p[2]);
33    }
34    p[tot++] = b;
35
36    double res = 0.0, theta, a0, a1, sgn;
37    for (int i = 0; i < tot-1; i++)
38    {
39        if (InCircle(p[i], r) == true && InCircle(p[i+1], r) == true)
40        {
41            res += 0.5*mult(p[i], p[i+1]);
42        }
43        else

```

```

44    {
45        a0 = atan2(p[i+1].y, p[i+1].x);
46        a1 = atan2(p[i].y, p[i].x);
47        if (a0 < a1) a0 += 2*pi;
48        theta = a0-a1;
49        if (cmp(theta, pi) >= 0) theta = 2*pi-theta;
50        sgn = mult(p[i], p[i+1])/2.0;
51        if (cmp(sgn, 0) < 0) theta = -theta;
52        res += 0.5*r*r*theta;
53    }
54 }
55 return res;
56 }
57
58 //调用
59
60 area2 = 0.0;
61 for (int i = 0; i < resn; i++) //遍历每条边, 按照逆时针
62     area2 += CalcArea(p[i], p[(i+1)%resn], r);

```

## 2.10 k-d tree

```

/*
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, 更容易查找出正确解。
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],
60         rg[rson][0][0]));
61     rg[id][1][0]=std::min(rg[id][1][0], std::min(rg[lson][1][0],
62         rg[rson][1][0]));
63
64     rg[id][0][1]=std::max(rg[id][0][1], std::max(rg[lson][0][1],
65         rg[rson][0][1]));
66     rg[id][1][1]=std::max(rg[id][1][1], std::max(rg[lson][1][1],
67         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; //点的个数
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;
25     while ( a != 0 )
26     {
27         if ( c[ a ] > b )
28         {
29             c[ a ] = b;
30             d[ a ] = i;
31         }
32         else break;
33         a >>= 1;
34     }
35 }
36
37 int find( int a ) //从c[0..a]中找最小的数, 线段树查询
38 {
39     a += ra;
40     int ret = d[ a ], max = c[ a ];
41     while ( a > 1 )
42     {
43         if ( ( a & 1 ) == 1 )
44             if ( c[ --a ] < max )
45             {
46                 max = c[ a ];
47                 ret = d[ a ];
48             }
49         a >>= 1;
50     }
51     return ret;
52 }
53
54 int ta[ 65536 ], tb[ 100000 ]; //基数排序临时变量
55
56 int radixsort( int *p ) //基数排序, 以为基准p
57 {
58     memset( ta, 0, sizeof( ta ) );
59     for ( int i = 0; i < n; i++ ) ta[ p[ i ] & 0xffff ]++;
60     for ( int i = 0; i < 65535; i++ ) ta[ i + 1 ] += ta[ i ];
61     for ( int i = n - 1; i >= 0; i-- ) tb[ --ta[ p[ order[ i ] ] & 0xffff ] ] = order[ i ];
62     memmove( order, tb, n * sizeof( int ) );
63     memset( ta, 0, sizeof( ta ) );
64     for ( int i = 0; i < n; i++ ) ta[ p[ i ] >> 16 ]++;
65     for ( int i = 0; i < 65535; i++ ) ta[ i + 1 ] += ta[ i ];
66     for ( int i = n - 1; i >= 0; i-- ) tb[ --ta[ p[ order[ i ] ] >> 16 ] ] = order[ i ];
67     memmove( order, tb, n * sizeof( int ) );
68 }
69
70 int work( int ii ) //求每个点在一个方向上最近的点
71 {
72     for ( int i = 0; i < n; i++ ) //排序前的准备工作
73     {
74         a[ i ] = y[ i ] - x[ i ] + srange;
75         b[ i ] = srange - y[ i ];
76         order[ i ] = i;
77     }
78     radixsort( b ); //排序
79     radixsort( a );
80     for ( int i = 0; i < n; i++ )
81     {
82         torder[ i ] = order[ i ];
83         order[ i ] = i;
84     }
85     radixsort( a ); //为线段树而做的排序
86     radixsort( b );
87     for ( int i = 0; i < n; i++ )
88     {
89         Index[ order[ i ] ] = i; //取反, 求orderIndex
90     }
91     for ( int i = 1; i < ra + n; i++ ) c[ i ] = 0x7fffffff; //线段树初始化
92     memset( d, 0xff, sizeof( d ) );
93     for ( int i = 0; i < n; i++ ) //线段树插入删除调用
94     {
95         int tt = torder[ i ];
96         road[ tt ][ ii ] = find( Index[ tt ] );
97         insert( Index[ tt ], y[ tt ] + x[ tt ], tt );
98     }
99 }
100
101 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
102 {
103     return abs( x[ a ] - x[ b ] ) + abs( y[ a ] - y[ b ] );
104 }
105
106 int ttb[ 400000 ]; //边排序的临时变量
107 int rx[ 400000 ], ry[ 400000 ], rd[ 400000 ]; //边的存储
108 int rr = 0;
109
110 int radixsort_2( int *p ) //还是基数排序, copy+的产物paste
111 {
112     memset( ta, 0, sizeof( ta ) );
113     for ( int i = 0; i < rr; i++ ) ta[ p[ i ] & 0xffff ]++;
114     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         ] >> 16 ] ] = order[ i ];
122         memmove( order, ttb, rr * sizeof( int ) );
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
185             //理
186             //为了降低算法复杂度, 只求出个方向的边
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 ] = strange - x[ j ];
194             }
195             work( i );
196             printf( "Case%d: Total Weight = ", ++casenum );
197             cout << kruskal() << endl;
198         }
199     return 0;
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,π]
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 的数字在哪一位上, 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一单位。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
7
8   $A = 2 \times i + b - 2$ 
9

```

## 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 —  点在内poly
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sider
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     if (OnSeg(side.e, ray))
39     {
40         if (side.e.y > side.s.y)
41             count++;
42     }
43     else
44         if (inter(ray, side))
45             count++;
46 }
47 return ((count % 2 == 1) ? 0 : 2);
48 }

```

## 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         t1=pnt[(i+1)%n]-pnt[i];
9         while(abs(t1.cross(pnt[(l+1)%n]-pnt[l]))>=abs(t1.cross(pnt[l+1]-pnt[l])))
10             l=(l+1)%n;
11         ans=std::max(ans, std::max(dist(pnt[l], pnt[i]), dist(pnt[l], pnt[(i+1)%n])));
12     }
13     return ans;
14 }
15
16 //两凸包最近距离
17 double go()
18 {
19     sq=sp=0;
20     for(i=1;i<ch[1].size();++i)
21         if(ch[1][sq]<ch[1][i])
22             sq=i;
23     tp=sp;
24     tq=sq;
25     ans=(ch[0][sp]-ch[1][sq]).len();
26     do
27     {
28         a1=ch[0][sp];
29         a2=ch[0][(sp+1)%ch[0].size()];
30         b1=ch[1][sq];
31         b2=ch[1][(sq+1)%ch[1].size()];
32         tpv=b1-(b2-a1);
33         tpv.x = b1.x - (b2.x - a1.x);
34         tpv.y = b1.y - (b2.y - a1.y);
35         len=(tpv-a1).cross(a2-a1);
36         if(fabs(len)<eps)
37         {
38             ans=std::min(ans, p2l(a1, b1, b2));
39             ans=std::min(ans, p2l(a2, b1, b2));
40             ans=std::min(ans, p2l(b1, a1, a2));
41             ans=std::min(ans, p2l(b2, a1, a2));
42             sp=(sp+1)%ch[0].size();
43             sq=(sq+1)%ch[1].size();
44         }
45         else
46             if(len<-eps)
47             {
48                 ans=std::min(ans, p2l(b1, a1, a2));
49                 sp=(sp+1)%ch[0].size();
50             }
51             else
52             {
53                 ans=std::min(ans, p2l(a1, b1, b2));
54                 sq=(sq+1)%ch[1].size();
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     vc = Point(-va.x, -va.y);
76     vb = 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
    对 (p(i), q(j)) 形成 P 和 Q 之间的桥当且仅当:
116
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
    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
    别计算
119
120
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
    的。、构造这些点的逐平切线,
123 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
    条切线直到其中一条与边相交。
124 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。
    、对于所有有效的并踵点对
125 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
    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
    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。
126 5 34、所有可能的桥此时都已确定。
127 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。
    运行时间受步骤, 约束。
128
129 156 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。
    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,
    桥也是计算凸多边形交的算法核心。
130
131
132
133 //临界切线、计算
134 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
    为)。ymaxQ、为多边形在
135 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
    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
    点对。检测是否有 p(i-1), p(i+1) 在线 (p(i), q(j)) 的一侧, 并
    且 q(j-1), q(j+1) 在另一侧。如果成立, (p(i), q(j)) 确定了一条
    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。
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
    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

```

```

140 | 7线。CS
141 |
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，
143 | 1 称之为， xminP , xmaxP , yminP , ymaxP、通过四个点构造
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
      重合，
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
      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。
146 | 4、计算新矩形的周长面积，
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息。
      、重复步骤和步骤，
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。
149 | 7

```

## 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 | {
68 |     return fabs((p-a[0]).cross(p-a[1]))<eps && (p-a[0]).dot(p-a[1])<eps;
69 | }
70 |
71 | pv rotate(pv v,pv p,double theta,double sc=1) // rotate vector
      v, theta [0,2]
72 | {
73 |     static pv re;
74 |     re=p;
75 |     v=v-p;
76 |     p.x=sc*cos(theta);

```

```

77 |     p.y=sc*sin(theta);
78 |     re.x+=v.x*p.x-v.y*p.y;
79 |     re.y+=v.x*p.y+v.y*p.x;
80 |     return re;
81 | }
82 |
83 | struct line
84 | {
85 |     pv pnt[2];
86 |     line(double a,double b,double c) // a*x + b*y + c = 0
87 |     {
88 |
89 | #define maxl 1e2 //preciseness should not be too high ( compare
      with eps )
90 |         if(fabs(b)>eps)
91 |         {
92 |             pnt[0]=pv(maxl,(c+a*maxl)/(-b));
93 |             pnt[1]=pv(-maxl,(c-a*maxl)/(-b));
94 |         }
95 |         else
96 |         {
97 |             pnt[0]=pv(-c/a,maxl);
98 |             pnt[1]=pv(-c/a,-maxl);
99 |         }
100 | #undef maxl
101 |     }
102 |     pv cross(const line &v) const
103 |     {
104 |         double a=(v.pnt[1]-v.pnt[0]).cross(pnt[0]-v.pnt[0]);
105 |         double b=(v.pnt[1]-v.pnt[0]).cross(pnt[1]-v.pnt[0]);
106 |         return pv((pnt[0].x*b-pnt[1].x*a)/(b-a),(pnt[0].y*b-pnt[1].y*a)/(b-a));
107 |     }
108 | };
109 |
110 | inline std::pair<pv,double> getcircle(const pv &a,const pv &b,
      const pv &c)
111 | {
112 |     static pv ct;
113 |     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()));
114 |     return std::make_pair(ct,sqrt((ct-a).len()));
115 | }

```

## 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 |  $\tan \frac{\alpha}{2} \tan \frac{\beta}{2} + \tan \frac{\beta}{2} \tan \frac{\gamma}{2} + \tan \frac{\gamma}{2} \tan \frac{\alpha}{2} = 1$ 
14 |  $\sin^2 \frac{\alpha}{2} + \sin^2 \frac{\beta}{2} + \sin^2 \frac{\gamma}{2} + 2 \sin \frac{\alpha}{2} \sin \frac{\beta}{2} \sin \frac{\gamma}{2} = 1$ 
15 |
16 | Circumscribed circle:
17 |  $diameter = \frac{abc}{2 \cdot area} = \frac{|AB||BC||CA|}{2|\Delta ABC|}$ 
18 |  $= \frac{abc}{2\sqrt{s(s-a)(s-b)(s-c)}}$ 
19 |  $= \frac{2abc}{\sqrt{(a+b+c)(-a+b+c)(a-b+c)(a+b-c)}}$ 
20 |  $diameter = \sqrt{\frac{2 \cdot area}{\sin A \sin B \sin C}}$ 
21 |  $diameter = \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$ 
22 | Incircle:
23 |  $inradius = \frac{2 \times area}{a+b+c}$ 
24 |  $coordinates(x_a, y_a) = \left( \frac{ax_a + bx_b + cx_c}{a+b+c}, \frac{ay_a + by_b + cy_c}{a+b+c} \right) =$ 
       $\frac{a}{a+b+c}(x_a, y_a) + \frac{b}{a+b+c}(x_b, y_b) + \frac{c}{a+b+c}(x_c, y_c)$ 

```

```

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  $\triangle ABC'$ ， $\triangle BCA'$ ， $\triangle CAB'$ 。
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 circle

```

1 | struct circle
2 | {
3 |     point p;
4 |     double r;
5 |     circle(){}
6 |     circle(point _p,double _r):
7 |     p(_p),r(_r){};
8 |     circle(double x,double y,double _r):
9 |     p(point(x,y)),r(_r){};
10 |    circle(point a,point b,point c)//三角形的外接圆
11 |    {
12 |        p=line(a.add(b).div(2),a.add(b).div(2).add(b.sub(a).
13 |            rotright()).crosspoint(line(c.add(b).div(2),c.add(b).
14 |            .div(2).add(b.sub(c).rotright())));
15 |        r=p.distance(a);
16 |    }
17 |    circle(point a,point b,point c,bool t)//三角形的内切圆
18 |    {
19 |        line u,v;
20 |        double m=atan2(b.y-a.y,b.x-a.x),n=atan2(c.y-a.y,c.x-a.x);
21 |        u.a=a;
22 |        u.b=u.a.add(point(cos((n+m)/2),sin((n+m)/2)));
23 |        v.a=b;
24 |        m=atan2(a.y-b.y,a.x-b.x),n=atan2(c.y-b.y,c.x-b.x);
25 |        v.b=v.a.add(point(cos((n+m)/2),sin((n+m)/2)));
26 |        p=u.crosspoint(v);
27 |        r=line(a,b).dispointtoseg(p);
28 |    }
29 |    void input()
30 |    {
31 |        p.input();
32 |        scanf("%lf",&r);
33 |    }
34 |    void output()
35 |    {
36 |        printf("%.2lf_%.2lf_%.2lf\n",p.x,p.y,r);
37 |    }
38 |    bool operator==(circle v)
39 |    {
40 |        return ((p==v.p)&&dbcmp(r-v.r)==0);
41 |    }
42 |    bool operator<(circle v)const
43 |    {
44 |        return ((p<v.p)||((p==v.p)&&dbcmp(r-v.r)<0));
45 |    }
46 |    double area()
47 |    {
48 |        return pi*sqr(r);
49 |    }
50 |    double circumference()
51 |    {
52 |        return 2*pi*r;
53 |    }
54 |    //0 圆外
55 |    //1 圆上
56 |    //2 圆内
57 |    int relation(point b)
58 |    {
59 |        double dst=b.distance(p);
60 |        if (dbcmp(dst-r)<0)return 2;
61 |        if (dbcmp(dst-r)==0)return 1;
62 |        return 0;
63 |    }
64 |    int relationseg(line v)
65 |    {
66 |        double dst=v.dispointtoseg(p);

```

```

65 |         if (dbcmp(dst-r)<0)return 2;
66 |         if (dbcmp(dst-r)==0)return 1;
67 |         return 0;
68 |     }
69 |     int relationline(line v)
70 |     {
71 |         double dst=v.dispointtoline(p);
72 |         if (dbcmp(dst-r)<0)return 2;
73 |         if (dbcmp(dst-r)==0)return 1;
74 |         return 0;
75 |     }
76 |     //过a 两点b 半径的两个圆r
77 |     int getcircle(point a,point b,double r,circle&c1,circle&c2)
78 |     {
79 |         circle x(a,r),y(b,r);
80 |         int t=x.pointcrosscircle(y,c1.p,c2.p);
81 |         if (!t)return 0;
82 |         c1.r=c2.r=r;
83 |         return t;
84 |     }
85 |     //与直线相切u 过点q 半径的圆r1
86 |     int getcircle(line u,point q,double r1,circle &c1,circle &
87 |         c2)
88 |     {
89 |         double dis=u.dispointtoline(q);
90 |         if (dbcmp(dis-r1*2)>0)return 0;
91 |         if (dbcmp(dis)==0)
92 |         {
93 |             c1.p=q.add(u.b.sub(u.a).rotright().trunc(r1));
94 |             c2.p=q.add(u.b.sub(u.a).rotright().trunc(r1));
95 |             c1.r=c2.r=r1;
96 |             return 2;
97 |         }
98 |         line u1=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.
99 |             b.add(u.b.sub(u.a).rotright().trunc(r1)));
100 |         line u2=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.
101 |             .b.add(u.b.sub(u.a).rotright().trunc(r1)));
102 |         circle cc=circle(q,r1);
103 |         point p1,p2;
104 |         if (!cc.pointcrossline(u1,p1,p2))cc.pointcrossline(u2,p1,
105 |             p2);
106 |         c1=circle(p1,r1);
107 |         if (p1==p2)
108 |         {
109 |             c2=c1;return 1;
110 |         }
111 |         c2=circle(p2,r1);
112 |         return 2;
113 |     }
114 |     //同时与直线u,相切v 半径的圆r1
115 |     int getcircle(line u,line v,double r1,circle &c1,circle &c2
116 |         ,circle &c3,circle &c4)
117 |     {
118 |         if (u.parallel(v))return 0;
119 |         line u1=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.
120 |             b.add(u.b.sub(u.a).rotright().trunc(r1)));
121 |         line u2=line(u.a.add(u.b.sub(u.a).rotright().trunc(r1)),u.
122 |             .b.add(u.b.sub(u.a).rotright().trunc(r1)));
123 |         line v1=line(v.a.add(v.b.sub(v.a).rotright().trunc(r1)),v.
124 |             b.add(v.b.sub(v.a).rotright().trunc(r1)));
125 |         line v2=line(v.a.add(v.b.sub(v.a).rotright().trunc(r1)),v.
126 |             .b.add(v.b.sub(v.a).rotright().trunc(r1)));
127 |         c1.r=c2.r=c3.r=c4.r=r1;
128 |         c1.p=u1.crosspoint(v1);
129 |         c2.p=u1.crosspoint(v2);
130 |         c3.p=u2.crosspoint(v1);
131 |         c4.p=u2.crosspoint(v2);
132 |         return 4;
133 |     }
134 |     //同时与不相交圆cx,相切cy 半径为的圆r1
135 |     int getcircle(circle cx,circle cy,double r1,circle&c1,circle&
136 |         c2)
137 |     {
138 |         circle x(cx.p,r1+cx.r),y(cy.p,r1+cy.r);
139 |         int t=x.pointcrosscircle(y,c1.p,c2.p);
140 |         if (!t)return 0;
141 |         c1.r=c2.r=r1;
142 |         return t;
143 |     }
144 |     int pointcrossline(line v,point &p1,point &p2)//求与线段交要
145 |         先判断relationseg
146 |     {
147 |         if (!(*this).relationline(v))return 0;
148 |         point a=v.lineprog(p);
149 |         double d=v.dispointtoline(p);
150 |         d=sqrt(r*r-d*d);
151 |         if (dbcmp(d)==0)
152 |         {
153 |             p1=a;
154 |             p2=a;
155 |             return 1;
156 |         }
157 |         p1=a.sub(v.b.sub(v.a).trunc(d));
158 |         p2=a.add(v.b.sub(v.a).trunc(d));
159 |         return 2;

```

```

149     }
150     //5 相离
151     //4 外切
152     //3 相交
153     //2 内切
154     //1 内含
155     int relationcircle(circle v)
156     {
157         double d=p.distance(v.p);
158         if (dblcmp(d-r-v.r)>0)return 5;
159         if (dblcmp(d-r-v.r)==0)return 4;
160         double l=fabs(r-v.r);
161         if (dblcmp(d-r-v.r)<0&&dblcmp(d-l)>0)return 3;
162         if (dblcmp(d-l)==0)return 2;
163         if (dblcmp(d-l)<0)return 1;
164     }
165     int pointcrosscircle(circle v,point &p1,point &p2)
166     {
167         int rel=relationcircle(v);
168         if (rel==1||rel==5)return 0;
169         double d=p.distance(v.p);
170         double l=(d+(sqrt(r)-sqrt(v.r))/d)/2;
171         double h=sqrt((sqrt(r)-sqrt(l)));
172         p1=p.add(v.p.sub(p).trunc(l).add(v.p.sub(p).rotleft().trunc(h)));
173         p2=p.add(v.p.sub(p).trunc(l).add(v.p.sub(p).rotright().trunc(h)));
174         if (rel==2||rel==4)
175         {
176             return 1;
177         }
178         return 2;
179     }
180     //过一点做圆的切线 先判断点和圆关系()
181     int tangentline(point q,line &u,line &v)
182     {
183         int x=relation(q);
184         if (x==2)return 0;
185         if (x==1)
186         {
187             u=line(q,q.add(q.sub(p).rotleft()));
188             v=u;
189             return 1;
190         }
191         double d=p.distance(q);
192         double l=sqrt(r)/d;
193         double h=sqrt((sqrt(r)-sqrt(l)));
194         u=line(q,p.add(q.sub(p).trunc(l).add(q.sub(p).rotleft().trunc(h))));
195         v=line(q,p.add(q.sub(p).trunc(l).add(q.sub(p).rotright().trunc(h))));
196         return 2;
197     }
198     double areacircle(circle v)
199     {
200         int rel=relationcircle(v);
201         if (rel>=4)return 0.0;
202         if (rel<=2)return min(area(),v.area());
203         double d=p.distance(v.p);
204         double hf=(r+v.r+d)/2.0;
205         double ss=2*sqrt(hf*(hf-r)*(hf-v.r)*(hf-d));
206         double a1=acos((r*r+d*d-v.r*v.r)/(2.0*r*d));
207         a1=a1*r;
208         double a2=acos((v.r*v.r+d*d-r*r)/(2.0*v.r*d));
209         a2=a2*v.r;
210         return a1+a2-ss;
211     }
212     double areatriangle(point a,point b)
213     {
214         if (dblcmp(p.sub(a).det(p.sub(b))==0)return 0.0;
215         point q[5];
216         int len=0;
217         q[len++]=a;
218         line l(a,b);
219         point p1,p2;
220         if (pointcrossline(l,q[1],q[2])==2)
221         {
222             if (dblcmp(a.sub(q[1]).dot(b.sub(q[1]))<0)q[len++]+=q[1];
223             if (dblcmp(a.sub(q[2]).dot(b.sub(q[2]))<0)q[len++]+=q[2];
224         }
225         q[len++]+=b;
226         if (len==4&&dblcmp(q[0].sub(q[1]).dot(q[2].sub(q[1]))>0)swap(q[1],q[2]);
227         double res=0;
228         int i;
229         for (i=0;i<len-1;i++)
230         {
231             if (relation(q[i])==0||relation(q[i+1])==0)
232             {
233                 double arg=p.rad(q[i],q[i+1]);
234                 res+=r*r*arg/2.0;
235             }
236             else

```

```

237         {
238             res+=fabs(q[i].sub(p).det(q[i+1].sub(p))/2.0);
239         }
240     }
241     return res;
242 }
243 };

```

## 3.2 circles

```

1 const int maxn=500;
2 struct circles
3 {
4     circle c[maxn];
5     double ans[maxn]; //ans[i]表示被覆盖了i次的面积
6     double pre[maxn];
7     int n;
8     circles(){}
9     void add(circle cc)
10    {
11        c[n++]=cc;
12    }
13    bool inner(circle x,circle y)
14    {
15        if (x.relationcircle(y)!=1)return 0;
16        return dblcmp(x.r-y.r)<=0?1:0;
17    }
18    void init_or() //圆的面积并去掉内含的圆
19    {
20        int i,j,k=0;
21        bool mark[maxn]={0};
22        for (i=0;i<n;i++)
23        {
24            for (j=0;j<n;j++)if (i!=j&&!mark[j])
25            {
26                if ((c[i]==c[j])||inner(c[i],c[j]))break;
27            }
28            if (j<n)mark[i]=1;
29        }
30        for (i=0;i<n;i++)if (!mark[i])c[k++]=c[i];
31        n=k;
32    }
33    void init_and() //圆的面积交去掉内含的圆
34    {
35        int i,j,k=0;
36        bool mark[maxn]={0};
37        for (i=0;i<n;i++)
38        {
39            for (j=0;j<n;j++)if (i!=j&&!mark[j])
40            {
41                if ((c[i]==c[j])||inner(c[j],c[i]))break;
42            }
43            if (j<n)mark[i]=1;
44        }
45        for (i=0;i<n;i++)if (!mark[i])c[k++]=c[i];
46        n=k;
47    }
48    double areaarc(double th,double r)
49    {
50        return 0.5*sqr(r)*(th-sin(th));
51    }
52    void getarea()
53    {
54        int i,j,k;
55        memset(ans,0,sizeof(ans));
56        vector<pair<double,int>> >v;
57        for (i=0;i<n;i++)
58        {
59            v.clear();
60            v.push_back(make_pair(-pi,1));
61            v.push_back(make_pair(pi,-1));
62            for (j=0;j<n;j++)if (i!=j)
63            {
64                point q=c[j].p.sub(c[i].p);
65                double ab=q.len(),ac=c[i].r,bc=c[j].r;
66                if (dblcmp(ab+ac-bc)<=0)
67                {
68                    v.push_back(make_pair(-pi,1));
69                    v.push_back(make_pair(pi,-1));
70                    continue;
71                }
72                if (dblcmp(ab+bc-ac)<=0)continue;
73                if (dblcmp(ab-ac-bc)>0) continue;
74                double th=atan2(q.y,q.x),fai=acos((ac*ac+ab*ab-bc*bc)/(2.0*ac*ab));
75                double a0=th-fai;
76                if (dblcmp(a0+pi)<0)a0+=2*pi;
77                double a1=th+fai;
78                if (dblcmp(a1-pi)>0)a1-=2*pi;
79                if (dblcmp(a0-a1)>0)
80                {
81                    v.push_back(make_pair(a0,1));
82                    v.push_back(make_pair(pi,-1));
83                    v.push_back(make_pair(-pi,1));
84                    v.push_back(make_pair(a1,-1));

```



```

85     }
86     else
87     {
88         v.push_back(make_pair(a0,1));
89         v.push_back(make_pair(a1,-1));
90     }
91 }
92 sort(v.begin(),v.end());
93 int cur=0;
94 for (j=0;j<v.size();j++)
95 {
96     if (cur&&dblcmp(v[j].first-pre[cur]))
97     {
98         ans[cur]+=areaarc(v[j].first-pre[cur],c[i].r);
99         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])).det(point(c[i].p.x+c[i].r*cos(v[j].first),c[i].p.y+c[i].r*sin(v[j].first)));
100     }
101     cur+=v[j].second;
102     pre[cur]=v[j].first;
103 }
104 }
105 for (i=1;i<=n;i++)
106 {
107     ans[i]-=ans[i+1];
108 }
109 }
110 };

```

### 3.3 halfplane

```

1 struct halfplane:public line
2 {
3     double angle;
4     halfplane(){}
5     //表示向量 a->逆时针b左侧()的半平面
6     halfplane(point _a,point _b)
7     {
8         a=_a;
9         b=_b;
10    }
11    halfplane(line v)
12    {
13        a=v.a;
14        b=v.b;
15    }
16    void calcangle()
17    {
18        angle=atan2(b.y-a.y,b.x-a.x);
19    }
20    bool operator<(const halfplane &b)const
21    {
22        return angle<b.angle;
23    }
24 };
25 struct halfplanes
26 {
27     int n;
28     halfplane hp[maxp];
29     point p[maxp];
30     int que[maxp];
31     int st,ed;
32     void push(halfplane tmp)
33     {
34         hp[n++]=tmp;
35     }
36     void unique()
37     {
38         int m=1,i;
39         for (i=1;i<n;i++)
40         {
41             if (dblcmp(hp[i].angle-hp[i-1].angle))hp[m++]=hp[i];
42             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];
43         }
44         n=m;
45     }
46     bool halfplaneinsert()
47     {
48         int i;
49         for (i=0;i<n;i++)hp[i].calcangle();
50         sort(hp,hp+n);
51         unique();
52         que[st=0]=0;
53         que[ed=1]=1;
54         p[1]=hp[0].crosspoint(hp[1]);
55         for (i=2;i<n;i++)
56         {
57             while (st<ed&&dblcmp((hp[i].b.sub(hp[i].a).det(p[ed].sub(hp[i].a))))<0)ed--;
58             while (st<ed&&dblcmp((hp[i].b.sub(hp[i].a).det(p[st+1].sub(hp[i].a))))<0)st++;
59             que[++ed]=i;
60             if (hp[i].parallel(hp[que[ed-1]]))return false;

```

```

61         p[ed]=hp[i].crosspoint(hp[que[ed-1]]);
62     }
63     while (st<ed&&dblcmp(hp[que[st]].b.sub(hp[que[st]].a).det(p[ed].sub(hp[que[st]].a)))<0)ed--;
64     while (st<ed&&dblcmp(hp[que[ed]].b.sub(hp[que[ed]].a).det(p[st+1].sub(hp[que[ed]].a)))<0)st++;
65     if (st+1==ed)return false;
66     return true;
67 }
68 void getconvex(polygon &con)
69 {
70     p[st]=hp[que[st]].crosspoint(hp[que[ed]]);
71     con.n=ed-st+1;
72     int j=st,i=0;
73     for (;j<=ed;i++,j++)
74     {
75         con.p[i]=p[j];
76     }
77 }
78 };

```

### 3.4 line

```

1 struct line
2 {
3     point a,b;
4     line(){}
5     line(point _a,point _b)
6     {
7         a=_a;
8         b=_b;
9     }
10    bool operator==(line v)
11    {
12        return (a==v.a)&&(b==v.b);
13    }
14    //倾斜角angle
15    line(point p,double angle)
16    {
17        a=p;
18        if (dblcmp(angle-pi/2)==0)
19        {
20            b=a.add(point(0,1));
21        }
22        else
23        {
24            b=a.add(point(1,tan(angle)));
25        }
26    }
27    //ax+by+c=0
28    line(double _a,double _b,double _c)
29    {
30        if (dblcmp(_a)==0)
31        {
32            a=point(0,-_c/_b);
33            b=point(1,-_c/_b);
34        }
35        else if (dblcmp(_b)==0)
36        {
37            a=point(-_c/_a,0);
38            b=point(-_c/_a,1);
39        }
40        else
41        {
42            a=point(0,-_c/_b);
43            b=point(1,(-_c-_a)/_b);
44        }
45    }
46    void input()
47    {
48        a.input();
49        b.input();
50    }
51    void adjust()
52    {
53        if (b<a)swap(a,b);
54    }
55    double length()
56    {
57        return a.distance(b);
58    }
59    double angle()//直线倾斜角 0<=angle<180
60    {
61        double k=atan2(b.y-a.y,b.x-a.x);
62        if (dblcmp(k)<0)k+=pi;
63        if (dblcmp(k-pi)==0)k=-pi;
64        return k;
65    }
66    //点和线段关系
67    //1 在逆时针
68    //2 在顺时针
69    //3 平行
70    int relation(point p)
71    {

```

```

72     int c=dblcmp(p.sub(a).det(b.sub(a)));
73     if (c<0)return 1;
74     if (c>0)return 2;
75     return 3;
76 }
77 bool pointonseg(point p)
78 {
79     return dblcmp(p.sub(a).det(b.sub(a)))==0&&dblcmp(p.sub(a).dot(p.sub(b)))<=0;
80 }
81 bool parallel(line v)
82 {
83     return dblcmp(b.sub(a).det(v.b.sub(v.a)))==0;
84 }
85 //2 规范相交
86 //1 非规范相交
87 //0 不相交
88 int segcrossseg(line v)
89 {
90     int d1=dblcmp(b.sub(a).det(v.a.sub(a)));
91     int d2=dblcmp(b.sub(a).det(v.b.sub(a)));
92     int d3=dblcmp(v.b.sub(v.a).det(a.sub(v.a)));
93     int d4=dblcmp(v.b.sub(v.a).det(b.sub(v.a)));
94     if ((d1^d2)==-2&&(d3^d4)==-2)return 2;
95     return (d1==0&&dblcmp(v.a.sub(a).dot(v.a.sub(b)))<=0||
96             d2==0&&dblcmp(v.b.sub(a).dot(v.b.sub(b)))<=0||
97             d3==0&&dblcmp(a.sub(v.a).dot(a.sub(v.b)))<=0||
98             d4==0&&dblcmp(b.sub(v.a).dot(b.sub(v.b)))<=0);
99 }
100 int linecrossseg(line v)/*this seg v line
101 {
102     int d1=dblcmp(b.sub(a).det(v.a.sub(a)));
103     int d2=dblcmp(b.sub(a).det(v.b.sub(a)));
104     if ((d1^d2)==-2)return 2;
105     return (d1==0||d2==0);
106 }
107 //0 平行
108 //1 重合
109 //2 相交
110 int linecrossline(line v)
111 {
112     if ((*this).parallel(v))
113     {
114         return v.relation(a)==3;
115     }
116     return 2;
117 }
118 point crosspoint(line v)
119 {
120     double a1=v.b.sub(v.a).det(a.sub(v.a));
121     double a2=v.b.sub(v.a).det(b.sub(v.a));
122     return point((a.x*a2-b.x*a1)/(a2-a1),(a.y*a2-b.y*a1)/(a2-a1));
123 }
124 double dispointtoline(point p)
125 {
126     return fabs(p.sub(a).det(b.sub(a)))/length();
127 }
128 double dispointtoseg(point p)
129 {
130     if (dblcmp(p.sub(b).dot(a.sub(b)))<0||dblcmp(p.sub(a).dot(b.sub(a)))<0)
131     {
132         return min(p.distance(a),p.distance(b));
133     }
134     return dispointtoline(p);
135 }
136 point lineprog(point p)
137 {
138     return a.add(b.sub(a).mul(b.sub(a).dot(p.sub(a))/b.sub(a).len()));
139 }
140 point symmetrypoint(point p)
141 {
142     point q=lineprog(p);
143     return point(2*q.x-p.x,2*q.y-p.y);
144 }
145 };

```

### 3.5 line3d

```

1 struct line3
2 {
3     point3 a,b;
4     line3(){}
5     line3(point3 _a,point3 _b)
6     {
7         a=_a;
8         b=_b;
9     }
10    bool operator==(line3 v)
11    {
12        return (a==v.a)&&(b==v.b);
13    }

```

```

14 void input()
15 {
16     a.input();
17     b.input();
18 }
19 double length()
20 {
21     return a.distance(b);
22 }
23 bool pointonseg(point3 p)
24 {
25     return dblcmp(p.sub(a).det(p.sub(b)).len())==0&&dblcmp(a.sub(p).dot(b.sub(p)))<=0;
26 }
27 double dispointtoline(point3 p)
28 {
29     return b.sub(a).det(p.sub(a)).len()/a.distance(b);
30 }
31 double dispointtoseg(point3 p)
32 {
33     if (dblcmp(p.sub(b).dot(a.sub(b)))<0||dblcmp(p.sub(a).dot(b.sub(a)))<0)
34     {
35         return min(p.distance(a),p.distance(b));
36     }
37     return dispointtoline(p);
38 }
39 point3 lineprog(point3 p)
40 {
41     return a.add(b.sub(a).trunc(b.sub(a).dot(p.sub(a))/b.distance(a)));
42 }
43 point3 rotate(point3 p,double ang)//绕此向量逆时针角度parg
44 {
45     if (dblcmp((p.sub(a).det(p.sub(b)).len()))==0)return p;
46     point3 f1=b.sub(a).det(p.sub(a));
47     point3 f2=b.sub(a).det(f1);
48     double len=fabs(a.sub(p).det(b.sub(p)).len()/a.distance(b));
49     f1=f1.trunc(len);f2=f2.trunc(len);
50     point3 h=p.add(f2);
51     point3 pp=h.add(f1);
52     return h.add((p.sub(h)).mul(cos(ang*1.0)).add((pp.sub(h)).mul(sin(ang*1.0))));
53 }
54 };

```

### 3.6 plane

```

1 struct plane
2 {
3     point3 a,b,c,o;
4     plane(){}
5     plane(point3 _a,point3 _b,point3 _c)
6     {
7         a=_a;
8         b=_b;
9         c=_c;
10        o=pvec();
11    }
12    plane(double _a,double _b,double _c,double _d)
13    {
14        //ax+by+cz+d=0
15        o=point3(_a,_b,_c);
16        if (dblcmp(_a)!=0)
17        {
18            a=point3((-_d-_c-_b)/_a,1,1);
19        }
20        else if (dblcmp(_b)!=0)
21        {
22            a=point3(1,(-_d-_c-_a)/_b,1);
23        }
24        else if (dblcmp(_c)!=0)
25        {
26            a=point3(1,1,(-_d-_a-_b)/_c);
27        }
28    }
29    void input()
30    {
31        a.input();
32        b.input();
33        c.input();
34        o=pvec();
35    }
36    point3 pvec()
37    {
38        return b.sub(a).det(c.sub(a));
39    }
40    bool pointonplane(point3 p)//点是否在平面上
41    {
42        return dblcmp(p.sub(a).dot(o))==0;
43    }
44    //0 不在
45    //1 在边界上
46    //2 在内部

```

```

47 int pointontriangle(point3 p)//点是否在空间三角形上abc
48 {
49     if (!pointonplane(p))return 0;
50     double s=a.sub(b).det(c.sub(b)).len();
51     double s1=p.sub(a).det(p.sub(b)).len();
52     double s2=p.sub(a).det(p.sub(c)).len();
53     double s3=p.sub(b).det(p.sub(c)).len();
54     if (dblcmp(s-s1-s2-s3))return 0;
55     if (dblcmp(s1)&&dblcmp(s2)&&dblcmp(s3))return 2;
56     return 1;
57 }
58 //判断两平面关系
59 //0 相交
60 //1 平行但不重合
61 //2 重合
62 bool relationplane(plane f)
63 {
64     if (dblcmp(o.det(f.o).len()))return 0;
65     if (pointonplane(f.a))return 2;
66     return 1;
67 }
68 double angleplane(plane f)//两平面夹角
69 {
70     return acos(o.dot(f.o)/(o.len()*f.o.len()));
71 }
72 double dispoint(point3 p)//点到平面距离
73 {
74     return fabs(p.sub(a).dot(o)/o.len());
75 }
76 point3 pttoplane(point3 p)//点到平面最近点
77 {
78     line3 u=line3(p,p.add(o));
79     crossline(u,p);
80     return p;
81 }
82 int crossline(line3 u,point3 &p)//平面和直线的交点
83 {
84     double x=o.dot(u.b.sub(a));
85     double y=o.dot(u.a.sub(a));
86     double d=x-y;
87     if (dblcmp(fabs(d))==0)return 0;
88     p=u.a.mul(x).sub(u.b.mul(y)).div(d);
89     return 1;
90 }
91 int crossplane(plane f,line3 &u)//平面和平面的交线
92 {
93     point3 oo=o.det(f.o);
94     point3 v=o.det(oo);
95     double d=fabs(f.o.dot(v));
96     if (dblcmp(d)==0)return 0;
97     point3 q=a.add(v.mul(f.o.dot(f.a.sub(a))/d));
98     u=line3(q,q.add(oo));
99     return 1;
100 }
101 };

```

### 3.7 point

```

1 using namespace std;
2
3 #define mp make_pair
4 #define pb push_back
5
6 const double eps=1e-8;
7 const double pi=acos(-1.0);
8 const double inf=1e20;
9 const int maxp=8;
10
11 int dblcmp(double d)
12 {
13     if (fabs(d)<eps)return 0;
14     return d>eps?1:-1;
15 }
16
17 inline double sqr(double x)
18 {
19     return x*x;
20 }
21
22 struct point
23 {
24     double x,y;
25     point(){}
26     point(double _x,double _y):
27     x(_x),y(_y){};
28     void input()
29     {
30         scanf("%lf%lf",&x,&y);
31     }
32     void output()
33     {
34         printf("%.2f %.2f\n",x,y);
35     }
36     bool operator==(point a)const

```

```

37 {
38     return dblcmp(a.x-x)==0&&dblcmp(a.y-y)==0;
39 }
40 bool operator<(point a)const
41 {
42     return dblcmp(a.x-x)==0?dblcmp(y-a.y)<0:x<a.x;
43 }
44 double len()
45 {
46     return hypot(x,y);
47 }
48 double len2()
49 {
50     return x*x+y*y;
51 }
52 double distance(point p)
53 {
54     return hypot(x-p.x,y-p.y);
55 }
56 point add(point p)
57 {
58     return point(x+p.x,y+p.y);
59 }
60 point sub(point p)
61 {
62     return point(x-p.x,y-p.y);
63 }
64 point mul(double b)
65 {
66     return point(x*b,y*b);
67 }
68 point div(double b)
69 {
70     return point(x/b,y/b);
71 }
72 double dot(point p)
73 {
74     return x*p.x+y*p.y;
75 }
76 double det(point p)
77 {
78     return x*p.y-y*p.x;
79 }
80 double rad(point a,point b)
81 {
82     point p=*this;
83     return fabs(atan2(fabs(a.sub(p).det(b.sub(p))),a.sub(p).
84         dot(b.sub(p))));
85 }
86 point trunc(double r)
87 {
88     double l=len();
89     if (!dblcmp(l))return *this;
90     r/=l;
91     return point(x*r,y*r);
92 }
93 point rotleft()
94 {
95     return point(-y,x);
96 }
97 point rotright()
98 {
99     return point(y,-x);
100 }
101 point rotate(point p,double angle)//绕点逆时针旋转角度pangle
102 {
103     point v=this->sub(p);
104     double c=cos(angle),s=sin(angle);
105     return point(p.x+v.x*c-v.y*s,p.y+v.x*s+v.y*c);
106 }
107 };

```

### 3.8 point3d

```

1 struct point3
2 {
3     double x,y,z;
4     point3(){}
5     point3(double _x,double _y,double _z):
6     x(_x),y(_y),z(_z){};
7     void input()
8     {
9         scanf("%lf%lf%lf",&x,&y,&z);
10     }
11     void output()
12     {
13         printf("%.2f %.2f %.2f\n",x,y,z);
14     }
15     bool operator==(point3 a)
16     {
17         return dblcmp(a.x-x)==0&&dblcmp(a.y-y)==0&&dblcmp(a.z-z)
18             ==0;
19     }
20     bool operator<(point3 a)const

```

```

21     return dblcmp(a.x-x)==0?dblcmp(y-a.y)==0?dblcmp(z-a.z)>0?y<a.y:x<a.x;
22     }
23     double len()
24     {
25         return sqrt(len2());
26     }
27     double len2()
28     {
29         return x*x+y*y+z*z;
30     }
31     double distance(point3 p)
32     {
33         return sqrt((p.x-x)*(p.x-x)+(p.y-y)*(p.y-y)+(p.z-z)*(p.z-z));
34     }
35     point3 add(point3 p)
36     {
37         return point3(x+p.x,y+p.y,z+p.z);
38     }
39     point3 sub(point3 p)
40     {
41         return point3(x-p.x,y-p.y,z-p.z);
42     }
43     point3 mul(double d)
44     {
45         return point3(x*d,y*d,z*d);
46     }
47     point3 div(double d)
48     {
49         return point3(x/d,y/d,z/d);
50     }
51     double dot(point3 p)
52     {
53         return x*p.x+y*p.y+z*p.z;
54     }
55     point3 det(point3 p)
56     {
57         return point3(y*p.z-p.y*z,p.x*z-x*p.z,x*p.y-p.x*y);
58     }
59     double rad(point3 a,point3 b)
60     {
61         point3 p=(*this);
62         return acos(a.sub(p).dot(b.sub(p))/(a.distance(p)*b.distance(p)));
63     }
64     point3 trunc(double r)
65     {
66         r/=len();
67         return point3(x*r,y*r,z*r);
68     }
69     point3 rotate(point3 o,double r) // building?
70     {
71     }
72 };

```

### 3.9 polygon

```

1 struct polygon
2 {
3     int n;
4     point p[maxp];
5     line l[maxp];
6     void input()
7     {
8         n=4;
9         p[0].input();
10        p[2].input();
11        double dis=p[0].distance(p[2]);
12        p[1]=p[2].rotate(p[0],pi/4);
13        p[1]=p[0].add((p[1].sub(p[0])).trunc(dis/sqrt(2.0)));
14        p[3]=p[2].rotate(p[0],2*pi-pi/4);
15        p[3]=p[0].add((p[3].sub(p[0])).trunc(dis/sqrt(2.0)));
16    }
17    void add(point q)
18    {
19        p[n++]=q;
20    }
21    void getline()
22    {
23        for (int i=0;i<n;i++)
24        {
25            l[i]=line(p[i],p[(i+1)%n]);
26        }
27    }
28    struct cmp
29    {
30        point p;
31        cmp(const point &p0){p=p0;}
32        bool operator()(const point &aa,const point &bb)
33        {
34            point a=aa,b=bb;
35            int d=dblcmp(a.sub(p).det(b.sub(p)));
36            if (d==0)
37            {

```

```

        return dblcmp(a.distance(p)-b.distance(p))<0;
    }
    return d>0;
}
};

void norm()
{
    point mi=p[0];
    for (int i=1;i<n;i++)mi=min(mi,p[i]);
    sort(p,p+n,cmp(mi));
}

void getconvex(polygon &convex)
{
    int i,j,k;
    sort(p,p+n);
    convex.n=n;
    for (i=0;i<min(n,2);i++)
    {
        convex.p[i]=p[i];
    }
    if (n<=2)return;
    int &top=convex.n;
    top=1;
    for (i=2;i<n;i++)
    {
        while (top&&convex.p[top].sub(p[i]).det(convex.p[top-1].sub(p[i]))<=0)
            top--;
        convex.p[++top]=p[i];
    }
    int temp=top;
    convex.p[++top]=p[n-2];
    for (i=n-3;i>=0;i--)
    {
        while (top!=temp&&convex.p[top].sub(p[i]).det(convex.p[top-1].sub(p[i]))<=0)
            top--;
        convex.p[++top]=p[i];
    }
}

bool isconvex()
{
    bool s[3];
    memset(s,0,sizeof(s));
    int i,j,k;
    for (i=0;i<n;i++)
    {
        j=(i+1)%n;
        k=(j+1)%n;
        s[dblcmp(p[j].sub(p[i]).det(p[k].sub(p[i])))+1]=1;
        if (s[0]&&s[2])return 0;
    }
    return 1;
}

//3 点上
//2 边上
//1 内部
//0 外部
int relationpoint(point q)
{
    int i,j;
    for (i=0;i<n;i++)
    {
        if (p[i]==q)return 3;
    }
    getline();
    for (i=0;i<n;i++)
    {
        if (l[i].pointonseg(q))return 2;
    }
    int cnt=0;
    for (i=0;i<n;i++)
    {
        j=(i+1)%n;
        int k=dblcmp(q.sub(p[j]).det(p[i].sub(p[j])));
        int u=dblcmp(p[i].y-q.y);
        int v=dblcmp(p[j].y-q.y);
        if (k>0&&k<0&&v>=0)cnt++;
        if (k<0&&v<0&&u>=0)cnt--;
    }
    return cnt!=0;
}

//1 在多边形内长度为正
//2 相交或与边平行
//0 无任何交点
int relationline(line u)
{
    int i,j,k=0;
    getline();
    for (i=0;i<n;i++)
    {
        if (l[i].segcrossseg(u)==2)return 1;
        if (l[i].segcrossseg(u)==1)k=1;
    }
    if (!k)return 0;
}

```

```

131 vector<point>vp;
132 for (i=0;i<n;i++)
133 {
134     if (l[i].segcrossseg(u))
135     {
136         if (l[i].parallel(u))
137         {
138             vp.pb(u.a);
139             vp.pb(u.b);
140             vp.pb(l[i].a);
141             vp.pb(l[i].b);
142             continue;
143         }
144         vp.pb(l[i].crosspoint(u));
145     }
146 }
147 sort(vp.begin(),vp.end());
148 int sz=vp.size();
149 for (i=0;i<sz-1;i++)
150 {
151     point mid=vp[i].add(vp[i+1]).div(2);
152     if (relationpoint(mid)==1)return 1;
153 }
154 return 2;
155 }
156 //直线切割凸多边形左侧u
157 //注意直线方向
158 void convexcut(line u,polygon &po)
159 {
160     int i,j,k;
161     int &top=po.n;
162     top=0;
163     for (i=0;i<n;i++)
164     {
165         int d1=dblcmp(p[i].sub(u.a).det(u.b.sub(u.a)));
166         int d2=dblcmp(p[(i+1)%n].sub(u.a).det(u.b.sub(u.a)));
167         if (d1>=0)po.p[top++]=p[i];
168         if (d1*d2<0)po.p[top++]=u.crosspoint(line(p[i],p[(i+1)%n]));
169     }
170 }
171 double getcircumference()
172 {
173     double sum=0;
174     int i;
175     for (i=0;i<n;i++)
176     {
177         sum+=p[i].distance(p[(i+1)%n]);
178     }
179     return sum;
180 }
181 double getarea()
182 {
183     double sum=0;
184     int i;
185     for (i=0;i<n;i++)
186     {
187         sum+=p[i].det(p[(i+1)%n]);
188     }
189     return fabs(sum)/2;
190 }
191 bool getdir()//代表逆时针1 代表顺时针0
192 {
193     double sum=0;
194     int i;
195     for (i=0;i<n;i++)
196     {
197         sum+=p[i].det(p[(i+1)%n]);
198     }
199     if (dblcmp(sum)>0)return 1;
200     return 0;
201 }
202 point getbarycentre() // centroid
203 {
204     point ret(0,0);
205     double area=0;
206     int i;
207     for (i=1;i<n-1;i++)
208     {
209         double tmp=p[i].sub(p[0]).det(p[i+1].sub(p[0]));
210         if (dblcmp(tmp)==0)continue;
211         area+=tmp;
212         ret.x+=(p[0].x+p[i].x+p[i+1].x)/3*tmp;
213         ret.y+=(p[0].y+p[i].y+p[i+1].y)/3*tmp;
214     }
215     if (dblcmp(area))ret=ret.div(area);
216     return ret;
217 }
218 double areaintersection(polygon po) // refer: HPI
219 {
220 }
221 double areaunion(polygon po)
222 {
223     return getarea()+po.getarea()-areaintersection(po);
224 }
225
226 double areacircle(circle c)
227 {
228     int i,j,k,l,m;
229     double ans=0;
230     for (i=0;i<n;i++)
231     {
232         int j=(i+1)%n;
233         if (dblcmp(p[j].sub(c.p).det(p[i].sub(c.p)))>=0)
234         {
235             ans+=c.reatriangle(p[i],p[j]);
236         }
237         else
238         {
239             ans-=c.reatriangle(p[i],p[j]);
240         }
241     }
242     return fabs(ans);
243 }
244 //多边形和圆关系
245 //0 一部分在圆外
246 //1 与圆某条边相切
247 //2 完全在圆内
248 int relationcircle(circle c)
249 {
250     getline();
251     int i,x=2;
252     if (relationpoint(c.p)!=1)return 0;
253     for (i=0;i<n;i++)
254     {
255         if (c.relationseg(l[i])==2)return 0;
256         if (c.relationseg(l[i])==1)x=1;
257     }
258     return x;
259 }
260 void find(int st,point tri[],circle &c)
261 {
262     if (!st)
263     {
264         c=circle(point(0,0),-2);
265     }
266     if (st==1)
267     {
268         c=circle(tri[0],0);
269     }
270     if (st==2)
271     {
272         c=circle(tri[0].add(tri[1]).div(2),tri[0].distance(tri[1])/2.0);
273     }
274     if (st==3)
275     {
276         c=circle(tri[0],tri[1],tri[2]);
277     }
278 }
279 void solve(int cur,int st,point tri[],circle &c)
280 {
281     find(st,tri,c);
282     if (st==3)return;
283     int i;
284     for (i=0;i<cur;i++)
285     {
286         if (dblcmp(p[i].distance(c.p)-c.r)>0)
287         {
288             tri[st]=p[i];
289             solve(i,st+1,tri,c);
290         }
291     }
292 }
293 circle mincircle()//点集最小圆覆盖
294 {
295     random_shuffle(p,p+n);
296     point tri[4];
297     circle c;
298     solve(n,0,tri,c);
299     return c;
300 }
301 int circlecover(double r)//单位圆覆盖
302 {
303     int ans=0,i,j;
304     vector<pair<double,int>>v;
305     for (i=0;i<n;i++)
306     {
307         v.clear();
308         for (j=0;j<n;j++)if (i!=j)
309         {
310             point q=p[i].sub(p[j]);
311             double d=q.len();
312             if (dblcmp(d-2*r)<=0)
313             {
314                 double arg=atan2(q.y,q.x);
315                 if (dblcmp(arg)<0)arg+=2*pi;
316                 double t=acos(d/(2*r));
317                 v.push_back(make_pair(arg-t+2*pi,-1));
318                 v.push_back(make_pair(arg+t+2*pi,1));
319             }
320         }
321     }
322 }

```

```

319     }
320     sort(v.begin(),v.end());
321     int cur=0;
322     for (j=0;j<v.size();j++)
323     {
324         if (v[j].second==-1)++cur;
325         else --cur;
326         ans=max(ans,cur);
327     }
328     }
329     return ans+1;
330 }
331 int pointinpolygon(point q)//点在凸多边形内部的判定
332 {
333     if (getdir())reverse(p,p+n);
334     if (dblcmp(q.sub(p[0]).det(p[n-1].sub(p[0]))==0)
335     {
336         if (line(p[n-1],p[0]).pointonseg(q))return n-1;
337         return -1;
338     }
339     int low=1,high=n-2,mid;
340     while (low<=high)
341     {
342         mid=(low+high)>>1;
343         if (dblcmp(q.sub(p[0]).det(p[mid].sub(p[0]))>=0&&dblcmp(
344             q.sub(p[0]).det(p[mid+1].sub(p[0]))<0)
345         {
346             polygon c;
347             c.p[0]=p[mid];
348             c.p[1]=p[mid+1];
349             c.p[2]=p[0];
350             c.n=3;
351             if (c.relationpoint(q))return mid;
352             return -1;
353         }
354         if (dblcmp(q.sub(p[0]).det(p[mid].sub(p[0]))>0)
355         {
356             low=mid+1;
357         }
358         else
359         {
360             high=mid-1;
361         }
362     }
363     return -1;
364 }
};

```

### 3.10 polygons

```

1 struct polygons
2 {
3     vector<polygon>p;
4     polygons()
5     {
6         p.clear();
7     }
8     void clear()
9     {
10         p.clear();
11     }
12     void push(polygon q)
13     {
14         if (dblcmp(q.getarea())>0)p.pb(q);
15     }
16     vector<pair<double,int>> >e;
17     void ins(point s,point t,point X,int i)
18     {
19         double r=fabs(t.x-s.x)>eps?(X.x-s.x)/(t.x-s.x):(X.y-s.y)/
20             (t.y-s.y);
21         r=min(r,1.0);r=max(r,0.0);
22         e.pb(mp(r,i));
23     }
24     double polyareaunion()
25     {
26         double ans=0.0;
27         int c0,c1,c2,i,j,k,w;
28         for (i=0;i<p.size();i++)
29         {
30             if (p[i].getdir()==0)reverse(p[i].p,p[i].p+p[i].n);
31         }
32         for (i=0;i<p.size();i++)
33         {
34             for (k=0;k<p[i].n;k++)
35             {
36                 point &s=p[i].p[k],&t=p[i].p[(k+1)%p[i].n];
37                 if (!dblcmp(s.det(t)))continue;
38                 e.clear();
39                 e.pb(mp(0.0,1));
40                 e.pb(mp(1.0,-1));
41                 for (j=0;j<p.size();j++)if (i!=j)
42                 {
43                     for (w=0;w<p[j].n;w++)
44                     {

```

```

44         point a=p[j].p[w],b=p[j].p[(w+1)%p[j].n],c=p[j].p[(
45             w-1+p[j].n)%p[j].n];
46         c0=dblcmp(t.sub(s).det(c.sub(s)));
47         c1=dblcmp(t.sub(s).det(a.sub(s)));
48         c2=dblcmp(t.sub(s).det(b.sub(s)));
49         if (c1*c2<0)ins(s,t,line(s,t).crosspoint(line(a,b))
50             ,-c2);
51         else if (!c1&&c0*c2<0)ins(s,t,a,-c2);
52         else if (!c1&&!c2)
53         {
54             int c3=dblcmp(t.sub(s).det(p[j].p[(w+2)%p[j].n].
55                 sub(s));
56             int dp=dblcmp(t.sub(s).dot(b.sub(a)));
57             if (dp&&c0)ins(s,t,a,dp>0?c0*((j>i)^(c0<0)):-c0
58                 <0);
59             if (dp&&c3)ins(s,t,b,dp>0?-c3*((j>i)^(c3<0)):c3
60                 <0);
61         }
62     }
63     }
64     sort(e.begin(),e.end());
65     int ct=0;
66     double tot=0.0,last;
67     for (j=0;j<e.size();j++)
68     {
69         if (ct==p.size())tot+=e[j].first-last;
70         ct+=e[j].second;
71         last=e[j].first;
72     }
73     ans+=s.det(t)*tot;
74     return fabs(ans)*0.5;
75 }
};

```

## 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; it++)
6         if(dfn[*it]==-1)
7         {
8             dfs(*it,now);
9             ++p;
10            low[now]=std::min(low[now],low[*it]);
11            if((now==1 && p>1) || (now!=1 && low[*it]>=dfn[now])) // 如果从出发点出发的子节点不能由兄弟节点到达,那么出发点为割点。如果现节点不是出发点,但是其子孙节点不能达到祖先节点,那么该节点为割点
12                ans.insert(now);
13        }
14        else
15            if(*it!=fa)
16                low[now]=std::min(low[now],dfn[*it]);
17    }

```

## 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<n; 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);
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<cstdio>
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--)
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(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(go(1))]);
128     }
129     return 0;
130 }

```

## 4.5 Biconnected Component

```

1  #include<cstdio>
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[MAXN<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<n; 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
25             vis[z]=0;
26             *qb++=z;
27         }
28 }
29
30 inline bool bfs(int now)
31 {
32     static int i,x,y,z,b;
33     for(i=0;i<n;++i)
34         p[i].resize(0);
35     p[now].push_back(now);
36     memset(vis,-1,sizeof vis);
37     vis[now]=0;
38     qf=q;
39     *qb++=now;
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[x][b]==p[y][b];++b);
69         --b;
70         label(x,y,b);
71         label(y,x,b);
72     }
73     return false;
74 }
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             {
14                 j=edge[now][i];
15                 k=now;
16             }
17             else
18             {
19                 j=now;
20                 k=edge[now][i];
21             }
22             ans.push_back(node(j,k));
23         }
24     }
25     else
26     if(edge[now][i]!=fa)
27         low[now]=std::min(low[now],low[edge[now][i]]);
28 }

```

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     }
92 }

```

```

91 |     puts("");
92 | }
93 | return 0;
94 | }

```

## 4.9 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。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集，但是极大独立集不一定是最大的独立集。

4 |  
5 | 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  $G$  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  $s$  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，最小支配集中顶点个数成为支配数。

6 |  
7 | 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顶点数最少，这个集合就是最小的点的覆盖。

8 |  
9 | 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  $u, v$  是最大团，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 = 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  $\langle u; v \rangle$  不包含于  $E$ ，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 | minimum cover:  
16 | vertex cover vertex bipartite graph = maximum cardinality bipartite matching  
17 | 找完最大二分匹配後，有三種情况要分別處理：  
18 | 甲、 $X$  側未匹配點的交錯樹們。  
19 | 乙、 $Y$  側未匹配點的交錯樹們。  
20 | 丙、層層疊疊的交錯環們（包含單獨的匹配邊）。  
21 | 這三個情况互不干涉。用 Graph Traversal 建立甲、乙的交錯樹們，剩下部分就是丙。  
22 | 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，是可以印出字典順序最小的點覆蓋的。

23 | 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。  
24 | vertex cover edge  
25 | edge cover vertex  
26 | 首先在圖上求得一個 Maximum Matching 之後，對於那些單身的點，都由匹配點連過去。如此便形成了 Minimum Edge Cover。

27 | edge cover edge  
28 | path cover vertex  
29 | general graph: NP-H  
30 | tree: DP  
31 | DAG: 将每个节点拆分为入点和出点, ans = 节点数 - 匹配数  
32 | path cover edge  
33 | minimize the count of euler path ( greedy is ok? )  
34 | cycle cover vertex  
35 | general: NP-H  
36 | weighted: do like path cover vertex, with KM algorithm  
37 | cycle cover edge  
38 | NP-H

## 4.10 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

```

## 4.11 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;
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];
34 |     return h[sink] != -1;
35 | }
36 |
37 | int dfs(int now, int maxcap)
38 | {
39 |     if (now == sink)
40 |         return maxcap;
41 |     int flow(maxcap), d;
42 |     for (int &i(w[now]); i != -1; i = nxt[i])
43 |         if (cap[i] && h[to[i]] == h[now] + 1) // 88 (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%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 }

```

## 4.12 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
14 Eulerian circuit:
15 计入度和出度之差
16 无向边任意定向
17 出入度之差为奇数则无解
18 然后构图:
19 原图有向边不变，容量 1 // 好像需要在新图中忽略有向边？
20 无向边按之前认定方向，容量 1
21 源点向所有度数为正的点连边，容量 abs(度数/2)
22 所有度数为负的点向汇点连边，容量 abs(度数/2)
23 两侧均满流则有解
24 相当于规约为可行流问题
25 注意连通性的 trick
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
31 Feasible flow problem:
32 由超级源点出发的边全部满流则有解
33 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
34
35 对于每条边 <a->b capu,d>，建边 <ss->b cap(u)>、<a->st cap(u)>、
   <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
   次最大流，此时 t->s 这条弧的流量即为最小流
43 判断可行流存在还是必须连原汇 -> 原源的边之后查看满流
44 所以可以使用跑流 -> 加 ts 弧 -> 跑流，最后检查超级源点满流情况来进一步搞定
45 tips:
46 合并流量、减少边数来加速
47
48
49
50 Minimum cost feasible flow problem:
51 TODO
52 看起来像是在上面那样跑费用流就行了……
53
54
55
56 Minimum weighted vertex cover edge for bipartite graph:
57 for all vertex in X:
58 edge < s->x cap(weight(x)) >
59 for all vertex in Y:
60 edge < y->t cap(weight(y)) >
61 for original edges
62 edge < x->y cap(inf) >
63
64 ans={maximum flow}={minimum cut}
65 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 && 汇点可

```

```

66 达) ) 对应着解
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
75 方格取数: // refer: hdu 3820 golden eggs 取方格获得收益当取了相邻方格时付出
   边的代价
76
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?"UNIQUE":"AMBIGUOUS");
115
116
117
118 Tips:
119 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；
120 两点间容量 inf 则可以设法化简为一个点；
121 点权始终要转化为边权；
122 不参与决策的边权设为 inf 来排除掉；
123 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……? );

```

## 4.13 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;i=nxt[i])
25         if(!done[to[i]])
26         {
27             edge[a]=nxt[i];
28             return to[i];
29         }
30 }

```

```

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]=true;
63                 ++cnt;
64             }
65             while(i=find(b))
66             {
67                 next[b]=i;
68                 done[b]=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 }

```

#### 4.14 Hopcroft-Karp algorithm

```

1 #include<cstdio>
2 #include<cstring>
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;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",&n,&m);
40     while(m--)
41     {
42         scanf("%d%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<=n;++i)
57             if(cx[i]==-1)
58                 *qb++=i;
59         while(qf==qb)
60             for(k=edge[i=*qf++];k;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<=n;++i)
75             if(cx[i]==-1 && ag(i))
76                 ++ans;
77     }
78     printf("%d\n",ans);
79     return 0;
80 }

```

#### 4.15 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,N,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 }

```

## 4.16 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=edger[i].next)
56         {
57             states v=u;
58             v.id=edger[i].to;
59             if(dist[v.id]>dist[u.id]+edger[i].cost)
60             {
61                 v.cost=dist[v.id]=dist[u.id]+edger[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_%d",&n,&m);
122     init(n);
123     for(int i=0; i<n; 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 }

```

### 4.17 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_%d", &n, &m);
28     memset(e, 0x3f, sizeof(e));
29     while(m--)
30     {
31         scanf("%d_%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 <= vt[0][i].second)
56                         vt[1].pop_back();
57                     vt[1].push_back(vt[0][i]);
58                 }
59                 d = inf;
60                 if(vt[1].size() == 1)
61                 {
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                 {
75                     for(i=1; i<vt[1].size(); ++i)
76                         if(d > e[i][j] + vt[1][i-1].first + vt[1][i-1].second)
77                         {
78                             ta = (e[i][j] + vt[1][i].second - vt[1][i-1].first) / (double)2.0f;
79                             d = e[i][j] + vt[1][i-1].first + vt[1][i-1].second;
80                         }
81                 }
82                 if(d < ans)

```

```

78     {
79         ans = d;
80         a = i;
81         b = j;
82         dp[i] = ta;
83         dp[j] = e[i][j] - ta;
84     }
85 }
86 printf("%d\n", ans);
87 for(i=1; i<=n; ++i)
88     if(i != a && i != b)
89         dp[i] = 1e20;
90 q.insert(pdi(dp[a], a));
91 if(a != b)
92     q.insert(pdi(dp[b], b));
93 if(a != b)
94     pre[b] = a;
95 while(!q.empty())
96 {
97     k = q.begin()->second;
98     q.erase(q.begin());
99     if(done[k])
100         continue;
101     done[k] = true;
102     for(i=1; i<=n; ++i)
103         if(e[k][i] != inf && dp[k] + e[k][i] < dp[i])
104         {
105             dp[i] = dp[k] + e[k][i];
106             q.insert(pdi(dp[i], i));
107             pre[i] = k;
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 }

```

### 4.18 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
69 //bupt
70
71 //算法：求二分图最佳匹配km n复杂度~3
72
73 int dfs(int u)//匈牙利求增广路
74 {
75     int v;
76     sx[u]=1;
77     for (v=1; v<=n; v++)
78         if (!sy[v] && lx[u]+ly[v]==map[u][v])
79         {
80             sy[v]=1;
81             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 }

```

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

```

## 4.20 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(
21         bb),id(idd){}
22 };
23
24 std::list<node> to[MAXX];
25
26 int find(const int &a)
27 {
28     if(set[a]==a)
29         return a;
30     int b(set[a]);
31     set[a]=find(set[a]);
32     max[a]=std::max(max[a],max[b]);
33     min[a]=std::min(min[a],min[b]);
34     return set[a];
35 }
36
37 void tarjan(const int &now)
38 {
39     done[now]=true;
40     for(std::list<std::pair<int,int>> >::const_iterator it(q[now]
41         ).begin()); it!=q[now].end();++it)
42         if(done[it->first])
43             if(it->second>0)
44                 to[find(it->first)].push_back(node(now,it->
45                     first,it->second));
46     else
47         to[find(it->first)].push_back(node(it->first,

```

```

37         now, -it->second));
45     for (std::list<std::pair<int, int> >::const_iterator it (edge
38         now].begin()); it!=edge[now].end(); ++it)
39     {
40         if (!done[it->first])
41         {
42             tarjan(it->first);
43             set[it->first]=now;
44             min[it->first]=it->second;
45             max[it->first]=it->second;
46         }
47     }
48     for (std::list<node>::const_iterator it (to[now].begin()); it
49     !=to[now].end(); ++it)
50     {
51         find(it->a);
52         find(it->b);
53         ans[0][it->id]=std::min(min[it->b], min[it->a]);
54         ans[1][it->id]=std::max(max[it->a], max[it->b]);
55     }
56 }
57
58 int main()
59 {
60     scanf("%hd",&T);
61     for (t=1; t<=T; ++t)
62     {
63         scanf("%d",&n);
64         for (i=1; i<=n; ++i)
65         {
66             edge[i].clear();
67             q[i].clear();
68             to[i].clear();
69             done[i]=false;
70             set[i]=i;
71             min[i]=inf;
72             max[i]=0;
73         }
74         for (i=1; i<=n; ++i)
75         {
76             scanf("%d%d",&j,&k,&l);
77             edge[j].push_back(std::make_pair(k, l));
78             edge[k].push_back(std::make_pair(j, l));
79         }
80         scanf("%d",&m);
81         for (i=0; i<=m; ++i)
82         {
83             scanf("%d,%d",&j,&k);
84             q[j].push_back(std::make_pair(k, i));
85             q[k].push_back(std::make_pair(j, -i));
86         }
87         tarjan(1);
88         printf("Case.%hd:\n", t);
89         for (i=0; i<=m; ++i)
90             printf("%d,%d\n", ans[0][i], ans[1][i]);
91     }
92     return 0;
93 }

```

## 4.21 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                 node[j].x)*(node[i].x-node[j].x)+(node[i].
67                 y-node[j].y)*(node[i].y-node[j].y));
68                 map[j][i].c=map[i][j].c=fabs(node[i].z-node[j].
69                 z);
70             }
71         a=0,b=mst(a);
72         while (fabs(b-a)>1e-8)
73         {
74             a=b;
75             b=mst(a);
76         }
77         printf("%.3lf\n",b);
78     }
79     return 0;
80 }

```

## 4.22 Minimum Steiner Tree

```

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

```

## 4.23 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!=0; 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!=0; 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!=0; i=pre[to[i^1]])
69         {
70             cap[i]-=min;
71             cap[i^1]+=min;
72         }
73     }
74     return ans;
75 }

```

## 4.24 Second-best MST

```

1 #include<stdio>
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[MAXN];
26
27 int map[MAXN][MAXN];
28 bool done[MAXN];
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[i]);
48             dfs(v,now);
49         }
50 }
51
52 int main()
53 {
54     scanf("%d%d",&n,&m);
55     for(i=0;i<=n;++i)
56         scanf("%d%d",&ed[i].a,&ed[i].b,&ed[i].c);
57     std::sort(ed,ed+m);
58     for(i=0;i<=n;++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: -1\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<=n;++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 Spanning tree

```

1 Minimum Bottleneck Spanning Tree:
2 Kruskal
3
4 All-pairs vertexes' Minimum Bottleneck Path:
5 DP in the Kruskal'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 (  $O(m\log n + n)$  with kruskal )
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  $O((1<<k)*( \{dijkstra\} ))$ 
32 then run a bit-mask DP(  $O(n*(1<<k))$  )
33
34 Count Spanning Trees:
35 TODO
36 Kirchhoff's theorem
37
38 k-best MST:
39 do like second-best MST for k times

```

## 4.26 Stable Marriage

```

//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
1
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
8     else
9     {
10         for(it=edge[edge[g.front()].front()].begin();it!=edge[
            edge[g.front()].front()].end();++it)
11             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
12                 break;
13
14         if(*it==g.front()) //如果更喜欢新的
15         {
16             g.push_back(dfn[edge[g.front()].front()]);
17             dfn[edge[g.front()].front()]=g.front();
18         }
19         else
20             g.push_back(g.front()); //否则放到队尾，重新等待匹配
21
22         edge[g.front()].pop_front(); //每组匹配最多只考虑一次
23         g.pop_front();
24     }
25 }

```

## 4.27 Stoer-Wagner Algorithm

```

1 #include<stdio>
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端点
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 }

```

## 4.28 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         }
23         ++p;
24     }
25 }

```

## 4.29 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
36 int aug(int now, int maxcap)
37 {
38     if (now == sink)
39     {
40         mf += maxcap;
41         cost += maxcap * pil;
42         return maxcap;
43     }
44     done[now] = true;
45     int l = maxcap;
46     for (int i(edge[now]); i != -1; i = nxt[i])
47         if (cap[i] && !cst[i] && !done[to[i]])
48         {
49             int d(aug(to[i], std::min(l, cap[i])));
50             cap[i] -= d;
51             cap[i^1] += d;
52             l -= d;
53             if (!l)
54                 return maxcap;
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 }
80 /* primal-dual approach
81 static int d[MAXN], i, j;
82 static std::deque<int> q;
83 memset(d, 0x3f, sizeof d);
84 d[sink] = 0;
85 q.push_back(sink);
86 while (!q.empty())
87 {
88     static int dt, now;
89     now = q.front();
90     q.pop_front();
91     for (i = edge[now]; i != -1; i = nxt[i])
92         if (cap[i^1] && (dt = d[now] - cst[i]) < d[to[i]])
93             if ((d[to[i]] = dt) <= d[q.empty() ? 0 : q.front()])
94                 q.push_front(to[i]);
95         else
96             q.push_back(to[i]);
97 }
98 for (i = 1; i <= n; ++i)
99     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].first)+abs(M[i].second-H[j].second));
133         for(i=0;i<M.size();++i)
134             add(source,i+1,1,0);
135         for(i=0;i<H.size();++i)
136             add(i+1+M.size(),sink,1,0);
137         mf=cost=pil=0;
138         do
139             do
140                 memset(done,0,sizeof done);
141                 while(aug(source,inf));
142             while(label());
143             /* primal-dual approach
144             while(label())
145                 do
146                     memset(done,0,sizeof done);
147                     while(aug(source,inf));
148             */
149             printf("%d\n",cost);
150         }
151         return 0;
152     }

```

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

```

```

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(√n)
2  //Pollard's rho algorithm for logarithms' running time is approximately
   O(√p) where p is n's largest prime factor.
3  #include<cstdio>
4  #include<cmath>
5  #include<cstring>
6
7  struct Hash // std::map is bad. clear() 时会付出巨大的代价
8  {
9      static const int mod=100003; // prime is good
10     static const int MAXX=47111; // bigger than √c
11     int hd[mod],nxt[MAXX],cnt;
12     long long v[MAXX],k[MAXX]; // a^k ≡ v (mod c)
13     inline void init()
14     {
15         memset(hd,0,sizeof hd);
16         cnt=0;
17     }
18     inline long long find(long long v)
19     {
20         static int now;
21         for(now=hd[v%mod];now;now=nxt[now])
22             if(this->v[now]==v)
23                 return k[now];
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
43     &y)
44 {
45     if(b)
46     {
47         long long re(exgcd(b,a%b,x,y)),tmp(x);
48         x=y;
49         y=tmp-(a/b)*y;
50         return re;
51     }
52     x=1ll;
53     y=0ll;
54     return a;
55 }
56
57 inline long long bsgs(long long a,long long b,long long c) //
58     a^x ≡ b
59     (mod c)
60 {
61     static long long x,y,d,g,m,am,k;
62     static int i,cnt;
63     a%=c;
64     b%=c;
65     x=1ll%c; // if c==1....
66     for(i=0;i<100;++i)
67     {
68         if(x==b)
69             return i;
70         x=(x*a)%c;
71     }
72     d=1ll%c;
73     cnt=0;
74     while((g=gcd(a,c))!=1ll)
75     {
76         if(b%g)
77             return -1ll;
78         ++cnt;
79         c/=g;
80         b/=g;
81         d=a/g*d%c;
82     }
83     hash.init();
84     m=sqrt((double)c); // maybe need a ceil
85     am=1ll%c;
86     hash.insert(0,am);
87     for(i=1;i<=m;++i)

```

```

85     {
86         am=am*a%c;
87         hash.insert(i,am);
88     }
89     for(i=0;i<=m++i)
90     {
91         g=exgcd(d,c,x,y);
92         x=(x*b/g%c+c)%c;
93         k=hash.find(x);
94         if(k!=-1ll)
95             return i*m+k+cnt;
96         d=d*a%c;
97     }
98     return -1ll;
99 }
100
101 long long k,p,n;
102
103 int main()
104 {
105     while(scanf("%lld_%lld_%lld",&k,&p,&n)!=EOF)
106     {
107         if(n>p || (k=bsgs(k,n,p))==-1ll)
108             puts("Orz,I can't find D!");
109         else
110             printf("%lld\n",k);
111     }
112     return 0;
113 }

```

### 5.3 Divisor function

1  $n = p_1^{a_1} \times p_2^{a_2} \times \dots \times p_s^{a_s}$   
2 sum of positive divisors function

$$3 \sigma(n) = \prod_{j=1}^s \frac{p_j^{a_j+1}-1}{p_j-1}$$

4 number of positive divisors function

$$5 \tau(n) = \prod_{j=1}^s (a_j + 1)$$

### 5.4 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 }

```

### 5.5 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+l<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         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     return 0;
96 }

```

### 5.6 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=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=1; i<=n; i++)
38          {
39              for(j=i+1; j<=n; j++)
40                  ta[i][j] = (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][i])
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][i])
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 - 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(1);
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<=n; 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<=n; 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<=n; j++)
128          if(a[j][n])
129              break;
130      if(j<=n)
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  }

```

## 5.7 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 power(long long x, long long y, int mod)
9  {
10     long long ret = 1;
11     for(long long a=x%mod; y; y>>=1, a=a*a%mod)
12         if(y&1)
13             ret = ret*a%mod;
14     return ret;
15 }
16
17 inline int getInv(int x, int mod) // mod 为素数
18 {
19     return power(x, mod-2);
20 }

```

## 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 + 1;
22     for(i=0; i<=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]; // maximum 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     }
94     return 0;
95 }

```

## 5.9 Lucas' theorem(2)

```

1 #include<cstdio>
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[n%p]%p)%p *getInv(num[n%p-m%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 int main()
72 {
73     long long n,k,p,ans;
74     int cas=0;
75     while(scanf("%d%d%d", &n,&k,&p)!=EOF)
76     {
77         if(k>n-k)
78             k=n-k;
79         ans=Lucas(n+1,k,p)+n-k;
80         printf("Case_#d: %d\n",++cas,ans%p);
81     }
82     return 0;
83 }

```

## 5.11 Matrix

```

1 struct Matrix
2 {
3     const int N(52);
4     int a[N][N];
5     inline Matrix operator*(const Matrix &b)const
6     {
7         static Matrix res;
8         static int i,j,k;
9         for(i=0;i<N;++i)
10             for(j=0;j<N;++j)
11             {
12                 res.a[i][j]=0;
13                 for(k=0;k<N;++k)
14                     res.a[i][j]+=a[i][k]*b.a[k][j];
15             }
16         return res;
17     }
18     inline Matrix operator^(int y)const
19     {
20         static Matrix res,x;
21         static int i,j;
22         for(i=0;i<N;++i)
23         {
24             for(j=0;j<N;++j)
25             {
26                 res.a[i][j]=0;
27                 x.a[i][j]=a[i][j];
28             }
29             res.a[i][i]=1;
30         }
31         for(;y>>=1,x=x*x)
32             if(y&1)
33                 res=res*x;
34         return res;
35     }
36 };
37
38 Fibonacci Matrix
39 | 1 1
40 | 1 0

```

## 5.12 Miller-Rabin Algorithm

```

1 inline unsigned long long multi_mod(const unsigned long long &a,
2     ,unsigned long long b,const unsigned long long &n)
3 {
4     unsigned long long exp(a%n),tmp(0);
5     while(b)
6     {
7         if(b&1)
8         {
9             tmp+=exp;
10            if(tmp>n)
11                tmp-=n;
12        }
13        exp<<=1;
14        if(exp>n)
15            exp-=n;
16        b>>=1;
17    }
18    return tmp;

```

```

18 }
19
20 inline unsigned long long exp_mod(unsigned long long a,unsigned
21     long long b,const unsigned long long &c)
22 {
23     unsigned long long tmp(1);
24     while(b)
25     {
26         if(b&1)
27             tmp=multi_mod(tmp,a,c);
28         a=multi_mod(a,a,c);
29         b>>=1;
30     }
31     return tmp;
32 }
33
34 inline bool miller_rabbin(const unsigned long long &n,short T)
35 {
36     if(n==2)
37         return true;
38     if(n<2 || !(n&1))
39         return false;
40     unsigned long long a,u(n-1),x,y;
41     short t(0),i;
42     while(!(u&1))
43     {
44         ++t;
45         u>>=1;
46     }
47     while(T-->0)
48     {
49         a=rand()%(n-1)+1;
50         x=exp_mod(a,u,n);
51         for(i=0;i<t;++i)
52         {
53             y=multi_mod(x,x,n);
54             if(y==1 && x!=1 && x!=n-1)
55                 return false;
56             x=y;
57         }
58         if(y!=1)
59             return false;
60     }
61     return true;

```

## 5.13 Multiset

```

1 Permutation:
2 MultiSet S={1 m,4 s,4 i,2 p}
3  $P(S) = \frac{(1+4+4+2)!}{1!4!4!2!}$ 
4
5 Combination:
6 MultiSet S={ $\infty a, \infty b, \infty c$ }
7  $\binom{S}{r} = \frac{(r+k-1)!}{r!(k-1)!} = \binom{r+k-1}{r}$ 
8
9 if (r>min{count(element[i])})
10     you have to resolve this problem with inclusion-exclusion
11     principle.
12
13 MS T={3 a,4 b,5 c}
14 MS T* = { $\infty a, \infty b, \infty c$ }
15  $A1 = \{ \binom{T_*}{10} | count(a) > 3 \} // \binom{8}{6}$ 
16  $A2 = \{ \binom{T_*}{10} | count(b) > 4 \} // \binom{7}{5}$ 
17  $A3 = \{ \binom{T_*}{10} | count(c) > 5 \} // \binom{6}{4}$ 
18  $\binom{T}{10} = \binom{T_*}{10} - (|A1| + |A2| + |A3|) + (|A1 \cap A2| + |A1 \cap A3| + |A2 \cap A3|) - |A1 \cap A2 \cap A3|$ 
19 ans=C(10,12)+C(1,3)+C(0,2)+0+0=6

```

## 5.14 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
9 or we can enumerate the continued fraction of  $\sqrt{n}$ , as  $\frac{x}{y}$ , it will be much
10 more faster
11
12 other solution pairs' matrix:
13
14 x1  n x y1
15 y1  x1
16
17 k-th solution is {matrix}k
18 */
19
20 import java.util.*;
21 import java.math.*;

```



```

17 public class Main
18 {
19     static BigInteger p,q,p1,p2,p3,q1,q2,q3,a1,a2,a0,h1,h2,g1,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))).equals(BigInteger.ONE))
39                 return ;
40             a1=a2;
41             g1=g2;
42             h1=h2;
43             p1=p2;
44             p2=p;
45             q1=q2;
46             q2=q;
47         }
48     }
49     public static void main(String[] args)
50     {
51         Scanner in=new Scanner(System.in);
52         t=in.nextInt();
53         for(int i=0;i<t;++i)
54         {
55             n=in.nextInt();
56             solve();
57             System.out.println(p+" "+q);
58         }
59     }
60 }

```

## 5.15 Pollard's rho algorithm

```

1 #include<cstdio>
2 #include<cstdlib>
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-->0)
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
77 inline unsigned long long pollar_rho(const unsigned long long n
78 ,const unsigned long long &c)
79 {
80     unsigned long long x(rand()%(n-1)+1),y,d,i(1),k(2);
81     y=x;
82     while(true)
83     {
84         ++i;
85         x=(multi_mod(x,x,n)+c)%n;
86         d=gcd((x-y+n)%n,n);
87         if(d>1 && d<n)
88             return d;
89         if(x==y)
90             return n;
91         if(i==k)
92         {
93             k<<=1;
94             y=x;
95         }
96     }
97 }
98
99 void find(const unsigned long long &n,short c)
100 {
101     if(n==1)
102         return;
103     if(miller_rabbin(n,6))
104     {
105         fac.push_back(n);
106         return;
107     }
108     unsigned long long p(n);
109     short k(c);
110     while(p>=n)
111         p=pollar_rho(p,c--);
112     find(p,k);
113     find(n/p,k);
114 }
115
116 int main()
117 {
118     scanf("%hd",&T);
119     while(T-->0)
120     {
121         scanf("%llu",&a);
122         fac.clear();
123         find(a,120);
124         if(fac.size()==1)
125             puts("Prime");
126         else
127         {
128             fac.sort();
129             printf("%llu\n",fac.front());
130         }
131     }
132     return 0;
133 }

```

## 5.16 Prime

```

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 | }

```

## 5.17 Reduced Residue System

1 | Euler's totient function:  
2 |  
3 | 对正整数  $n$ , 欧拉函数  $\varphi$  是少于或等于  $n$  的数中与  $n$  互质的数的数目, 也就是对  
4 | 的简化剩余系的大小。  
5 |  $\varphi(2)=1$  (唯一和 1 互质的数就是 1 本身)。  
6 | 若  $m, n$  互质,  $\varphi(m \times n) = \varphi(m) \times \varphi(n)$ 。  
7 | 对于  $n$  来说, 所有这样的数的和为  $\frac{n \times \varphi(n)}{2}$ 。

```

8 | inline long long phi(int n)
9 | {
10 |     static int i;
11 |     static int re;
12 |     re=n;
13 |     for(i=0;prm[i]*prm[i]<=n;++i)
14 |         if(n%prm[i]==0)
15 |         {
16 |             re-=re/prm[i];
17 |             do
18 |                 n/=prm[i];
19 |             while(n%prm[i]==0);
20 |         }
21 |     if(n!=1)
22 |         re-=re/n;
23 |     return re;
24 | }
25 |
26 | inline void Euler()
27 | {
28 |     static int i, j;
29 |     phi[1]=1;
30 |     for(i=2;i<MAXX;++i)
31 |         if(!phi[i])
32 |             for(j=i;j<MAXX;j+=i)
33 |             {
34 |                 if(!phi[j])
35 |                     phi[j]=j;
36 |                 phi[j]=phi[j]/i*(i-1);
37 |             }
38 | }

```

40 | Multiplicative order:

41 |  
42 | the multiplicative order of a modulo n is the smallest positive  
43 | integer k with  
44 |  $a^k \equiv 1 \pmod{n}$

45 | 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  
46 | totient theorem)

47 | 求:  
48 | method 1、根据定义, 对  $\varphi(m)$  分解素因子之后暴力枚举所有  $\varphi(m)$  的约数, 找到  
49 | 最小的一个  $d$ , 满足  $x^d \equiv 1 \pmod{m}$ ;

49 | method 2  
50 | inline long long ord(long long x, long long m)  
51 | {  
52 | static long long ans;  
53 | static int i, j;  
54 | ans=phi(m);  
55 | for(i=0;i<fac.size();++i)  
56 | for(j=0;j<fac[i].second && pow(x, ans/fac[i].first, m) == 1  
57 | ll; ++j)  
58 | ans/=fac[i].first;  
59 | return ans;  
60 | }  
61 |

62 | Primitive root:

63 |  
64 | 若  $\text{ord}(x) = \varphi(m)$ , 则  $x$  为  $m$  的一个原根  
65 | 因此只需检查所有  $x^d \not\equiv 1 \pmod{m}$  { $d$  为  $\varphi(m)$  的约数} 找到使  $x^d \equiv 1 \pmod{m}$  的所有  $d$ , 当且  
66 | 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

67 | 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  
68 | 指存在对于完全剩余系的原根……?

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

70 | 求:

71 |  
72 | 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  $p[j], i^{\frac{\varphi(m)}{p[j]}} \not\equiv 1 \pmod{m}$ ,  
73 | 那么  $i$  为  $m$  的一个原根。也就是说,  $\text{ord}(i) = \varphi(m)$ 。  
74 | 最小原根通常极小。

75 | Carmichael function:

76 |  
77 |  $\lambda(n)$  is defined as the smallest positive integer  $m$  such that

78 |  $a^m \equiv 1 \pmod{n}$  { forall  $a! \equiv 1$  &&  $\text{gcd}(a, n) = 1$  }

79 | 也就是简化剩余系 (完全剩余系中存在乘法群中无法得到 1 的数) 中所有  $x$  的  
80 |  $\text{lcm}\{\text{ord}(x)\}$

81 | if  $n = p[0]^{a[0]} \times p[1]^{a[1]} \times \dots \times p[m-1]^{a[m-1]}$   
82 | then  $\lambda(n) = \text{lcm}(\lambda(p[0]^{a[0]}), \lambda(p[1]^{a[1]}), \dots, \lambda(p[m-1]^{a[m-1]}))$ ;  
83 |

84 | if  $n = 2^c \times p[0]^{a[0]} \times p[1]^{a[1]} \times \dots \times p[m-1]^{a[m-1]}$   
85 | then  $\lambda(n) = \text{lcm}(2^{c-1}, \varphi(p[0]^{a[0]}), \varphi(p[1]^{a[1]}), \dots, \varphi(p[m-1]^{a[m-1]}))$ ;  
86 | {  $c=0$  if  $a<2$ ;  $c=1$  if  $a==2$ ;  $c=a-2$  if  $a>3$ ; }  
87 |

88 | Carmichael's theorem:

89 | if  $\text{gcd}(a, n) = 1$

90 | then  $\lambda(n) \equiv 1 \pmod{n}$   
91 |

## 5.18 Simpson's rule

```

1 | // thx for mzry
2 | inline double f(double)
3 | {
4 |     /*
5 |     define the function
6 |     */
7 | }
8 |
9 | inline double simp(double l, double r)
10 | {
11 |     double h = (r-l)/2.0;
12 |     return h*(f(l)+4*f((l+r)/2.0)+f(r))/3.0;
13 | }
14 |
15 | inline double rsimp(double l, double r) // call here
16 | {
17 |     double mid = (l+r)/2.0;
18 |     if(fabs((simp(l, r)-simp(l, mid)-simp(mid, r)))/15 < eps)
19 |         return simp(l, r);
20 |     else
21 |         return rsimp(l, mid)+rsimp(mid, r);
22 | }

```

## 5.19 System of linear congruences

1 | // minimal val that for all  $(m, a)$ ,  $\text{val} \% m = a$   
2 | #include<cstdio>

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     printf("Case_%d: %d\n",t,i<n?-1:(a[0]?a[0]:lcm));
53 }
54 return 0;
55 }

```

## 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 存

```

// normal version

```

55 #define N 128
56
57 char buf[MAXX];
58 int cnt[1111];
59
60 struct node
61 {
62     node *fal,*nxt[N];
63     int idx;
64     node() { memset(this,0,sizeof node); }
65 }*rt;
66 std::queue<node*>q;
67
68 void free(node *p)

```

```

69 {
70     for(int i(0);i<N;++i)
71         if(p->nxt[i])
72             free(p->nxt[i]);
73     delete p;
74 }
75
76 inline void add(char *s,int idx)
77 {
78     static node *p;
79     for(p=rt;*s;++s)
80     {
81         if(!p->nxt[*s])
82             p->nxt[*s]=new node();
83         p=p->nxt[*s];
84     }
85     p->idx=idx;
86 }
87
88 inline void make()
89 {
90     Q.push(rt);
91     static node *p,*q;
92     static int i;
93     while(!Q.empty())
94     {
95         p=Q.front();
96         Q.pop();
97         for(i=0;i<N;++i)
98             if(p->nxt[i])
99             {
100                 q=p->fal;
101                 while(q)
102                 {
103                     if(q->nxt[i])
104                     {
105                         p->nxt[i]->fal=q->nxt[i];
106                         break;
107                     }
108                     q=q->fal;
109                 }
110                 if(!q)
111                     p->nxt[i]->fal=rt;
112                 Q.push(p->nxt[i]);
113             }
114     }
115 }
116
117 inline void match(const char *s)
118 {
119     static node *p,*q;
120     for(p=rt;*s;++s)
121     {
122         while(p!=rt && !p->nxt[*s])
123             p=p->fal;
124         p=p->nxt[*s];
125         if(!p)
126             p=rt;
127         for(q=p;q!=rt && q->idx;q=q->fal) // why q->idx ? looks

```

128 //可以考虑 dfs 一下，拉直 fal 指针来跳过无效的匹配  
129 //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 或者线段树进行  
130 区间修改  
131 //大量内容匹配并且需要记录关键字出现次数的时候，可以考虑记录每个节点被覆盖  
132 的次数，然后沿着 fal 指针构成的 DAG 往上传递覆盖次数

### 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 |
24 | 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>
    &str)
2 | {
3 |     static int i;
4 |     i=0;
5 |     while(a-i>=0 && b+i<str.size() && str[a-i]==str[b+i])//注意3
        是 i 不是 1, 打错过很多次了
6 |         ++i;
7 |     return i;
8 | }
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 |
20 |         if(i>r)
21 |         {
22 |             z[i]=match(i,i,str);
23 |             l=i;
24 |             r=i+z[i]-1;
25 |         }
26 |         else
27 |             if(z[ii]==n)
28 |             {
29 |                 z[i]=n+match(i-n,i+n,str);
30 |                 l=i;
31 |                 r=i+z[i]-1;
32 |             }
33 |             else
34 |                 z[i]=std::min(z[ii],n);
35 |             if(z[i]>z[c])
36 |                 c=i;
37 |         }
38 |     }
39 |
40 | inline bool check(int *z,int a,int b) //检查子串 [a,b] 是否回文
41 | {
42 |     a=a*2-1;
43 |     b=b*2-1;
44 |     int m=(a+b)/2;
45 |     return z[m]>=b-m+1;
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 |

```

## 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]==
        str[b+2];
14 | }
15 |
16 | inline bool c12(const int *str,const int &k,const int &a,const
    int &b)
17 | {
18 |     if(k==2)
19 |         return str[a]<str[b] || str[a]==str[b] && c12(str,1,a
        +1,b+1);
20 |     else
21 |         return str[a]<str[b] || str[a]==str[b] && wv[a+1]<wv[b
        +1];
22 | }
23 |
24 | inline void sort(int *str,int *a,int *b,const int &n,const int
    &m)
25 | {
26 |     memset(ws,0,sizeof(ws));
27 |     int i;
28 |     for(i=0;i<n;++i)
29 |         ++ws[wv[i]=str[a[i]]];
30 |     for(i=1;i<n;++i)
31 |         ws[i]+=ws[i-1];
32 |     for(i=n-1;i>=0;--i)
33 |         b[--ws[wv[i]]]=a[i];
34 | }
35 |
36 | inline void dc3(int *str,int *sa,const int &n,const int &m)
37 | {
38 |     int *strn(str+n);
39 |     int *san(sa+n),tb((n+1)/3),ta(0),tbc(0),i,j,k;
40 |     str[n]=str[n+1]=0;
41 |     for(i=0;i<n;++i)
42 |         if(i%3)
43 |             wa[tbc++]=i;
44 |     sort(str+2,wa,wb,tbc,m);
45 |     sort(str+1,wb,wa,tbc,m);
46 |     sort(str,wa,wb,tbc,m);
47 |     for(i=j=1,strn[F(wb[0])]=0;i<tbc;++i)
48 |         strn[F(wb[i])]=c0(str,wb[i-1],wb[i])?j-1:j++;
49 |     if(j<tbc)
50 |         dc3(strn,san,tbc,j);
51 |     else
52 |         for(i=0;i<tbc;++i)
53 |             san[strn[i]]=i;
54 |     for(i=0;i<tbc;++i)
55 |         if(san[i]<tbc)
56 |             wb[ta++]=san[i]*3;
57 |     if(n%3==1)
58 |         wb[ta++]=n-1;
59 |     sort(str,wb,wa,ta,m);
60 |     for(i=0;i<tbc;++i)
61 |         wv[wb[i]]=G(san[i]);
62 |     for(i=j=k=0;i<ta && j<tbc;)
63 |         sa[k++]=c12(str,wb[j]%3,wa[i],wb[j])?wa[i++]:wb[j++];
64 |     while(i<ta)
65 |         sa[k++]=wa[i++];
66 |     while(j<tbc)
67 |         sa[k++]=wb[j++];

```

```

68 }
69
70 int rk[MAXX], lcpa[MAXX], sa[MAXX*3];
71 int str[MAXX*3]; //必须 int
72
73 int main()
74 {
75     scanf("%d.%d",&n,&j);
76     for(i=0; i<n; ++i)
77     {
78         scanf("%d",&k);
79         num[i]=k-j+100;
80         j=k;
81     }
82     num[n]=0;
83
84     dc3(num, sa, n+1, 191); //191: str 中取值范围, 桶排序
85
86     for(i=1; i<=n; ++i) // rank 数组
87         rk[sa[i]]=i;
88     for(i=k=0; i<n; ++i) // lcp 数组
89         if(!rk[i])
90             lcpa[0]=0;
91     else
92     {
93         j=sa[rk[i]-1];
94         if(k>0)
95             --k;
96         while(num[i+k]==num[j+k])
97             ++k;
98         lcpa[rk[i]]=k;
99     }
100
101     for(i=1; i<=n; ++i)
102         sptb[0][i]=i;
103     for(i=1; i<=lg[n]; ++i) //sparse table RMQ
104     {
105         k=n+1-(1<<i);
106         for(j=1; j<=k; ++j)
107         {
108             a=sptb[i-1][j];
109             b=sptb[i-1][j+(1<<(i-1))];
110             sptb[i][j]=lcpa[a]<lcpa[b]?a:b;
111         }
112     }
113 }
114
115 inline int ask(int l, int r)
116 {
117     a=lg[r-l+1];
118     r--=(1<<a)-1;
119     l=sptb[a][l];
120     r=sptb[a][r];
121     return lcpa[l]<lcpa[r]?l:r;
122 }
123
124 inline int lcp(int l, int r) // 字符串上 [l,r] 区间的 rmq
125 {
126     l=rk[l];
127     r=rk[r];
128     if(l>r)
129         std::swap(l, r);
130     return lcpa[ask(l+1, r)];
131 }
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<n; ++i)
13        wss[i]=0;
14    for(i=0; i<n; ++i)
15        wss[x[i]=s[i]]++;
16    for(i=1; i<n; ++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<n; ++i)
30            wss[i]=0;
31        for(i=0; i<n; ++i)
32            wss[wv[i]]++;
33        for(i=1; i<n; ++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     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     last=np;
49 }
50
51 int v[MAXN], the[MAXN];
52
53 inline void make(char *str)
54 {
55     cnt=0;
56     rt=last=neww();
57     static int i, len, now;
58     for(i=0; str[i]; ++i)
59         add(str[i]-'a');
60     len=i;
61     memset(v, 0, sizeof v);
62     for(i=1; i<=cnt; ++i)
63         ++v[val[i]];
64     for(i=1; i<=len; ++i)
65         v[i]+=v[i-1];
66     for(i=1; i<=cnt; ++i)
67         the[v[val[i]]--]=i;
68     for(i=cnt; i--i)
69     {
70         now=the[i];
71         // topsort already

```

```

72     }
73 }
74 /*
75 sizeof right(s):
76     init:
77         for all np:
78             count[np]=1;
79     process:
80         for all status s:
81             count[fal[s]]+=count[s];
82 */

```

## 7 search

### 7.1 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  
3 与该行冲突的行。  
4 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。  
5 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。  
6 该行冲突的行可能满足重复覆盖。

### 7.2 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[MAXN], d[MAXN], l[MAXN], r[MAXN], ch[MAXN], rh[MAXN];
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rowx
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colx
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 //删除一列以及相关的所有行
163 inline void remove(int c)
164 {
165     l[r[c]] = l[c];
166     r[l[c]] = r[c];
167     for (int i = d[c]; i != c; i = d[i])
168         for (int j = r[i]; j != i; j = r[j])
169             {
170                 u[d[j]] = u[j];
171                 d[u[j]] = d[j];
172                 cntcol[col[j]]--;
173             }
174 }
175 //恢复一列以及相关的所有行
176 inline void resume(int c)
177 {
178     for (int i = u[c]; i != c; i = u[i])
179         for (int j = l[i]; j != i; j = l[j])
180             {
181                 u[d[j]] = j;
182                 d[u[j]] = j;
183                 cntcol[col[j]]++;
184             }
185     l[r[c]] = c;
186     r[l[c]] = c;
187 }
188 //搜索部分
189 bool DLX(int deep)
190 {
191     if (r[0] == 0)
192     {
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 }

```

### 7.3 dlx - repeat cover

```

1 #include<stdio>
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 }

```

## 7.4 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 short n, T, t, i;
13 long long carry, sumw, sumc;
14 long long ans, las[MAXX];
15
16 int com(const void *n, const void *m)
17 {
18     struct mono *a = (struct mono *)n, *b = (struct mono *)m;
19     if(a->weig != b->weig)
20         return a->weig - b->weig;
21     else
22         return b->cost - a->cost;
23 }
24
25 bool comp(const struct mono a, const struct mono b)
26 {
27     if(a.weig != b.weig)
28         return a.weig < b.weig;
29     else
30         return b.cost < a.cost;
31 }
32
33 void dfs(short i, long long cost_n, long long carry_n, short last)
34 {
35     if(ans < cost_n)
36         ans = cost_n;
37     if(i == n || goods[i].weig > carry_n || cost_n + las[i] <= ans)
38         return;
39     if(last || (goods[i].weig != goods[i-1].weig && goods[i].cost
40 > goods[i-1].cost))
41         dfs(i+1, cost_n + goods[i].cost, carry_n - goods[i].weig, 1);
42     dfs(i+1, cost_n, carry_n, 0);
43 }
44
45 int main()
46 {
47     // freopen("asdf", "r", stdin);
48     scanf("%hd", &T);
49     for(t=1; t<=T; ++t)
50     {
51         scanf("%hd%lld", &n, &carry);
52         sumw=0;
53         sumc=0;
54         ans=0;
55         for(i=0; i<n; ++i)
56         {
57             scanf("%lld%lld", &goods[i].weig, &goods[i].cost);
58             sumw += goods[i].weig;
59             sumc += goods[i].cost;
60         }
61         if(sumw <= carry)
62         {
63             printf("Case_%hd: %lld\n", t, sumc);
64             continue;
65         }
66         // qsort(goods, n, sizeof(struct mono), com);
67         std::sort(goods, goods+n, comp);
68         for(i=0; i<n; ++i)
69         {
70             printf("%lld %lld\n", goods[i].weig, goods[i].cost);
71             ;
72             las[i] = sumc;
73             sumc -= goods[i].cost;
74         }
75         dfs(0, 0, carry, 1);
76         printf("Case_%hd: %lld\n", t, ans);
77     }
78     return 0;
79 }

```

## 8 dynamic programming

### 8.1 knapsack problem

1 | multiple-choice knapsack problem:

```

2
3 for 所有的组k
4     for v=V..0
5         for 所有的属于组ik
6             f[v] = max{f[v], f[v-c[i]]+w[i]}

```

## 8.2 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         }
45         n=0;
46         p=-1;
47         for(i=0; i<the[1].size(); ++i)
48             if(dp[i] > n)
49                 n = dp[i];
50         printf("%d\n", n);
51         for(i=n-1; i>=0; --i)
52         {
53             ans[i] = the[1][path[i]];
54             p = path[i];
55         }
56         for(i=0; i<n; ++i)
57             printf("%d ", ans[i]);
58         puts("");
59     }
60     return 0;
61 }

```

## 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 nocp
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() ?
73                 b.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         {
123             c.a.insert( c.a.begin(), '0' );
124             c = c + a.substr( i, 1 );
125             while( !( c < b ) )
126             {
127                 c = c - b;
128                 d.a[i]++;
129             }
130         }
131         return d.normalize(dSign);
132     }
133     Bigint operator % ( Bigint b ) // modulo operator
134                                     overloading
135     {
136         if( b.size() == 1 && b.a[0] == '0' )
137             b.a[0] /= ( b.a[0] - 48 );
138         Bigint c("0");
139         b.sign = 1;
140         for( int i = a.size() - 1; i >= 0; i-- )
141         {
142             c.a.insert( c.a.begin(), '0' );
143             c = c + a.substr( i, 1 );
144             while( !( c < b ) )
145                 c = c - b;
146         }
147         return c.normalize(sign);
148     }
149     // output method
150     void print()
151     {
152         if( sign == -1 )
153             putchar('-');
154         for( int i = a.size() - 1; i >= 0; i-- )
155             putchar(a[i]);
156     }
157 };
158
159 int main()
160 {
161     Bigint a, b, c; // declared some Bigint variables
162     // taking Bigint input
163     std::string input; // std::string to take input
164     std::cin >> input; // take the Big integer as std::string
165     a = input; // assign the std::string to Bigint a
166
167     std::cin >> input; // take the Big integer as std::string
168     b = input; // assign the std::string to Bigint b
169
170     // Using mathematical operators
171     c = a + b; // adding a and b
172     c.print(); // printing the Bigint
173     puts(""); // newline
174
175     c = a - b; // subtracting b from a
176     c.print(); // printing the Bigint
177     puts(""); // newline
178
179     c = a * b; // multiplying a and b
180     c.print(); // printing the Bigint
181 }

```

175 puts(""); // newline  
176  
177 c = a / b; // dividing a by b  
178 c.print(); // printing the Bigint  
179 puts(""); // newline  
180  
181 c = a % b; // a modulo b  
182 c.print(); // printing the Bigint  
183 puts(""); // newline  
184  
185 ///////////////////////////////////  
186 // Using conditional operators //  
187 ///////////////////////////////////  
188  
189 if( a == b )  
190 puts("equal"); // checking equality  
191 else  
192 puts("not equal");  
193  
194 if( a < b )  
195 puts("a is smaller than b"); // checking less than  
196 operator  
197  
198 return 0;  
199 }

65 {  
66 static int l,r,mid,re;  
67 l=0;  
68 r=n-1;  
69 re=-1;  
70 while(l<=r)  
71 {  
72 mid=l+r>>1;  
73 if(A[mid]<=x)  
74 {  
75 l=mid+1;  
76 re=mid;  
77 }  
78 else  
79 r=mid-1;  
80 }  
81 return re;  
82 }  
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 {  
93 mid=l+r>>1;  
94 if(A[mid]<=x)  
95 l=mid+1;  
96 else  
97 {  
98 r=mid-1;  
99 re=mid;  
100 }  
101 }  
102 return re;  
103 }  
104  
105 inline int go(int A[],int n,int x)// upper\_bound();  
106 {  
107 static int l,r,mid;  
108 l=0;  
109 r=n-1;  
110 while(l<r)  
111 {  
112 mid=l+r>>1;  
113 if(A[mid]<=x)  
114 l=mid+1;  
115 else  
116 r=mid;  
117 }  
118 return r;  
119 }  
120  
121 inline int go(int A[],int n,int x)// lower\_bound();  
122 {  
123 static int l,r,mid;  
124 l=0;  
125 r=n-1;  
126 while(l<r)  
127 {  
128 mid=l+r>>1;  
129 if(A[mid]<x)  
130 l=mid+1;  
131 else  
132 r=mid;  
133 }  
134 return r;  
135 }

9.3 Binary Search

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  
24 inline int go(int A[],int n,int x) // return the largest i that  
25 make A[i]==x;  
26 {  
27 static int l,r,mid,re;  
28 l=0;  
29 r=n-1;  
30 re=-1;  
31 while(l<=r)  
32 {  
33 mid=l+r>>1;  
34 if(A[mid]<=x)  
35 {  
36 l=mid+1;  
37 if(A[mid]==x)  
38 re=mid;  
39 }  
40 else  
41 r=mid-1;  
42 }  
43 return re;  
44 }  
45  
46 inline int go(int A[],int n,int x) // retrun the largest i that  
47 make A[i]<x;  
48 {  
49 static int l,r,mid,re;  
50 l=0;  
51 r=n-1;  
52 re=-1;  
53 while(l<=r)  
54 {  
55 mid=l+r>>1;  
56 if(A[mid]<x)  
57 {  
58 l=mid+1;  
59 re=mid;  
60 }  
61 else  
62 r=mid-1;  
63 }  
64 return re;  
65 }  
66  
67 inline int go(int A[],int n,int x)// return the largest i that  
68 make A[i]<=x;  
69 {  
70 static int l,r,mid,re;  
71 l=0;  
72 r=n-1;  
73 re=-1;  
74 while(l<=r)  
75 {  
76 mid=l+r>>1;  
77 if(A[mid]<=x)  
78 {  
79 l=mid+1;  
80 re=mid;  
81 }  
82 else  
83 r=mid-1;  
84 }  
85 return re;  
86 }  
87  
88 inline int go(int A[],int n,int x)// return the least i that  
89 make A[i]>=x;  
90 {  
91 static int l,r,mid,re;  
92 l=0;  
93 r=n-1;  
94 re=-1;  
95 while(l<=r)  
96 {  
97 mid=l+r>>1;  
98 if(A[mid]<=x)  
99 l=mid+1;  
100 else  
101 {  
102 r=mid-1;  
103 re=mid;  
104 }  
105 }  
106 return re;  
107 }  
108  
109 inline int go(int A[],int n,int x)// upper\_bound();  
110 {  
111 static int l,r,mid;  
112 l=0;  
113 r=n-1;  
114 while(l<r)  
115 {  
116 mid=l+r>>1;  
117 if(A[mid]<=x)  
118 l=mid+1;  
119 else  
120 r=mid;  
121 }  
122 return r;  
123 }  
124  
125 inline int go(int A[],int n,int x)// lower\_bound();  
126 {  
127 static int l,r,mid;  
128 l=0;  
129 r=n-1;  
130 while(l<r)  
131 {  
132 mid=l+r>>1;  
133 if(A[mid]<x)  
134 l=mid+1;  
135 else  
136 r=mid;  
137 }  
138 return r;  
139 }  
140 }

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  
19 Scanner in.useRadix(int radix);// Sets this scanner's

	<i>default radix to the specified radix.</i>	15	done
20	<b>void</b> in.close();//Closes this scanner.	16	
21		17	
22	//String	18	1、状态状态状态状态状态状态状态状态状态
23		19	2、calm_down();calm_down();calm_down();
24	<b>char</b> str.charAt( <b>int</b> index);	20	3、读完题目读完题目读完题目
25	<b>int</b> str.compareTo(String anotherString); // <0 if less. ==0 if equal. >0 if greater.	21	4、不盲目跟版
26	<b>int</b> str.compareToIgnoreCase(String str);	22	5、考虑换题/换想法
27	String str.concat(String str);	23	6、对数/离线/hash/观察问题本身/点 ↔ 区间互转
28	<b>boolean</b> str.contains(CharSequence s);	24	6.1、对数调整精度 or 将乘法转换成加法
29	<b>boolean</b> str.endsWith(String suffix);	25	6.2、点化区间, 区间化点
30	<b>boolean</b> str.startsWith(String prefix);	26	7、数组大小……
31	<b>boolean</b> str.startsWith(String prefix, <b>int</b> toffset);		
32	<b>int</b> str.hashCode();		
33	<b>int</b> str.indexOf( <b>int</b> ch);		
34	<b>int</b> str.indexOf( <b>int</b> ch, <b>int</b> fromIndex);		
35	<b>int</b> str.indexOf(String str);		
36	<b>int</b> str.indexOf(String str, <b>int</b> fromIndex);		
37	<b>int</b> str.lastIndexOf( <b>int</b> ch);		
38	<b>int</b> str.lastIndexOf( <b>int</b> ch, <b>int</b> fromIndex);		
39	//(ry		
40	<b>int</b> str.length();		
41	String str.substring( <b>int</b> beginIndex);		
42	String str.substring( <b>int</b> beginIndex, <b>int</b> 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			
47	//StringBuilder		
48	StringBuilder str.insert( <b>int</b> offset,...);		
49	StringBuilder str.reverse();		
50	<b>void</b> str.setCharAt( <b>int</b> index, <b>int</b> ch);		
51			
52	//BigInteger		
53	compareTo(); equals(); doubleValue(); longValue(); hashCode(); toString(); toString( <b>int</b> radix); max(); min(); mod(); modPow(BigInteger exp, BigInteger m); nextProbablePrime(); pow();		
54	andNot(); and(); xor(); not(); or(); getLowestSetBit(); bitCount(); bitLength(); setBit( <b>int</b> n); shiftLeft( <b>int</b> n); shiftRight( <b>int</b> n);		
55	add(); divide(); divideAndRemainder(); remainder(); multiply(); subtract(); gcd(); abs(); signum(); negate();		
56			
57	//BigDecimal		
58	movePointLeft(); movePointRight(); precision(); stripTrailingZeros(); toBigInteger(); toPlainString();		
59			
60			
61	//sort		
62	<b>class</b> pii implements Comparable		
63	{		
64	<b>public int</b> a,b;		
65	<b>public int</b> compareTo(Object i)		
66	{		
67	pii c=(pii)i;		
68	<b>return</b> a==c.a?c.b-b:c.a-a;		
69	}		
70	}		
71			
72	<b>class</b> Main		
73	{		
74	<b>public static void</b> main(String[] args)		
75	{		
76	pii[] the=new pii[2];		
77	the[0]=new pii();		
78	the[1]=new pii();		
79	the[0].a=1;		
80	the[0].b=1;		
81	the[1].a=1;		
82	the[1].b=2;		
83	Arrays.sort(the);		
84	<b>for</b> ( <b>int</b> i=0;i<2;++i)		
85	System.out.printf("%d.%d\n",the[i].a,the[i].b);		
86	}		
87	}		

## 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

```