

Code Library for Lmxyy

Lmxyy

Shanghai Jiao Tong University

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目录

Chapter 1

Algorithms

1.1 1D1D Dynamic Programming

```
1 // noi2009 诗人小 G
2 #include<cstring>
3 #include<cstdio>
4 #include<cstdlib>
5 using namespace std;
6
7 #define limit (1e18)
8 #define maxn 100010
9 #define maxm 40
10 int N,L,P,pre[maxn],top;
11 char s[maxm];
12 long double f[maxn];
13 struct node { int l,r,key; }stack[maxn];
14
15 inline long double qsm(int a,int b)
16 {
17     long double ret = 1;
18     while (b--) ret *= 1.0*a;
19     return ret;
20 }
21
22 inline long double calc(int a,int b)
23 {
24     return f[b]+qsm(abs(pre[a]-pre[b]-L),P);
25 }
26
27 inline int find(int a)
28 {
29     int l = 1,r = top,mid;
30     while (l <= r)
31     {
32         mid = (l + r) >> 1;
33         if (stack[mid].l<=a&&stack[mid].r>=a) return stack[mid].key;
```

```

34         if (a < stack[mid].l) r = mid - 1;
35         else l = mid + 1;
36     }
37 }
38
39 inline void updata(int now)
40 {
41     int l = 1, r;
42     while (top)
43     {
44         if (calc(stack[top].l, stack[top].key) >= calc(stack[top].l, now))
45             --top;
46         else
47         {
48             l = stack[top].l, r = stack[top].r;
49             while (l <= r)
50             {
51                 int mid = (l + r) >> 1;
52                 if (calc(mid, stack[top].key) >= calc(mid, now)) r = mid - 1;
53                 else l = mid + 1;
54             }
55             stack[top].r = r;
56             break;
57         }
58     }
59     if (l <= N) stack[++top] = (node){l, N, now};
60 }
61
62 inline void dp()
63 {
64     f[0] = 0;
65     stack[top = 1] = (node) {1, N, 0};
66     for (int i = 1; i <= N; ++i)
67     {
68         int key = find(i);
69         f[i] = calc(i, key);
70         updata(i);
71     }
72 }
73
74 int main()
75 {
76     freopen("1563.in", "r", stdin);
77     freopen("1563.out", "w", stdout);
78     int T; scanf("%d", &T);
79     while (T--)
80     {
81         scanf("%d %d %d\n", &N, &L, &P);
82         L++;

```

```

83     for (int i = 1; i <= N; ++i)
84     {
85         scanf("%s", s);
86         pre[i] = strlen(s) + 1 + pre[i - 1];
87     }
88     dp();
89     if (f[N] > limit) printf("Too hard to arrange\n");
90     else printf("%.0Lf\n", f[N]);
91     printf("-----\n");
92 }
93 fclose(stdin); fclose(stdout);
94 return 0;
95 }

```

1.2 Dynamic Minimal Spanning Tree

```

1  // 每次修改一条边，每次修改一条边权值，求最小生成树
2  #include<algorithm>
3  #include<cstring>
4  #include<vector>
5  #include<iostream>
6  #include<cstdio>
7  #include<stdlib.h>
8  using namespace std;
9
10 typedef long long ll;
11 const int maxn = 100010; const ll inf = 1LL<<40;
12 int N, M, Q, father[maxn], cnt[maxn], reid[maxn]; ll ans[maxn];
13
14 inline int find(int a) { if (father[a] != a) return father[a] = find(father[a]); return
    ↪ father[a]; }
15
16 inline int gi()
17 {
18     char ch; int ret = 0, f = 1;
19     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
20     if (ch == '-') f = -1, ch = getchar();
21     do ret = ret * 10 + ch - '0', ch = getchar(); while (ch >= '0' && ch <= '9');
22     return ret * f;
23 }
24
25 struct Edge
26 {
27     int a, b, id; ll c;
28     inline Edge() = default;
29     inline Edge(int _a, int _b, int _id, ll _c): a(_a), b(_b), id(_id), c(_c) {}
30     inline void read(int i) { a = gi(), b = gi(), c = gi(); id = i; }
31     friend inline bool operator <(const Edge &x, const Edge &y) { return x.c < y.c; }
32 } edge[22][maxn], tmp[maxn], bac[maxn];

```

```

33
34 struct Operation
35 {
36     int x; ll y;
37     inline Operation() = default;
38     inline Operation(int _x,ll _y):x(_x),y(_y) {}
39     inline void read() { x = gi(),y = gi(); }
40 }opt[maxn];
41
42 inline void construct(int &tot,ll &sum)
43 {
44     sort(tmp+1,tmp+tot+1);
45     for (int i = 1;i <= tot;++i)
46         father[tmp[i].a] = tmp[i].a,father[tmp[i].b] = tmp[i].b;
47     vector <Edge> vec;
48     for (int i = 1;i <= tot;++i)
49     {
50         int u = find(tmp[i].a),v = find(tmp[i].b);
51         if (u != v) father[u] = v,vec.push_back(tmp[i]);
52     }
53     for (int i = 0;i < (int)vec.size();++i)
54         father[vec[i].a] = vec[i].a,father[vec[i].b] = vec[i].b;
55     for (int i = 0;i < (int)vec.size();++i)
56     {
57         Edge e = vec[i];
58         if (e.c != -inf) father[find(e.a)] = find(e.b),sum += e.c;
59     }
60     vec.clear();
61     for (int i = 1;i <= tot;++i)
62     {
63         int u = find(tmp[i].a),v = find(tmp[i].b);
64         if (u != v)
65         {
66             tmp[i].a = u,tmp[i].b = v;
67             vec.push_back(tmp[i]);
68         }
69     }
70     for (int i = 0;i < (int)vec.size();++i) tmp[i+1] = vec[i];
71     for (int i = 1;i <= tot;++i) reid[tmp[i].id] = i;
72     tot = (int)vec.size();
73 }
74
75 inline void destruct(int &tot)
76 {
77     sort(tmp+1,tmp+tot+1);
78     for (int i = 1;i <= tot;++i)
79         father[tmp[i].a] = tmp[i].a,father[tmp[i].b] = tmp[i].b;
80     vector <Edge> vec;
81     for (int i = 1;i <= tot;++i)

```

```

82     {
83         int u = find(tmp[i].a), v = find(tmp[i].b);
84         if (u != v) father[u] = v, vec.push_back(tmp[i]);
85         else if (tmp[i].c == inf) vec.push_back(tmp[i]);
86     }
87     for (int i = 0; i < (int)vec.size(); ++i) tmp[i+1] = vec[i];
88     tot = (int)vec.size();
89 }
90
91 inline void work(int l, int r, int dep, ll sum)
92 {
93     int tot = cnt[dep];
94     for (int i = 1; i <= tot; ++i) tmp[i] = edge[dep][i];
95     if (l == r)
96     {
97         bac[opt[l].x].c = opt[l].y;
98         for (int i = 1; i <= tot; ++i)
99         {
100             tmp[i].c = bac[tmp[i].id].c;
101             father[tmp[i].a] = tmp[i].a;
102             father[tmp[i].b] = tmp[i].b;
103         }
104         sort(tmp+1, tmp+tot+1);
105         for (int i = 1; i <= tot; ++i)
106         {
107             int u = find(tmp[i].a), v = find(tmp[i].b);
108             if (u != v) sum += tmp[i].c, father[u] = v;
109         }
110         ans[l] = sum; return;
111     }
112     for (int i = 1; i <= tot; ++i)
113         tmp[i].c = bac[tmp[i].id].c, reid[tmp[i].id] = i;
114     for (int i = 1; i <= r; ++i) tmp[reid[opt[i].x]].c = -inf;
115     construct(tot, sum);
116     for (int i = 1; i <= r; ++i)
117         tmp[reid[opt[i].x]].c = inf;
118     destruct(tot);
119     for (int i = 1; i <= tot; ++i) edge[dep+1][i] = tmp[i];
120     int mid = (l+r)>>1; cnt[dep+1] = tot;
121     work(l, mid, dep+1, sum); work(mid+1, r, dep+1, sum);
122 }
123
124 int main()
125 {
126     // freopen("B.in", "r", stdin);
127     N = gi(), M = gi(), Q = gi();
128     for (int i = 1; i <= M; ++i) bac[i].read(i), edge[0][i] = bac[i];
129     for (int i = 1; i <= Q; ++i) opt[i].read();
130     for (int i = 1; i <= N; ++i) father[i] = i;

```

```

131     cnt[0] = M; work(1,Q,0,0);
132     for (int i = 1;i <= Q;++i) printf("%lld\n",ans[i]);
133     return 0;
134 }

```

1.3 Plug-like Dynamic Programming

```

1  // ural 1519
2  #include<cstdio>
3  #include<cstdlib>
4  #include<cstring>
5  #include<iostream>
6  #include<algorithm>
7  using namespace std;
8
9  typedef long long ll;
10 const int maxn = 14,maxs = 300010;
11 int mp[maxn][maxn],N,M,cur,last,total[2];
12 int size,ex,ey,head[maxs],nxt[maxs],Hash[maxs];
13 ll f[2][maxs],state[2][maxs];
14
15 inline void init()
16 {
17     memset(mp,0,sizeof mp); ex = ey = 0;
18     size = cur = 0; last = 1;
19     total[cur] = 1;
20     state[cur][1] = 0;
21     f[cur][1] = 1;
22 }
23
24 inline void calc(ll s,ll inc)
25 {
26     int pos = s%maxs;
27     for (int i = head[pos];i;i = nxt[i])
28         if (state[cur][Hash[i]] == s)
29             {
30                 f[cur][Hash[i]] += inc;
31                 return;
32             }
33     ++total[cur];
34     state[cur][total[cur]] = s;
35     f[cur][total[cur]] = inc;
36     nxt[++size] = head[pos];
37     head[pos] = size;
38     Hash[size] = total[cur];
39 }
40
41 inline ll work()
42 {

```



```

43     ll ret = 0;
44     for (int i = 1; i <= N; ++i)
45     {
46         for (int k = 1; k <= total[cur]; ++k) state[cur][k] <= 2;
47         for (int j = 1; j <= M; ++j)
48         {
49             memset(head, 0, sizeof head);
50             size = 0; cur ^= 1, last ^= 1;
51             total[cur] = 0;
52             for (int k = 1; k <= total[last]; ++k)
53             {
54                 ll s = state[last][k], num = f[last][k];
55                 int p = (s >> ((j-1) << 1)) % 4, q = (s >> (j << 1)) % 4;
56                 if (!mp[i][j]) { if (!p && !q) calc(s, num); }
57                 else if (!p && !q)
58                 {
59                     if (mp[i+1][j] && mp[i][j+1])
60                         calc(s + (1 << ((j-1) << 1)) + 2 * (1 << (j << 1)), num);
61                 }
62                 else if (!p && q)
63                 {
64                     if (mp[i][j+1]) calc(s, num);
65                     if (mp[i+1][j]) calc(s - q * (1 << (j << 1)) + q * (1 << ((j-1) << 1)), num);
66                 }
67                 else if (p && !q)
68                 {
69                     if (mp[i+1][j]) calc(s, num);
70                     if (mp[i][j+1]) calc(s - p * (1 << ((j-1) << 1)) + p * (1 << (j << 1)), num);
71                 }
72                 else if (p == 1 && q == 1)
73                 {
74                     int b = 1;
75                     for (int t = j+1; t <= M; ++t)
76                     {
77                         int v = (s >> (t << 1)) % 4;
78                         if (v == 1) ++b; else if (v == 2) --b;
79                         if (b == 0) { s -= 1 * (1 << (t << 1)); break; }
80                     }
81                     calc(s - (1 << ((j-1) << 1)) - (1 << (j << 1)), num);
82                 }
83                 else if (p == 2 && q == 2)
84                 {
85                     int b = 1;
86                     for (int t = j-2; t >= 0; --t)
87                     {
88                         int v = (s >> (t << 1)) % 4;
89                         if (v == 2) ++b; else if (v == 1) --b;
90                         if (b == 0) { s += 1 * (1 << (t << 1)); break; }
91                     }

```

```

92         calc(s-2*(1<<((j-1)<<1))-2*(1<<(j<<1)),num);
93     }
94     else if (p == 1&&q == 2) { if (i == ex&&j == ey) ret += num; }
95     else if (p == 2&&q == 1)
96         calc(s-2*(1<<((j-1)<<1))-1<<(j<<1)),num);
97     }
98 }
99 }
100 return ret;
101 }
102
103 int main()
104 {
105     freopen("1519.in","r",stdin);
106     while (scanf("%d%d",&N,&M) != EOF)
107     {
108         init();
109         for (int i = 1;i <= N;++i)
110             for (int j = 1;j <= M;++j)
111             {
112                 char ch; do ch = getchar(); while (ch != '.'&&ch != '*');
113                 if (ch == '.') ex = i,ey = j,mp[i][j] = 1;
114             }
115         cout << work() << endl;
116     }
117     return 0;
118 }

```

1.4 Slop Optimization

```

1  #include<algorithm>
2  #include<cstring>
3  #include<iostream>
4  #include<cstdio>
5  #include<cstdlib>
6  using namespace std;
7
8  typedef long long ll;
9  const int maxn = 500010; const ll inf = 1LL<<60;
10 int N,K,A[maxn]; ll pre[maxn],f[maxn];
11
12 struct Point
13 {
14     ll x,y;
15     inline Point() = default;
16     inline Point(ll _x,ll _y):x(_x),y(_y) {}
17     friend inline Point operator -(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
18     friend inline ll operator /(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }

```

```

19  };
20
21  inline ll calc(const Point &a,int b) { return -a.x*b+a.y; }
22
23  struct Queue
24  {
25      Point array[maxn]; int h,t;
26      inline Queue() = default;
27      inline void init() { h = t = 0; }
28      inline void pop_front(int i) { while (t-h >= 2&&calc(array[h+1],i) > calc(array[h+2],i))
↪      ++h; }
29      inline void push(const Point &a,int i) { while (t-h >=
↪      2&&(a-array[t-1])/(array[t]-array[t-1]) >= 0) --t; array[++t] = a; }
30      inline Point front() const { return array[h+1]; }
31  }team;
32
33  inline int gi()
34  {
35      char ch; int ret = 0,f = 1;
36      do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
37      if (ch == '-') f = -1,ch = getchar();
38      do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
39      return ret*f;
40  }
41
42  int main()
43  {
44      // freopen("E.in","r",stdin);
45      for (int T = gi();T--;)
46      {
47          N = gi(),K = gi(); team.init();
48          for (int i = 1;i <= N;++i) A[i] = gi();
49          for (int i = 1;i <= N;++i) pre[i] = pre[i-1]+A[i];
50          for (int i = 1;i <= N;++i)
51          {
52              if (i >= K)
53              {
54                  if (f[i-K] != inf)
55                      team.push(Point(A[i-K+1],f[i-K]-pre[i-K]+(ll)(i-K)*A[i-K+1]),i);
56                  team.pop_front(i);
57                  f[i] = calc(team.front(),i)+pre[i];
58              }
59              else f[i] = inf;
60          }
61          cout << f[N] << endl;
62      }
63      return 0;
64  }

```

1.5 Three-dimension Partial Order

```

1  //三维偏序, CDQ 分治
2  #define lowbit(a) (a&-a)
3  int M,N,A,B,tree[maxn];
4
5  inline void ins(int a,int b) { for (;a < maxn;a += lowbit(a)) tree[a] = max(tree[a],b); }
6  inline void clear(int a) { for (;a < maxn;a += lowbit(a)) tree[a] = 0; }
7  inline int calc(int a) { int ret = 0; for (;a;a -= lowbit(a)) ret = max(tree[a],ret); return
   ↪ ret; }
8
9  struct Node
10 {
11     int x,y,z,res;
12     inline Node(int _x = 0,int _y = 0,int _z = 0,int _res = 0):x(_x),y(_y),z(_z),res(_res) {}
13     inline void update() { ++x,++y,++z; }
14 }E[maxn];
15
16 inline bool cmpx(const Node &a,const Node &b)
17 {
18     if (a.x != b.x) return a.x < b.x;
19     else if (a.y != b.y) return a.y > b.y;
20     else return a.z > b.z;
21 }
22 inline bool cmpy(const Node &a,const Node &b) { return a.y < b.y; }
23
24 inline void work(int l,int r)
25 {
26     if (l == r) { E[l].res = max(E[l].res,1); return; }
27     int mid = (l+r) >> 1,p = 1;
28     work(l,mid);
29     sort(E+l,E+mid+1,cmpy);
30     sort(E+mid+1,E+r+1,cmpy);
31     for (int i = mid+1;i <= r;++i)
32     {
33         for (;p <= mid&&E[p].y < E[i].y;++p) ins(E[p].z,E[p].res);
34         E[i].res = max(E[i].res,calc(E[i].z-1)+1);
35     }
36     while (p > 1) clear(E[--p].z);
37     sort(E+mid+1,E+r+1,cmpx);
38     work(mid+1,r);
39 }
40
41 inline int run()
42 {
43     for (int i = 1;i <= N+M;++i) E[i].update();
44     sort(E+1,E+N+M+1,cmpx); work(1,N+M);
45     int ret = 0;
46     for (int i = 1;i <= N+M;++i) ret = max(ret,E[i].res);
47     return ret;

```


Chapter 2

Computational Geometry

2.1 Circle Intersection

```
1  //modified
2  const double eps = 1e-7, pi = acos(-1.0);
3  int N,M; double area[maxn]; // area[k] -> area of intersections >= k.
4
5  inline int dcmp(double a)
6  {
7      if (-eps <= a && a <= eps) return 0;
8      else if (a > 0) return 1; else return -1;
9  }
10
11 struct Point
12 {
13     double x,y;
14     inline Point() = default;
15     inline Point(double _x,double _y):x(_x),y(_y) {}
16     inline void read() { x = gi(),y = gi(); }
17     inline double norm() const { return sqrt(x*x+y*y); }
18     inline double angle() const { return atan2(y,x); }
19     inline Point unit() const { double len = norm(); return Point(x/len,y/len); }
20     friend inline Point operator-(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
21     friend inline Point operator+(const Point &a,const Point &b) { return
↪ Point(a.x+b.x,a.y+b.y); }
22     friend inline Point operator*(const Point &a,double b) { return Point(a.x*b,a.y*b); }
23     friend inline Point operator*(double b,const Point &a) { return Point(a.x*b,a.y*b); }
24     friend inline Point operator/(const Point &a,double b) { return Point(a.x/b,a.y/b); }
25     friend inline double operator/(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
26 };
27 struct Circle
28 {
29     Point C; double r; int sgn;
30     inline Circle() = default;
```

```

31     inline Circle(const Point &_C,double _r,int _sgn):C(_C),r(_r),sgn(_sgn) {}
    ↪ // sgn 代表该圆的权值, 默认 1
32     friend inline bool operator==(const Circle &a,const Circle &b)
33     {
34         if (dcmp(a.r-b.r)) return false;
35         if (dcmp(a.C.x-b.C.x)) return false;
36         if (dcmp(a.C.y-b.C.y)) return false;
37         if (a.sgn != b.sgn) return false;
38         return true;
39     }
40     friend inline bool operator!=(const Circle &a,const Circle &b) { return !(a == b); }
41 }cir[maxn];
42
43 inline Point rotate(const Point &p,double cost,double sint)
44 {
45     double x = p.x,y = p.y;
46     return Point(x*cost-y*sint,x*sint+y*cost);
47 }
48 inline pair <Point,Point> crosspoint(const Point &ap,double ar,const Point &bp,double br)
49 {
50     double d = (ap-bp).norm(),cost = (ar*ar+d*d-br*br)/(2*ar*d),sint = sqrt(1-cost*cost);
51     Point v = ((bp-ap).unit())*ar;
52     return make_pair(ap+rotate(v,cost,-sint),ap+rotate(v,cost,sint));
53 }
54 inline pair <Point,Point> crosspoint(const Circle &a,const Circle &b) { return
    ↪ crosspoint(a.C,a.r,b.C,b.r); }
55
56 inline bool overlap(const Circle &a,const Circle &b) { return dcmp(a.r-b.r-(a.C-b.C).norm()) >=
    ↪ 0; } // b 是不是在 a 里面
57 inline bool intersect(const Circle &a,const Circle &b)
58 {
59     if (overlap(a,b)) return false;
60     if (overlap(b,a)) return false;
61     return dcmp((a.C-b.C).norm()-a.r-b.r) < 0;
62 }
63
64 struct Event
65 {
66     Point p; double a; int d;
67     inline Event() = default;
68     inline Event(const Point &p,double _a,double _d):p(_p),a(_a),d(_d) {}
69     friend inline bool operator <(const Event &a,const Event &b) { return a.a < b.a; }
70 };
71
72 inline void solve()
73 {
74     for (int i = 1;i <= M;++i) area[i] = 0;
75     for (int i = 1;i <= M;++i)
76     {

```

```

77     int cnt = cir[i].sgn; if (cnt<0) cnt = 0; vector <Event> event;
78     for (int j = 1;j < i;++j) if (cir[i] == cir[j]) cnt += cir[j].sgn;
79     for (int j = 1;j <= M;++j)
80         if (j != i&&cir[i] != cir[j]&&overlap(cir[j],cir[i])) cnt += cir[j].sgn;
81     for (int j = 1;j <= M;++j)
82         if (j != i&&intersect(cir[i],cir[j]))
83         {
84             pair <Point,Point> res = crosspoint(cir[i],cir[j]); swap(res.first,res.second);
85             double alpha1 = (res.first-cir[i].C).angle(),alpha2 =
↪ (res.second-cir[i].C).angle();
86             event.push_back(Event(res.second,alpha2,cir[j].sgn));
87             event.push_back(Event(res.first,alpha1,-cir[j].sgn));
88             cnt += (alpha2 > alpha1)*cir[j].sgn;
89         }
90     if (!event.size()) area[cnt] += pi*cir[i].r*cir[i].r*cir[i].sgn;
91     else
92     {
93         sort(event.begin(),event.end());
94         event.push_back(event.front());
95         for (int j = 0;j+1 < (int)event.size();++j)
96         {
97             cnt += event[j].d;
98             area[cnt] += event[j].p/event[j+1].p/2*cir[i].sgn;
99             double alpha = event[j+1].a-event[j].a;
100             if (alpha < 0) alpha += 2*pi;
101             if (!dcmp(alpha)) continue;
102             area[cnt] += alpha*cir[i].r*cir[i].r/2*cir[i].sgn;
103             area[cnt] += -sin(alpha)*cir[i].r*cir[i].r/2*cir[i].sgn;
104         }
105     }
106 }
107 }
108
109 // origin
110 struct Event {
111     Point p;
112     double ang;
113     int delta;
114     Event (Point p = Point(0, 0), double ang = 0, double delta = 0) : p(p), ang(ang),
↪ delta(delta) {}
115 };
116 bool operator < (const Event &a, const Event &b) {
117     return a.ang < b.ang;
118 }
119 void addEvent(const Circle &a, const Circle &b, vector<Event> &evt, int &cnt) {
120     double d2 = (a.o - b.o).len2(),
121     dRatio = ((a.r - b.r) * (a.r + b.r) / d2 + 1) / 2,
122     pRatio = sqrt(-(d2 - sqr(a.r - b.r)) * (d2 - sqr(a.r + b.r)) / (d2 * d2 * 4));
123     Point d = b.o - a.o, p = d.rotate(PI / 2),

```



```

124         q0 = a.o + d * dRatio + p * pRatio,
125         q1 = a.o + d * dRatio - p * pRatio;
126     double ang0 = (q0 - a.o).ang(),
127         ang1 = (q1 - a.o).ang();
128     evt.push_back(Event(q1, ang1, 1));
129     evt.push_back(Event(q0, ang0, -1));
130     cnt += ang1 > ang0;
131 }
132 bool issame(const Circle &a, const Circle &b) { return sign((a.o - b.o).len()) == 0 && sign(a.r
↪ - b.r) == 0; }
133 bool overlap(const Circle &a, const Circle &b) { return sign(a.r - b.r - (a.o - b.o).len()) >=
↪ 0; }
134 bool intersect(const Circle &a, const Circle &b) { return sign((a.o - b.o).len() - a.r - b.r) <
↪ 0; }
135 Circle c[N];
136 double area[N]; // area[k] -> area of intersections >= k.
137 Point centroid[N]; //k 次圆的质心
138 bool keep[N];
139 void add(int cnt, DB a, Point c) {
140     area[cnt] += a;
141     centroid[cnt] = centroid[cnt] + c * a;
142 }
143 void solve(int C) {
144     for (int i = 1; i <= C; ++i) {
145         area[i] = 0;
146         centroid[i] = Point(0, 0);
147     }
148     for (int i = 0; i < C; ++i) {
149         int cnt = 1;
150         vector<Event> evt;
151         for (int j = 0; j < i; ++j) if (issame(c[i], c[j])) ++cnt;
152         for (int j = 0; j < C; ++j) {
153             if (j != i && !issame(c[i], c[j]) && overlap(c[j], c[i])) {
154                 ++cnt;
155             }
156         }
157         for (int j = 0; j < C; ++j) {
158             if (j != i && !overlap(c[j], c[i]) && !overlap(c[i], c[j]) && intersect(c[i], c[j]))
↪ {
159                 addEvent(c[i], c[j], evt, cnt);
160             }
161         }
162         if (evt.size() == 0u) {
163             add(cnt, PI * c[i].r * c[i].r, c[i].o);
164         } else {
165             sort(evt.begin(), evt.end());
166             evt.push_back(evt.front());
167             for (int j = 0; j + 1 < (int)evt.size(); ++j) {
168                 cnt += evt[j].delta;

```

```

169         add(cnt, det(evt[j].p, evt[j + 1].p) / 2, (evt[j].p + evt[j + 1].p) / 3);
170         double ang = evt[j + 1].ang - evt[j].ang;
171         if (ang < 0) {
172             ang += PI * 2;
173         }
174         if (sign(ang) == 0) continue;
175         double ang0 = evt[j].a, ang1 = evt[j+1].a;
176         add(cnt, ang * c[i].r * c[i].r / 2, c[i].o +
177             Point(sin(ang1) - sin(ang0), -cos(ang1) + cos(ang0)) * (2 / (3 * ang) *
↪ c[i].r));
178         add(cnt, -sin(ang) * c[i].r * c[i].r / 2, (c[i].o + evt[j].p + evt[j + 1].p) /
↪ 3);
179     }
180 }
181 }
182 for (int i = 1; i <= C; ++ i)
183     if (sign(area[i])) {
184         centroid[i] = centroid[i] / area[i];
185     }
186 }

```

2.2 Common Formulas

```

1 //计算几何常用公式
2 inline int dcmp(double a)
3 {
4     if (fabs(a) <= eps) return 0;
5     else if (a > 0) return 1;
6     else return -1;
7 }
8 struct Point
9 {
10     double x,y;
11     inline Point() = default;
12     inline Point(double _x,double _y):x(_x),y(_y) {}
13     inline Point unit() const
14     {
15         double len = norm();
16         if (!dcmp(len)) return Point(1,0);
17         else return *this/len;
18     }
19     inline double norm() const { return sqrt(x*x+y*y); }
20     inline Point reflect(const Point &p) const
21     {
22         Point v = *this-p; double len = v.norm();
23         v = v/len; return p+v*(1/len);
24     }
25     inline void read() { scanf("%lf %lf",&x,&y); }
26     inline Point vertical() const { return Point(y,-x); }

```

```

27     inline double angle() const
28     {
29         double ret = atan2(y,x);
30         if (ret < 0) ret += 2*pi;
31         return ret;
32     }
33     friend inline bool operator ==(const Point &a,const Point &b) { return
↪ !dcmp(a.x-b.x)&&!dcmp(a.y-b.y); }
34     friend inline Point operator -(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
35     friend inline Point operator +(const Point &a,const Point &b) { return
↪ Point(a.x+b.x,a.y+b.y); }
36     friend inline Point operator /(const Point &a,double b) { return Point(a.x/b,a.y/b); }
37     friend inline Point operator *(const Point &a,double b) { return Point(a.x*b,a.y*b); }
38     friend inline Point operator *(double b,const Point &a) { return Point(a.x*b,a.y*b); }
39     friend inline double operator /(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
40 };
41 struct Line
42 {
43     Point p,v; double slop;
44     inline Line() = default;
45     inline Line(const Point &p,const Point &v):p(_p),v(_v) {}
46     inline void update() { slop = v.alpha(); }
47     friend inline bool operator <(const Line &l1,const Line &l2)
48     { return l1.slop < l2.slop; }
49     inline double dis(const Point &a) { fabs((a-p)/v)/(v.len()); } //点到直线距离
50 };
51
52 inline bool OnLine(const Line &l,const Point &p) { return !dcmp(l.v/(p-l.p)); } //点在直线上
53
54 inline Point CrossPoint(const Line &a,const Line &b) //直线交点
55 {
56     Point u = a.p - b.p;
57     double t = (b.v/u)/(a.v/b.v);
58     return a.p+a.v*t;
59 }
60
61 inline bool parallel(const Line &a,const Line &b) { return !dcmp(a.v/b.v); } //直线平行

```

2.3 Convex Hull

```

1 struct Point
2 {
3     inline Point() = default;
4     inline Point(double _x,double _y):x(_x),y(_y) {}
5     inline Point unit() const
6     {
7         double len = norm();
8         if (!dcmp(len)) return Point(1,0);

```

```

9         else return *this/len;
10    }
11    inline double norm() const { return sqrt(x*x+y*y); }
12    inline Point reflect(const Point &p) const
13    {
14        Point v = *this-p; double len = v.norm();
15        v = v/len; return p+v*(1/len);
16    }
17    inline void read() { scanf("%lf %lf",&x,&y); }
18    inline Point vertical() const { return Point(y,-x); }
19    inline double angle() const
20    {
21        double ret = atan2(y,x);
22        if (ret < 0) ret += 2*pi;
23        return ret;
24    }
25    friend inline bool operator ==(const Point &a,const Point &b) { return
↪ !dcmp(a.x-b.x)&&!dcmp(a.y-b.y); }
26    friend inline Point operator -(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
27    friend inline Point operator +(const Point &a,const Point &b) { return
↪ Point(a.x+b.x,a.y+b.y); }
28    friend inline Point operator /(const Point &a,double b) { return Point(a.x/b,a.y/b); }
29    friend inline Point operator *(const Point &a,double b) { return Point(a.x*b,a.y*b); }
30    friend inline Point operator *(double b,const Point &a) { return Point(a.x*b,a.y*b); }
31    friend inline double operator /(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
32    friend inline bool operator <(const Point &a,const Point &b)
33    {
34        if (a.x != b.x) return a.x < b.x;
35        else return a.y < b.y;
36    }
37 }P[maxn],convex[maxn];
38
39 inline void ConvexHull()
40 {
41     sort(P+1,P+N+1); //x 第一关键字, y 第二关键字从小到大排序
42     for (int i = 1;i <= N;++i)
43     {
44         while (m > 1&&(convex[m]-convex[m-1])/(P[i]-convex[m-1]) <= 0) --m;
45         convex[++m] = P[i];
46     }
47     int k = m;
48     for (int i = N-1;i-->0)
49     {
50         while (m > k&&(convex[m]-convex[m-1])/(P[i]-convex[m-1]) <= 0) --m;
51         convex[++m] = P[i];
52     }
53     if (N > 1) m--;
54 }

```

2.4 Cross Points of Circles

```

1 //圓圓求交，需先判定兩圓有交
2 inline Point rotate(const Point &p,double cost,double sint)
3 {
4     double x = p.x,y = p.y;
5     return Point(x*cost-y*sint,x*sint+y*cost);
6 }
7
8 inline pair <Point,Point> CrossPoint(const Point &ap,double ar,const Point &bp,double br)
9 {
10     double d = (ap-bp).norm();
11     double cost = (ar*ar+d*d-br*br)/(2*ar*d),sint = sqrt(1-cost*cost);
12     Point v = ((bp-ap)/(bp-ap).norm())*ar;
13     return make_pair(ap+rotate(v,cost,-sint),ap+rotate(v,cost,sint));
14 }

```

2.5 Cross Points of Line and Circle

```

1 //a b 直线两点, o 圆心
2 //若 a b 为线段, 则 0 <= t1,t2 <= 1
3 inline void CrossPoint(const Point &a,const Point &b,const Point &o,double r,Point *ret,int
4     ↪ &num)
5 {
6     double X0 = o.x,Y0 = o.y;
7     double X1 = a.x,Y1 = a.y;
8     double X2 = b.x,Y2 = b.y;
9     double dx = X2-X1,dy = Y2-Y1;
10    double A = dx*dx+dy*dy;
11    double B = 2*dx*(X1-X0)+2*dy*(Y1-Y0);
12    double C = (X1-X0)*(X1-X0)+(Y1-Y0)*(Y1-Y0)-r*r;
13    double delta = B*B-4*A*C+eps;
14    num = 0;
15    if (delta >= 0)
16    {
17        double t1 = (-B-sqrt(delta))/(2*A);
18        double t2 = (-B+sqrt(delta))/(2*A);
19        ret[++num] = Point(X1+t1*dx,Y1+t1*dy);
20        ret[++num] = Point(X1+t2*dx,Y1+t2*dy);
21    }
22 }

```

2.6 Graham Scanning Algorithm

```

1 //凸包上最大四边形面积
2 #include <cmath>
3 #include <algorithm>
4 #include <cstring>
5 #include <iostream>

```

```

6  #include<cstdio>
7  #include<cstdlib>
8  using namespace std;
9
10 const int maxn = 2010;
11 int N,M; double ans;
12
13 struct Point
14 {
15     double x,y;
16     Point() = default;
17     Point(double _x,double _y):x(_x),y(_y) {}
18     inline void read() { scanf("%lf %lf",&x,&y); }
19     friend inline Point operator -(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
20     friend inline double operator /(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
21     friend inline double operator <(const Point &a,const Point &b)
22     {
23         if (a.x != b.x) return a.x < b.x;
24         else return a.y < b.y;
25     }
26 }P[maxn],convex[maxn];
27
28 inline int gi()
29 {
30     char ch; int ret = 0,f = 1;
31     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
32     if (ch == '-') f = -1,ch = getchar();
33     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
34     return ret*f;
35 }
36
37 inline void ConvexHull()
38 {
39     int m = 0;
40     sort(P+1,P+N+1); //x 第一关键字, y 第二关键字从小到大排序
41     for (int i = 1;i <= N;++i)
42     {
43         while (m > 1&&(convex[m]-convex[m-1])/(P[i]-convex[m-1]) <= 0) --m;
44         convex[++m] = P[i];
45     }
46     int k = m;
47     for (int i = N-1;i--i)
48     {
49         while (m > k&&(convex[m]-convex[m-1])/(P[i]-convex[m-1]) <= 0) --m;
50         convex[++m] = P[i];
51     }
52     if (N > 1) m--; M = m;
53 }

```

```

54
55 inline void Graham()
56 {
57     for (int i = 1; i <= M; ++i) convex[i+M] = convex[i];
58     int p1, p2, p3, p4;
59     for (p1 = 1; p1 <= M; ++p1)
60     {
61         p2 = p1+1;
62         p3 = p2+1;
63         p4 = p3+1;
64         for (; p3 < p1+M-1; ++p3)
65         {
66             Point v = convex[p3]-convex[p1];
67             while (p2 < p3 && fabs((convex[p2]-convex[p1])/v) <
↪ fabs((convex[p2+1]-convex[p1])/v)) ++p2;
68             while (p4 < p1+M && fabs((convex[p4]-convex[p1])/v) <
↪ fabs((convex[p4+1]-convex[p1])/v)) ++p4;
69             ans = max(ans, fabs((convex[p2]-convex[p1])/v)+fabs((convex[p4]-convex[p1])/v));
70         }
71     }
72     ans = ans/2;
73 }
74
75 int main()
76 {
77     N = gi();
78     for (int i = 1; i <= N; ++i) P[i].read();
79     ConvexHull();
80     Graham();
81     printf("%.3f\n", ans);
82     return 0;
83 }
84 ///////////////////////////////////////////////////////////////////
85 inline void jam() //凸包上最大四边形面积
86 {
87     for (int i = 1; i <= m; ++i) ch[i+m] = ch[i]; //凸包倍长
88     for (int p1 = 1, p2, p3, p4; p1 <= m; ++p1)
89     {
90         p2 = p1 + 1;
91         p3 = p2 + 1;
92         p4 = p3 + 1;
93         for (; p3 < p1 + m - 1; ++p3)
94         {
95             Line l = ((SEG) { ch[p1], ch[p3] }).extend(); //枚举对角线，线段变成直线
96             while (p2 < p3 && l.dis(ch[p2]) < l.dis(ch[p2 + 1])) ++p2; //点到直线距离
97             while (p4 < p1 + m && l.dis(ch[p4]) < l.dis(ch[p4 + 1])) ++p4;
98             ans = max(ans, (l.dis(ch[p2])+l.dis(ch[p4]))*(ch[p1] - ch[p3]).len()/2); //更新答案
99         }
100     }

```

101 }

2.7 Half Plane Intersection

```

1 //半平面交，直线左侧半平面，注意最后是 tail-head <= 0 还是 tail-head <= 1
2 inline int dcmp(double a)
3 {
4     if (-eps <= a && a <= eps) return 0;
5     else if (a > 0) return 1; else return -1;
6 }
7
8 struct Point
9 {
10     double x,y;
11     inline Point() = default;
12     inline Point(double _x,double _y):x(_x),y(_y) {}
13     inline void read() { x = gi(),y = gi(); }
14     inline Point vertical() const { return Point(-y,x); }
15     inline Point unit() const
16     {
17         double len = norm();
18         if (!dcmp(len)) return Point(1,0);
19         else return *this/len;
20     }
21     inline double norm() const { return sqrt(x*x+y*y); }
22     inline double angle() const { return atan2(y,x); }
23     friend inline Point operator+(const Point &a,const Point &b) { return
↪ Point(a.x+b.x,a.y+b.y); }
24     friend inline Point operator-(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
25     friend inline Point operator*(const Point &a,double b) { return Point(a.x*b,a.y*b); }
26     friend inline Point operator*(double b,const Point &a) { return Point(a.x*b,a.y*b); }
27     friend inline double operator/(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
28 }P[maxn],pp[maxn],pol[maxn];
29
30 struct Line
31 {
32     Point p,v;
33     inline Line(const Point _p = Point(),const Point _v = Point()):p(_p),v(_v) {}
34     inline double slop() const { return v.angle(); }
35     friend inline bool operator<(const Line &a,const Line &b) { return a.slop() < b.slop(); }
36 }line[maxn],qq[maxn];
37
38 inline bool onleft(const Line &L,const Point &p)
39 {
40     return dcmp(L.v/(p-L.p)) > 0;
41 }
42 inline bool parallel(const Line &a,const Line &b) { return !dcmp(a.v/b.v); }
43 inline Point crosspoint(const Line &a,const Line &b)

```



```

44 {
45     Point u = a.p-b.p;
46     double t = (b.v/u)/(a.v/b.v);
47     return a.p+(a.v*t);
48 }
49
50 inline int half_plane_intersection()
51 {
52     sort(lines+1,lines+tot+1); //直线按斜率排序
53     int head,tail;
54     qq[head = tail = 1] = lines[1];
55     for (int i = 2;i <= tot;++i)
56     {
57         while (head < tail&&!onleft(lines[i],pp[tail-1])) --tail;
58         while (head < tail&&!onleft(lines[i],pp[head])) ++head;
59         qq[++tail] = lines[i];
60         if (parallel(qq[tail],qq[tail-1]))
61         {
62             tail--;
63             if (onleft(qq[tail],lines[i].p)) qq[tail] = lines[i];
64         }
65         if (head < tail) pp[tail-1] = crosspoint(qq[tail],qq[tail-1]);
66     }
67     while (head < tail && !onleft(qq[head],pp[tail-1])) --tail;
68     if (tail-head <= 0) return 0;
69     pp[tail] = crosspoint(qq[tail],qq[head]);
70     for (int i = head;i <= tail;++i) pol[++m] = pp[i]; //半平面交点
71     pol[0] = pol[m];
72     return m;
73 }

```

2.8 Intersecting Area of Circle and Polygon

```

1  const int maxn = 510;
2  const double eps = 1e-9;
3
4  inline int dcmp(double a)
5  {
6      if (a > eps) return 1;
7      else if (a < -eps) return -1;
8      else return 0;
9  }
10
11 struct Point
12 {
13     double x,y;
14     Point() = default;
15     Point(double _x,double _y):x(_x),y(_y) {}
16     inline double norm() const { return sqrt(x*x+y*y); }

```

```

17     inline Point unit() const { double len = norm(); return Point(x/len,y/len); }
18     friend Point operator +(const Point &a,const Point &b) { return Point(a.x+b.x,a.y+b.y); }
19     friend Point operator -(const Point &a,const Point &b) { return Point(a.x-b.x,a.y-b.y); }
20     friend Point operator *(const Point &a,double b) { return Point(a.x*b,a.y*b); }
21     friend Point operator *(double b,const Point &a) { return Point(a.x*b,a.y*b); }
22     friend Point operator /(const Point &a,double b) { return Point(a.x/b,a.y/b); }
23     friend double operator /(const Point &a,const Point &b) { return a.x*b.y-b.x*a.y; }
24     friend double operator *(const Point &a,const Point &b) { return a.x*b.x+a.y*b.y; }
25     inline void read() { scanf("%lf %lf",&x,&y); }
26 }P[maxn],A,B;
27 int N; double K;
28
29 inline double getSectorArea(const Point &a,const Point &b,double r)
30 {
31     double c = (2*r*r-((a-b)*(a-b)))/(2*r*r);
32     double alpha = acos(c);
33     return r*r*alpha/2.0;
34 }
35
36 inline pair <double,double> getSolution(double a,double b,double c)
37 {
38     double delta = b*b-4*a*c;
39     if (dcmp(delta) < 0) return make_pair(0,0);
40     else return make_pair((-b-sqrt(delta))/(2*a),(-b+sqrt(delta))/(2*a));
41 }
42
43 inline pair <Point,Point> getIntersection(const Point &a,const Point &b,double r)
44 {
45     Point d = b-a;
46     double A = d*d,B = 2*(d*a),C = (a*a)-r*r;
47     pair <double,double> s = getSolution(A,B,C);
48     return make_pair(a+(d*s.first),a+(d*s.second));
49 }
50
51 inline double getPointDist(const Point &a,const Point &b)
52 {
53     Point d = b-a;
54     int sA = dcmp(a*d),sB = dcmp(b*d);
55     if (sA*sB <= 0) return (a/b)/((a-b).norm());
56     else return min(a.norm(),b.norm());
57 }
58
59 double getArea(const Point &a,const Point &b,double r)
60 {
61     double dA = a*a,dB = b*b,dC = getPointDist(a,b),ans = 0;
62     if (dcmp(dA-r*r) <= 0&& dcmp(dB-r*r) <= 0) return (a/b)/2;
63     Point tA = a.unit()*r,tB = b.unit()*r;
64     if (dcmp(dC-r) > 0) return getSectorArea(tA,tB,r);
65     pair <Point,Point> ret = getIntersection(a,b,r);

```

```

66     if (dcmp(dA-r*r) > 0&&dcmp(dB-r*r) > 0)
67     {
68         ans += getSectorArea(tA,ret.first,r);
69         ans += (ret.first/ret.second)/2;
70         ans += getSectorArea(ret.second,tB,r);
71         return ans;
72     }
73     if (dcmp(dA-r*r) > 0) return (ret.first/b)/2+getSectorArea(tA,ret.first,r);
74     else return (a/ret.second)/2.0+getSectorArea(ret.second,tB,r);
75 }
76
77 double getArea(int n,Point *p,const Point &c,double r)
78 {
79     double ret = 0;
80     for (int i = 0;i < n;++i)
81     {
82         int sgn = dcmp((p[i]-c)/(p[(i+1)%n]-c));
83         if (sgn > 0) ret += getArea(p[i]-c,p[(i+1)%n]-c,r);
84         else ret -= getArea(p[(i+1)%n]-c,p[i]-c,r);
85     }
86     return fabs(ret);
87 }

```

2.9 Intersection of Line and Convex Hull

```

1  //O(logN)
2  inline double getA(const Node &a)
3  {
4      double ret = atan2(a.y,a.x);
5      if (ret <= -pi/2) ret += 2*pi;
6      return ret;
7  }
8
9  inline int find(double x)
10 {
11     if (x <= w[1]||x >= w[m]) return 1;
12     return upper_bound(w+1,w+m+1,x)-w;
13 }
14
15 inline bool intersect(const Node &a,const Node &b)
16 {
17     int i = find(getA(b-a)),j = find(getA(a-b));
18     if (dcmp((b-a)/(hull[i]-a))*dcmp((b-a)/(hull[j]-a)) > 0) return false;
19     else return true;
20 }
21
22 inline void convex()
23 {
24     for (int i = 1;i <= N;++i)

```

```

25     {
26         while (m > 1 && (hull[m]-hull[m-1])/(P[i]-hull[m-1]) <= 0) --m;
27         hull[++m] = P[i];
28     }
29     int k = m;
30     for (int i = N-1; i; --i)
31     {
32         while (m > k && (hull[m]-hull[m-1])/(P[i]-hull[m-1]) <= 0) --m;
33         hull[++m] = P[i];
34     }
35     if (N > 1) m--;
36     for (int i = 1; i <= m; ++i)
37         w[i] = getA(hull[i+1]-hull[i]);
38 }

```

2.10 Minimal Product

```

1  // 最小乘积匹配
2  #include<algorithm>
3  #include<cstring>
4  #include<iostream>
5  #include<cstdio>
6  #include<cstdlib>
7  using namespace std;
8
9  const int maxn = 80, inf = 1<<29;
10 int N, ans, A[maxn][maxn], B[maxn][maxn];
11
12 inline int gi()
13 {
14     char ch; int ret = 0, f = 1;
15     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
16     if (ch == '-') f = -1, ch = getchar();
17     do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
18     return ret*f;
19 }
20
21 struct KM
22 {
23     int w[maxn][maxn], lx[maxn], ly[maxn], match[maxn], way[maxn], slack[maxn]; bool used[maxn];
24
25     inline void init()
26     {
27         for (int i = 1; i <= N; ++i)
28             match[i] = lx[i] = ly[i] = way[i] = 0;
29     }
30
31     inline void hungary(int x)
32     {

```

```

33     match[0] = x; int j0 = 0;
34     for (int j = 0; j <= N; ++j)
35         slack[j] = -inf, used[j] = false;
36     do
37     {
38         used[j0] = true;
39         int i0 = match[j0], delta = -inf, j1 = 0;
40         for (int j = 1; j <= N; ++j)
41             if (!used[j])
42             {
43                 int cur = -w[i0][j] - lx[i0] - ly[j];
44                 if (cur > slack[j]) slack[j] = cur, way[j] = j0;
45                 if (slack[j] > delta) delta = slack[j], j1 = j;
46             }
47         for (int j = 0; j <= N; ++j)
48         {
49             if (used[j]) lx[match[j]] += delta, ly[j] -= delta;
50             else slack[j] -= delta;
51         }
52         j0 = j1;
53     }
54     while (match[j0]);
55     do
56     {
57         int j1 = way[j0];
58         match[j0] = match[j1];
59         j0 = j1;
60     }
61     while (j0);
62 }
63
64 inline void work() { for (int i = 1; i <= N; ++i) hungary(i); }
65
66 inline int get_ans()
67 {
68     int sum = 0;
69     for (int i = 1; i <= N; ++i)
70     {
71         // if (w[match[i]][i] == inf) ; // 无解
72         if (match[i] > 0) sum += w[match[i]][i];
73     }
74     return sum;
75 }
76
77 inline void getp(int &x, int &y)
78 {
79     x = y = 0;
80     for (int i = 1; i <= N; ++i)
81         x += A[match[i]][i], y += B[match[i]][i];

```

```

82     }
83 }km;
84
85 inline void work(int X1,int Y1,int X2,int Y2)
86 {
87     km.init();
88     for (int i = 1;i <= N;++i)
89         for (int j = 1;j <= N;++j)
90             km.w[i][j] = (X2-X1)*B[i][j]+(Y1-Y2)*A[i][j];
91     km.work();
92     if (km.get_ans() >= X2*Y1-X1*Y2) return;
93     int x,y; km.getp(x,y);
94     ans = min(ans,x*y);
95     work(X1,Y1,x,y); work(x,y,X2,Y2);
96 }
97
98 int main()
99 {
100     // freopen("B.in","r",stdin);
101     for (int T = gi();T--;)
102     {
103         N = gi(); ans = inf;
104         for (int i = 1;i <= N;++i) for (int j = 1;j <= N;++j) A[i][j] = gi();
105         for (int i = 1;i <= N;++i) for (int j = 1;j <= N;++j) B[i][j] = gi();
106         int X1,Y1,X2,Y2;
107         km.init();
108         for (int i = 1;i <= N;++i)
109             for (int j = 1;j <= N;++j)
110                 km.w[i][j] = A[i][j];
111         km.work(); km.getp(X1,Y1);
112         km.init();
113         for (int i = 1;i <= N;++i)
114             for (int j = 1;j <= N;++j)
115                 km.w[i][j] = B[i][j];
116         km.work(); km.getp(X2,Y2);
117         ans = min(X1*Y1,X2*Y2);
118         work(X1,Y1,X2,Y2);
119         cout << ans << endl;
120     }
121     fclose(stdin); fclose(stdout);
122     return 0;
123 }

```

2.11 Planar Graph

```

1 // 包括平面图转对偶图
2 inline int dcmp(double a)
3 {
4     if (fabs(a) <= eps) return 0;

```

```

5     else if (a > 0) return 1;
6     else return -1;
7 }
8 struct Point
9 {
10     double x,y;
11     inline Point(double _x = 0,double _y = 0):x(_x),y(_y) {}
12     inline void read() { x = gi(),y = gi(); }
13     friend inline Point operator-(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
14     friend inline double operator/(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
15     inline double angle() { return atan2(y,x); }
16 }pp[maxn];
17 struct Segment
18 {
19     int from,to,h,id,sur; // from 号点到 to 号点, h 为边权,suf 为这条有向边维出来的平面编号。
20     inline Segment(int _from = 0,int _to = 0,int _h = 0,int _id = 0,int _sur =
↪ 0):from(_from),to(_to),h(_h),id(_id),sur(_sur) {}
21     friend inline bool operator<(const Segment &a,const Segment &b) { return
↪ (pp[a.to]-pp[a.from]).angle() < (pp[b.to]-pp[b.from]).angle(); }
22 }edge[maxm*2];
23 vector <int> G[maxn];
24
25 inline void nadd(int u,int v,int h) { ++ncnt; G[u].push_back(ncnt); edge[ncnt] = Segment(u,v,h);
↪ }
26 inline void nins(int u,int v,int h) { nadd(u,v,h); nadd(v,u,h); }
27
28 inline bool cmp(int a,int b) { return edge[a] < edge[b]; }
29
30 inline void find_surface()
31 {
32     for (int i = 1;i <= N;++i) sort(G[i].begin(),G[i].end(),cmp);
33     for (int i = 1;i <= N;++i)
34     {
35         int nn = G[i].size();
36         for (int j = 0;j < nn;++j)
37             edge[G[i][j]].id = j;
38     }
39     for (int i = 2;i <= ncnt;++i)
40         if (!edge[i].sur)
41         {
42             ++tot; int j = i,p,nn; vector <Point> vec;
43             while (!edge[j].sur)
44             {
45                 edge[j].sur = tot; vec.push_back(pp[edge[j].from]);
46                 p = edge[j].to; nn = G[p].size();
47                 j ^= 1; j = G[p][(edge[j].id+1)%nn];
48             }
49             double res = 0; nn = vec.size();

```

```

50         for (j = 0; j < nn; ++j)
51             res += (vec[j]-vec[0])/(vec[(j+1)%nn]-vec[0]);
52         res /= 2; space[tot] = res;
53     }
54     // 开始建边, 以 mst 为例
55     // for (int i = 2; i <= cnt; i += 2)
56     // {
57     //     if (space[edge[i].sur]<0&&space[edge[i^1].sur]<0)
58     //         arr[++all] = (ARR) { edge[i].sur, edge[i^1].sur, edge[i].h };
59     //     else arr[++all] = (ARR) { edge[i].sur, edge[i^1].sur, inf};
60     // }
61 }
62
63 // 点定位
64 struct Scan
65 {
66     double x,y; int bel,sign;
67     inline Scan(double _x = 0,double _y = 0,int _bel = 0,int _sign =
68     ↪ 0):x(_x),y(_y),bel(_bel),sign(_sign) {}
69     friend inline bool operator < (const Scan &a,const Scan &b)
70     {
71         if (a.x != b.x) return a.x < b.x;
72         else return a.sign > b.sign;
73     }
74 }bac[maxn*4];
75
76 struct Splay
77 {
78     int num,root,ch[maxn][2],fa[maxn],key[maxn]; queue <int> team;
79
80     inline int newnode()
81     {
82         int ret;
83         if (team.empty()) ret = ++num;
84         else ret = team.front(),team.pop();
85         fa[ret] = ch[ret][0] = ch[ret][1] = 0;
86         return ret;
87     }
88
89     inline void init() { num = 0; root = newnode(); key[root] = cnt; }
90
91     inline void rotate(int x)
92     {
93         int y = fa[x],z = fa[y],l = ch[y][1] == x,r = l^1;
94         if (z != 0) ch[z][ch[z][1] == y] = x;
95         fa[x] = z; fa[y] = x; fa[ch[x][r]] = y;
96         ch[y][1] = ch[x][r]; ch[x][r] = y;
97     }

```



```

97
98     inline void splay(int x)
99     {
100         while (fa[x] != 0)
101         {
102             int y = fa[x], z = fa[y];
103             if (fa[y] != 0)
104             {
105                 if ((ch[y][0] == x) ^ (ch[z][0] == y)) rotate(x);
106                 else rotate(y);
107             }
108             rotate(x);
109         }
110         root = x;
111     }
112
113     inline int lower_bound(const Point &p)
114     {
115         int now = root, ret = 0;
116         while (now)
117         {
118             int k = key[now];
119             if ((p - pp[edge[k].from]) / (pp[edge[k].to] - pp[edge[k].from]) >= 0)
120                 ret = k, now = ch[now][0];
121             else now = ch[now][1];
122         }
123         return ret;
124     }
125
126     inline int find(int w)
127     {
128         int now = root;
129         double x = pp[edge[w].to].x, y = pp[edge[w].to].y;
130         double ang = (pp[edge[w].to] - pp[edge[w].from]).angle();
131         while (now)
132         {
133             int k = key[now];
134             if (k == w) return now;
135             NODE p = pp[edge[k].to] - pp[edge[k].from], q = pp[edge[k].from];
136             double xx = x - q.x, yy = q.y + xx / p.x * p.y;
137             if (equal(yy, y))
138             {
139                 double t = p.angle();
140                 now = ch[now][ang < t];
141             }
142             else now = ch[now][y > yy];
143         }
144     }
145

```

```

146 inline void erase(int w)
147 {
148     int p = find(w);
149     while (ch[p][0] || ch[p][1])
150     {
151         if (ch[p][0])
152         {
153             rotate(ch[p][0]);
154             if (p == root) root = fa[p];
155         }
156         else
157         {
158             rotate(ch[p][1]);
159             if (p == root) root = fa[p];
160         }
161     }
162     team.push(p);
163     ch[fa[p]][ch[fa[p]][1] == p] = 0;
164     fa[p] = 0;
165 }
166
167 inline void insert(int w)
168 {
169     int now = root, pre;
170     double x = pp[edge[w].from].x, y = pp[edge[w].from].y;
171     double ang = (pp[edge[w].to] - pp[edge[w].from]).angle();
172     double xx, yy;
173     while (true)
174     {
175         int k = key[now];
176         NODE p = pp[edge[k].to] - pp[edge[k].from], q = pp[edge[k].from];
177         xx = x - q.x, yy = q.y + xx / p.x * p.y;
178         if (equal(yy, y))
179         {
180             double t = p.angle();
181             pre = now, now = ch[now][ang > t];
182             if (!now)
183             {
184                 now = newnode();
185                 fa[now] = pre; ch[pre][ang > t] = now; key[now] = w;
186                 break;
187             }
188         }
189         else
190         {
191             pre = now, now = ch[now][y > yy];
192             if (!now)
193             {
194                 now = newnode();

```

```

195         fa[now] = pre; ch[pre][y>yy] = now; key[now] = w;
196         break;
197     }
198 }
199 }
200 splay(now);
201 }
202 }S;
203
204 inline void locate()
205 {
206     int nn = 0;
207     for (int i = 2; i <= cnt; i += 2)
208     {
209         if (!dcmp(pp[edge[i].from].x - pp[edge[i].to].x)) continue;
210         bac[++nn] = Scan(pp[edge[i].from].x, pp[edge[i].from].y, i, 2);
211         bac[++nn] = Scan(pp[edge[i].to].x, pp[edge[i].to].y, i, 3);
212     }
213     scanf("%d", &T); double x, y;
214     // 查询 (x,y) 所在平面
215     for (int i = 1; i <= T; ++i)
216     {
217         scanf("%lf %lf", &x, &y);
218         bac[++nn] = Scan(x, y, i, 0);
219         scanf("%lf %lf", &x, &y);
220         bac[++nn] = Scan(x, y, i, 1);
221     }
222     sort(bac+1, bac+nn+1);
223     pp[++n] = Point(-oo, -oo); pp[++n] = (oo, oo);
224     edge[++cnt] = Edge(n-1, n);
225     S.init(); int p;
226     for (int i = 1; i <= nn; ++i)
227     {
228         if (bac[i].sign == 2 || bac[i].sign == 3)
229         {
230             if (bac[i].sign == 2) S.insert(bac[i].bel);
231             else S.erase(bac[i].bel);
232         }
233         else
234         {
235             p = S.lower_bound(Point(bac[i].x, bac[i].y));
236             query[bac[i].bel][bac[i].sign] = edge[p].sur;
237         }
238     }
239 }

```

2.12 Polygon Class

```

1  inline bool PointOnSegment(const Point &t,const Point &a,const Point &b)
2  {
3      if (dcmp((t-a)/(b-a))) return false;
4      if (dcmp((t-a)*(t-b)) > 0) return false;
5      return true;
6  }
7
8  inline bool in(const Point &a,const Point &b,const Point &c)
9  {
10     double alpha = a.angle(),beta = b.angle(),gamma = c.angle(); // angle 返回 [0,2pi]
11     if (alpha <= beta) return dcmp(gamma-alpha) > 0&&dcmp(beta-gamma) > 0;
12     else return dcmp(gamma-alpha) > 0||dcmp(beta-gamma) > 0;
13 }
14
15 struct Polygon
16 {
17     int n; Point a[maxn];
18     inline Polygon() {}
19     inline void read()
20     {
21         n = gi();
22         for (int i = 0;i < n;++i) a[i].read();
23         a[n] = a[0];
24     }
25     // 点是否在多边形内部, 内部为 1, 外部为 0, 边界为 2, 不管顺逆时针
26     inline int Point_In(const Point &t) const
27     {
28         int num = 0;
29         for (int i = 0;i < n;++i)
30         {
31             if (PointOnSegment(t,a[i],a[i+1])) return 2;
32             int k = dcmp((a[i+1]-a[i])/(t-a[i]));
33             int d1 = dcmp(a[i].y-t.y),d2 = dcmp(a[i+1].y-t.y);
34             if (k > 0&&d1 <= 0&&d2 > 0) ++num;
35             if (k < 0&&d2 <= 0&&d1 > 0) --num;
36         }
37         return num != 0;
38     }
39     // 判断多边形的方向, true 为逆时针, false 为顺时针, 用叉积判断哪个多
40     inline bool CalculateClockDirection()
41     {
42         int res = 0;
43         for (int i = 0;i < n;++i)
44         {
45             int p = i-1,s = i+1,sgn;
46             if (p < 0) p += n; if (s >= n) s -= n;
47             sgn = dcmp((a[i]-a[p])/(a[s]-a[i]));
48             if (sgn) { if (sgn > 0) ++res; else --res; }

```

```

49     }
50     return res > 0;
51 }
52 // 判断多边形方向, true 为逆时针, false 为顺时针, 用 Green 公式
53 inline bool CalculateClockDirection()
54 {
55     double res = 0;
56     for (int i = 0; i < n; ++i)
57         res -= 0.5*(a[i+1].y+a[i].y)*(a[i+1].x-a[i].x);
58     return res > 0;
59 }
60
61 // 线段 ab 是否有点严格在多边形内部, 先判断线段是否与多边形边界有交, 再判断 ab 是否与多边形有交, 内部 false, 外
62 inline bool can(int ia, int ib)
63 {
64     Point a = P[ia], b = P[ib], v = b-a;
65     if (in(P[ia+1]-a, P[ia-1]-a, b-a) || in(P[ib+1]-b, P[ib-1]-b, a-b)) return false;
66     for (register int i = 0; i < N; ++i)
67     {
68         if (dcmp(v/(P[i]-a))*dcmp(v/(P[i+1]-a)) <
        ↪ 0 && dcmp(vec[i]/(a-P[i]))*dcmp(vec[i]/(b-P[i])) < 0)
69             return false;
70         if (PointOnSegment(a, P[i], P[i+1]) || PointOnSegment(b, P[i], P[i+1])) return false;
71         if (PointOnSegment(P[i], a, b) || PointOnSegment(P[i+1], a, b)) return false;
72     }
73     return true;
74 }
75 }poly;

```

2.13 Union Area of Circles

```

1 //N 为开始圆的个数, M 为离散化后圆的个数, cnt 为去包含后圆的个数
2 int N, M, cnt;
3
4 struct Node
5 {
6     double x, y;
7     inline Node(double _x = 0, double _y = 0):x(_x), y(_y) {}
8     inline void read() { x = gi(), y = gi(); }
9     inline double norm() const { return sqrt(x*x+y*y); }
10    inline double angle() const { return atan2(y, x); }
11    inline Node unit() const { double len = norm(); return Node(x/len, y/len); }
12    friend inline Node operator-(const Node &a, const Node &b) { return Node(a.x-b.x, a.y-b.y); }
13    friend inline Node operator+(const Node &a, const Node &b) { return Node(a.x+b.x, a.y+b.y); }
14    friend inline Node operator*(const Node &a, double b) { return Node(a.x*b, a.y*b); }
15    friend inline Node operator*(double b, const Node &a) { return Node(a.x*b, a.y*b); }
16    friend inline double operator/(const Node &a, const Node &b) { return a.x*b.y-a.y*b.x; }
17 };
18 struct Circle

```

```

19 {
20     Node C; double r;
21     inline Circle(const Node &_C = Node(), double _r = 0):C(_C),r(_r) {}
22     friend inline bool operator<(const Circle &a, const Circle &b)
23     {
24         if (dcmp(a.r-b.r)) return dcmp(a.r-b.r) < 0;
25         else if (dcmp(a.C.x-b.C.x)) return dcmp(a.C.x-b.C.x) < 0;
26         else return dcmp(a.C.y-b.C.y) < 0;
27     }
28     friend inline bool operator==(const Circle &a, const Circle &b)
29     {
30         if (dcmp(a.r-b.r)) return false;
31         if (dcmp(a.C.x-b.C.x)) return false;
32         if (dcmp(a.C.y-b.C.y)) return false;
33         return true;
34     }
35 }tc[maxn], cir[maxn];
36
37 inline Node rotate(const Node &p, double cost, double sint)
38 {
39     double x = p.x, y = p.y;
40     return Node(x*cost-y*sint, x*sint+y*cost);
41 }
42 inline pair <Node, Node> crosspoint(const Node &ap, double ar, const Node &bp, double br)
43 {
44     double d = (ap-bp).norm(), cost = (ar*ar+d*d-br*br)/(2*ar*d), sint = sqrt(1-cost*cost);
45     Node v = ((bp-ap).unit())*ar;
46     return make_pair(ap+rotate(v, cost, -sint), ap+rotate(v, cost, sint));
47 }
48 inline pair <Node, Node> crosspoint(const Circle &a, const Circle &b) { return
    ↪ crosspoint(a.C, a.r, b.C, b.r); }
49
50 struct Event
51 {
52     Node p; double a; int d;
53     inline Event(const Node &_p = Node(), double _a = 0, double _d = 0):p(_p), a(_a), d(_d) {}
54     friend inline bool operator <(const Event &a, const Event &b) { return a.a < b.a; }
55 };
56
57 inline double work()
58 {
59     sort(tc+1, tc+M+1); M = unique(tc+1, tc+M+1)-tc-1;
60     for (int i = M; i--;)
61     {
62         bool ok = true;
63         for (int j = i+1; j <= M; ++j)
64         {
65             double d = (tc[i].C-tc[j].C).norm();
66             if (dcmp(d-fabs(tc[i].r-tc[j].r)) <= 0) { ok = false; break; }

```

```

67     }
68     if (ok) cir[++cnt] = tc[i];
69 }
70 // for (int i = M;i;--i) cir[++cnt] = tc[i];
71 double ret = 0;
72 for (int i = 1;i <= cnt;++i)
73 {
74     vector <Event> event;
75     Node boundary = cir[i].C+Node(cir[i].r,0);
76     event.push_back(Event(boundary,-pi,0));
77     event.push_back(Event(boundary,pi,0));
78     for (int j = 1;j <= cnt;++j)
79     {
80         if (i == j) continue;
81         double d = (cir[i].C-cir[j].C).norm();
82         if (dcmp(d-(cir[i].r+cir[j].r)) < 0)
83         {
84             pair <Node,Node> res = crosspoint(cir[i],cir[j]);
85             double x = (res.first-cir[i].C).angle(),y = (res.second-cir[i].C).angle();
86             if (dcmp(x-y) > 0)
87             {
88                 event.push_back(Event(res.first,x,1));
89                 event.push_back(Event(boundary,pi,-1));
90                 event.push_back(Event(boundary,-pi,1));
91                 event.push_back(Event(res.second,y,-1));
92             }
93             else
94             {
95                 event.push_back(Event(res.first,x,1));
96                 event.push_back(Event(res.second,y,-1));
97             }
98         }
99     }
100     sort(event.begin(),event.end());
101     int sum = event[0].d;
102     for (int j = 1;j < (int)event.size();++j)
103     {
104         if (!sum)
105         {
106             ret += (event[j-1].p/event[j].p)/2;
107             double x = event[j-1].a,y = event[j].a;
108             double area = cir[i].r*cir[i].r*(y-x)/2;
109             Node v1 = event[j-1].p-cir[i].C,v2 = event[j].p-cir[i].C;
110             area -= (v1/v2)/2; ret += area;
111         }
112         sum += event[j].d;
113     }
114 }
115 return ret;

```


Chapter 3

Data Structure

3.1 Divide and Conquer on Tree

```
1  #include<cstring>
2  #include<iostream>
3  #include<cstdio>
4  #include<cstdlib>
5  using namespace std;
6
7  #define maxn (100010)
8  int best,cnt = 1,side[maxn],toit[maxn],next[maxn],large[maxn];
9  int sd[maxn],d[maxn],ns,nd,ans,N,K,size[maxn]; bool vis[maxn];
10
11 inline void add(int a,int b)
12 { next[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
13 inline void ins(int a,int b)
14 { add(a,b); add(b,a); }
15
16 inline void getroot(int now,int fa,int rest)
17 {
18     size[now] = 1; large[now] = 0;
19     for (int i = side[now];i;i = next[i])
20     {
21         if (toit[i] == fa||vis[toit[i]]) continue;
22         getroot(toit[i],now,rest);
23         size[now] += size[toit[i]];
24         large[now] = max(large[now],size[toit[i]]);
25     }
26     large[now] = max(large[now],rest-size[now]);
27     if (large[now] < large[best]) best = now;
28 }
29 inline int find_root(int now,int rest)
30 { best = 0; getroot(now,0,rest); return best; }
31
32 inline void dfs(int now,int fa,int dep)
33 {
```

```

34     size[now] = 1; nd = max(dep,nd); ++d[dep];
35     for (int i = side[now];i;i = next[i])
36         if (toit[i] != fa&&!vis[toit[i]])
37             dfs(toit[i],now,dep+1),size[now] += size[toit[i]];
38 }
39
40 inline void subdivide(int now)
41 {
42     vis[now] = true;
43     for (int i = side[now];i;i = next[i])
44     {
45         if (vis[toit[i]]) continue;
46         dfs(toit[i],now,1); ans += d[K];
47         for (int j = 1;j < K;++j) ans += d[j]*sd[K-j];
48         for (int j = 1;j <= nd;++j) sd[j] += d[j],d[j] = 0;
49         ns = max(nd,ns); nd = 0;
50     }
51     memset(sd,0,4*(ns+1)); ns = 0;
52     for (int i = side[now];i;i = next[i])
53         if (!vis[toit[i]])
54             subdivide(find_root(toit[i],size[toit[i]]));
55 }
56
57 int main()
58 {
59     freopen("D.in","r",stdin);
60     freopen("D.out","w",stdout);
61     scanf("%d %d",&N,&K);
62     for (int i = 1,a,b;i < N;++i) scanf("%d %d",&a,&b),ins(a,b);
63     large[0] = 1<<30; subdivide(find_root(1,N));
64     printf("%d",ans);
65     fclose(stdin); fclose(stdout);
66     return 0;
67 }

```

3.2 Dynamicly Divide and Conquer on Tree

```

1  // N 个点的树，每个点点权 0/1，询问两个 0 点之间最远距离，每次可以 flip 一个点的点权
2  #include<set>
3  #include<vector>
4  #include<algorithm>
5  #include<cstring>
6  #include<iostream>
7  #include<cstdio>
8  #include<cstdlib>
9  using namespace std;
10
11 const int maxn = 200010,inf = 1<<29,lhh = 4000037;

```

```

12  int
    ↪ N,cnt,nlight,tot,best,Root,side[maxn],toit[maxn],nxt[maxn],size[maxn],large[maxn],optimal[maxn];
13  int father[maxn],L[maxn],R[maxn],leaf[maxn],rechain[lhh],depth[lhh]; bool off[maxn],vis[maxn];
14  vector <int> son[maxn]; pair <int,int> Hash[lhh]; multiset <int> mx[maxn],S[maxn];
15
16  struct Value
17  {
18      int a,b;
19      inline Value() {}
20      inline Value(int _a,int _b):a(_a),b(_b) {}
21      friend inline Value operator +(const Value &x,const Value &y)
22      {
23          Value ret;
24          if (x.a > y.a)
25          {
26              ret.a = x.a;
27              if (x.b > y.a) ret.b = x.b;
28              else ret.b = y.a;
29          }
30          else
31          {
32              ret.a = y.a;
33              if (y.b > x.a) ret.b = y.b;
34              else ret.b = x.a;
35          }
36          return ret;
37      }
38  }tree[maxn*2];
39
40  inline void add(int a,int b) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
41  inline void ins(int a,int b) { add(a,b); add(b,a); }
42
43  inline int gi()
44  {
45      char ch; int ret = 0,f = 1;
46      do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
47      if (ch == '-') f = -1, ch = getchar();
48      do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
49      return ret*f;
50  }
51
52  inline int find(const pair <int,int> &key)
53  {
54      int now = (2333*key.first+5003*key.second)%lhh;
55      while (true)
56      {
57          if (Hash[now].first == 0 || Hash[now] == key) return now;
58          else ++now;
59          if (now >= lhh) now -= lhh;

```

```

60     }
61 }
62
63 inline void getroot(int now,int rest,int fa)
64 {
65     size[now] = 1; large[now] = 0;
66     for (int i = side[now];i;i = nxt[i])
67     {
68         if (vis[toit[i]]||toit[i] == fa) continue;
69         getroot(toit[i],rest,now);
70         size[now] += size[toit[i]];
71         large[now] = max(large[now],size[toit[i]]);
72     }
73     large[now] = max(large[now],rest-size[now]);
74     if (large[now] < large[best]) best = now;
75 }
76 inline int find_root(int rest,int now) { best = 0; getroot(now,rest,0); return best; }
77
78 inline void dfs(int id,int root,int now,int fa,int dep)
79 {
80     S[id].insert(dep);
81     pair <int,int> key = make_pair(root,now); int pos = find(key);
82     rechain[pos] = id; depth[pos] = dep; Hash[pos] = key;
83     size[now] = 1;
84     for (int i = side[now];i;i = nxt[i])
85     {
86         if (vis[toit[i]]||toit[i] == fa) continue;
87         dfs(id,root,toit[i],now,dep+1); size[now] += size[toit[i]];
88     }
89 }
90
91 inline void subdivide(int root)
92 {
93     optimal[root] = -inf; mx[root].insert(-inf);
94     L[root] = tot+1;
95     for (int i = side[root];i;i = nxt[i])
96     {
97         if (vis[toit[i]]) continue;
98         ++tot; dfs(tot,root,toit[i],root,1);
99         S[tot].insert(-inf);
100     }
101     R[root] = tot; vis[root] = true;
102     for (int i = side[root];i;i = nxt[i])
103     {
104         if (vis[toit[i]]) continue;
105         int tmp = find_root(size[toit[i]],toit[i]);
106         father[tmp] = root; son[root].push_back(tmp);
107         subdivide(tmp);
108     }

```

```

109 }
110
111 inline void build(int now,int l,int r)
112 {
113     if (l == r)
114     {
115         tree[now] = Value(*S[l].rbegin(),-inf);
116         leaf[l] = now; return;
117     }
118     int mid = (l+r)>>1;
119     build(now<<1,l,mid); build(now<<1|1,mid+1,r);
120     tree[now] = tree[now<<1]+tree[now<<1|1];
121 }
122
123 inline Value query(int now,int l,int r,int ql,int qr)
124 {
125     if (l == ql&&qr == r) return tree[now];
126     int mid = (l+r)>>1;
127     if (qr <= mid) return query(now<<1,l,mid,ql,qr);
128     else if (ql > mid) return query(now<<1|1,mid+1,r,ql,qr);
129     else return query(now<<1,l,mid,ql,mid)+query(now<<1|1,mid+1,r,mid+1,qr);
130 }
131
132 inline void upd(int &a,int b) { if (a < b) a = b; }
133
134 inline void modify(int pos,int dep,bool sign)
135 {
136     if (sign) S[pos].insert(dep); else S[pos].erase(S[pos].find(dep));
137     tree[leaf[pos]] = Value(*S[pos].rbegin(),-inf);
138     for (int now = leaf[pos]>>1;now;now >>= 1)
139         tree[now] = tree[now<<1]+tree[now<<1|1];
140 }
141 inline void modify(int pos)
142 {
143     int c = 0;
144     if (father[pos]) mx[father[pos]].erase(mx[father[pos]].find(optimal[pos]));
145     off[pos] ^= 1; if (off[pos]) nlight++; else nlight--;
146     if (L[pos] <= R[pos])
147     {
148         Value res = query(1,1,tot,L[pos],R[pos]);
149         optimal[pos] = max(res.a+res.b,*mx[pos].rbegin());
150         if (off[pos]) upd(optimal[pos],res.a);
151     }
152     if (father[pos]) mx[father[pos]].insert(optimal[pos]);
153     for (int now = father[pos];now;now = father[now])
154     {
155         int t = find(make_pair(now,pos));
156         int id = rechain[t],dep = depth[t];
157         modify(id,dep,off[pos]);

```

```

158         if (father[now]) mx[father[now]].erase(mx[father[now]].find(optimal[now]));
159         Value res = query(1,1,tot,L[now],R[now]);
160         optimal[now] = max(res.a+res.b,*mx[now].rbegin());
161         if (off[now]) upd(optimal[now],res.a);
162         if (father[now]) mx[father[now]].insert(optimal[now]);
163         ++c;
164     }
165 }
166
167 inline void redfs(int now)
168 {
169     for (int i = 0; i < (int)son[now].size(); ++i)
170         redfs(son[now][i]), mx[now].insert(optimal[son[now][i]]);
171     if (L[now] <= R[now])
172     {
173         Value res = query(1,1,tot,L[now],R[now]);
174         optimal[now] = max(res.a+res.b,*mx[now].rbegin());
175         if (off[now]) upd(optimal[now],res.a);
176     }
177 }
178
179 int main()
180 {
181     // freopen("A.in", "r", stdin);
182     memset(off, true, sizeof off);
183     nlight = N = gi();
184     for (int i = 1; i < N; ++i) ins(gi(), gi());
185     large[0] = inf;
186     subdivide(Root = find_root(N, 1));
187     build(1, 1, tot); redfs(Root);
188     for (int Q = gi(); Q--;)
189     {
190         char opt; do opt = getchar(); while (opt != 'G' && opt != 'C');
191         if (opt == 'G')
192         {
193             if (!nlight) puts("-1");
194             else if (nlight == 1) puts("0");
195             else printf("%d\n", optimal[Root]);
196         }
197         else modify(gi());
198     }
199     return 0;
200 }

```

3.3 Heavy Path Decomposition

```

1  int side[maxn], toit[maxn<<1], nxt[maxn<<1], nxt[maxn<<1];
2  int timestamp, father[maxn], dfn[maxn], redfn[maxn], top[maxn], size[maxn];
3

```

```

4  void decompose(int now,int tp)
5  {
6      redfn[dfn[now] = ++timestamp] = now;
7      top[now] = tp; int heavy = 0;
8      for (int i = side[now];i;i = nxt[i])
9          if (toit[i] != father[now]&&size[toit[i]] > size[heavy]) heavy = toit[i];
10     if (!heavy) return; decompose(heavy,tp);
11     for (int i = side[now];i;i = nxt[i])
12         if (toit[i] != father[now]&&toit[i] != heavy) decompose(toit[i],toit[i]);
13 }
14
15 void dfs(int now)
16 {
17     size[now] = 1;
18     for (int i = side[now];i;i = nxt[i])
19         if (toit[i] != father[now])
20             {
21                 father[toit[i]] = now,con[toit[i]] = i;
22                 dep[toit[i]] = dep[now]+1,dfs(toit[i]);
23                 size[now] += size[toit[i]] ;
24             }
25 }
26
27 // 对点操作
28 inline int query(int a,int b)
29 {
30     int ret = -inf;
31     while (top[a] != top[b])
32     {
33         if (dep[top[a]] < dep[top[b]]) swap(a,b);
34         ret = max(ret,ask(1,1,N,dfn[top[a]],dfn[a]));
35         a = father[top[a]];
36     }
37     if (dep[a] < dep[b]) swap(a,b);
38     ret = max(ret,query(1,1,N,dfn[b],dfn[a]));
39     return ret;
40 }
41
42 // 对边操作
43 inline int query(int a,int b)
44 {
45     int ret = -inf;
46     while (top[a] != top[b])
47     {
48         if (dep[top[a]] < dep[top[b]]) swap(a,b);
49         ret = max(ret,ask(1,1,N,dfn[top[a]],dfn[a]));
50         a = father[top[a]];
51     }
52     if (a == b) return ret;

```

```

53     if (dep[a] < dep[b]) swap(a,b);
54     ret = max(ret,ask(1,1,N,dfn[b]+1,dfn[a]));
55     return ret;
56 }

```

3.4 K-Dimension Tree

```

1  struct Point
2  {
3      double x,y; int id;
4      inline Point() = default;
5      inline Point(double _x,double _y,int _id):x(_x),y(_y),id(_id) {}
6      inline void read(int i = 0) { scanf("%lf %lf",&x,&y); id = i; }
7      inline double norm() { return sqrt(x*x+y*y); }
8      friend inline Point operator+(const Point &a,const Point &b) { return
↪ Point(a.x+b.x,a.y+b.y); }
9      friend inline Point operator-(const Point &a,const Point &b) { return
↪ Point(a.x-b.x,a.y-b.y); }
10     friend inline double operator*(const Point &a,const Point &b) { return a.x*b.x+a.y*b.y; }
11     friend inline double operator/(const Point &a,const Point &b) { return a.x*b.y-a.y*b.x; }
12 }P[maxn];
13
14 struct Rectangle
15 {
16     double lx,rx,ly,ry;
17     inline Rectangle() = default;
18     inline Rectangle(double _lx,double _rx,double _ly,double
↪ _ry):lx(_lx),rx(_rx),ly(_ly),ry(_ry) {}
19     inline void set(const Point &p) { lx = rx = p.x; ly = ry = p.y; }
20     inline void merge(const Point &p)
21     {
22         lx = min(lx,p.x); rx = max(rx,p.x);
23         ly = min(ly,p.y); ry = max(ry,p.y);
24     }
25     inline void merge(const Rectangle &r)
26     {
27         lx = min(lx,r.lx); rx = max(rx,r.rx);
28         ly = min(ly,r.ly); ry = max(ry,r.ry);
29     }
30     // 最小距离, 到 4 个角和 4 条边距离
31     inline double dist(const Point &p)
32     {
33         if (p.x <= lx&&p.y <= ly) return (p-Point(lx,ly)).norm();
34         else if (p.x <= rx&&p.y <= ly) return p.y-ly;
35         else if (p.x >= rx&&p.y <= ly) return (p-Point(rx,ly)).norm();
36         else if (p.x >= rx&&p.y <= ry) return p.x-rx;
37         else if (p.x >= rx&&p.y >= ry) return (p-Point(rx,ry)).norm();
38         else if (p.x >= lx&&p.y >= ry) return p.y-ry;
39         else if (p.x <= lx&&p.y >= ry) return (p-Point(lx,ry)).norm();

```



```

40         else if (p.x <= lx&& p.y >= ly) return p.x-lx;
41         return 0;
42     }
43     // 最大距离, 到 4 个角的距离
44     inline double dist(const Point &p)
45     {
46         double ret = 0;
47         ret += max((rx-p.x)*(rx-p.x), (lx-p.x)*(lx-p.x));
48         ret += max((ry-p.y)*(ry-p.y), (ly-p.y)*(ly-p.y));
49         return ret;
50     }
51 };
52
53 struct Node
54 {
55     int child[2]; Point p; Rectangle r;
56     inline Node() = default;
57     inline Node(const Point &p, const Rectangle &r): p(_p), r(_r) { r.set(p); memset(child, 0, 8);
    ↪ }
58     inline void set(const Point &p) { p = _p; r.set(p); memset(child, 0, 8); }
59 } tree[maxn];
60
61 inline bool cmpx(const Point &a, const Point &b)
62 {
63     if (a.x != b.x) return a.x < b.x;
64     else return a.y < b.y;
65 }
66 inline bool cmpy(const Point &a, const Point &b)
67 {
68     if (a.y != b.y) return a.y < b.y;
69     else return a.x < b.x;
70 }
71
72 inline bool cmp(pair <double, int> a, pair <double, int> b)
73 {
74     int sgn = dcmp(a.first-b.first);
75     if (sgn) return sgn < 0;
76     else return a.second < b.second;
77 }
78
79 // 查询 k 大/小
80 inline void query(int now, const Point &p, int k, pair <double, int> ret[], bool dim = false)
81 {
82     if (dcmp(tree[now].r.dist(p)-ret[k].first) > 0) return;
83     pair <double, int> val = make_pair((p-tree[now].p).norm(), tree[now].p.id);
84     for (int i = 1; i <= k; ++i)
85         if (cmp(val, ret[i]))
86             {
87                 for (int j = k+1; j > i; --j) ret[j] = ret[j-1];

```

```

88         ret[i] = val; break;
89     }
90     if ((dim&&cmpx(p,tree[now].p))||(!dim&&cmpy(p,tree[now].p)))
91     {
92         if (tree[now].child[0]) query(tree[now].child[0],p,k,ret,dim^1);
93         if (tree[now].child[1]) query(tree[now].child[1],p,k,ret,dim^1);
94     }
95     else
96     {
97         if (tree[now].child[1]) query(tree[now].child[1],p,k,ret,dim^1);
98         if (tree[now].child[0]) query(tree[now].child[0],p,k,ret,dim^1);
99     }
100 }
101
102 // 查询最小/大
103 inline void query(int x,const Point &p,pair <double,int> ret,bool dim = false)
104 {
105     if (dcmp(tree[now].r.disp(p)-ret.first) > 0) return;
106     pair <double,int> val = make_pair((p-tree[now].p).norm(),tree[now].p.id);
107     if (cmp(val,ret)) ret = val;
108     if ((dim&&cmpx(p,tree[now].p))||(!dim&&cmpy(p,tree[now].p)))
109     {
110         if (tree[now].child[0]) query(tree[now].child[0],p,ret,dim^1);
111         if (tree[now].child[1]) query(tree[now].child[1],p,ret,dim^1);
112     }
113     else
114     {
115         if (tree[now].child[1]) query(tree[now].child[1],p,ret,dim^1);
116         if (tree[now].child[0]) query(tree[now].child[0],p,ret,dim^1);
117     }
118 }
119
120 inline int build(int l,int r,bool dim)
121 {
122     int now = ++size,mid = (l+r)>>1;
123     nth_element(vec.begin()+l-1,vec.begin()+mid-1,vec.begin()+r,dim?cmpx:cmpy);
124     tree[now].set(vec[mid-1]);
125     if (l < mid)
126     {
127         tree[now].child[0] = build(l,mid-1,dim^1);
128         tree[now].r.merge(tree[tree[now].child[0]].r);
129     }
130     if (r > mid)
131     {
132         tree[now].child[1] = build(mid+1,r,dim^1);
133         tree[now].r.merge(tree[tree[now].child[1]].r);
134     }
135     return now;
136 }

```

3.5 Leftlist Tree

```

1  // It's correct, but it needs be rewritten.
2  #include<iostream>
3  #include<cstdio>
4  #include<cstdlib>
5  using namespace std;
6
7  #define maxn (600010)
8  int N,M,root[maxn],size[maxn],v[maxn],dep[maxn],l[maxn],r[maxn],tot;
9
10 inline int Merge(int x,int y)
11 {
12     if (!x||!y) return x+y;
13     if (v[x]>v[y]) swap(x,y);
14     r[x] = Merge(r[x],y);
15     if (dep[l[x]] < dep[r[x]]) swap(l[x],r[x]);
16     dep[x] = dep[r[x]]+1;
17     return x;
18 }
19 inline int Init(int x) { v[++tot] = x; l[tot] = r[tot] = dep[tot] = 0; return tot;}
20 inline int Insert(int x,int y) { return Merge(x,Init(y)); }
21 inline int pop(int x) { return Merge(l[x],r[x]); }
22
23 inline int read()
24 {
25     char ch; int f = 1,ret = 0;
26     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
27     if (ch == '-') f = -1,ch = getchar();
28     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
29     return ret*f;
30 }
31
32 int main()
33 {
34     freopen("1050.in","r",stdin);
35     freopen("1050.out","w",stdout);
36     scanf("%d %d",&N,&M);
37     for (int i = 1;i <= N;++i) root[i] = Init(read()),size[i] = 1;
38     while (M--)
39     {
40         int opt = read();
41         if (!opt)
42         {
43             int a = read()+1,b = read()+1;
44             if (size[b]) root[a] = Merge(root[a],root[b]);
45             size[a] += size[b]; size[b] = 0;
46         }
47         else if (opt == 1)
48         {

```

```

49         int a = read()+1;
50         if (!size[a]) puts("-1");
51         else printf("%d\n",v[root[a]]),root[a] = pop(root[a]),--size[a];
52     }
53     else
54     {
55         int a = read()+1; ++size[a];
56         root[a] = Insert(root[a],read());
57     }
58 }
59 fclose(stdin); fclose(stdout);
60 return 0;
61 }

```

3.6 Link Cut Tree

```

1  inline bool isroot(int a) { return ch[fa[a]][0] != a&&ch[fa[a]][1] != a; }
2
3  inline void update(int x) { val[x] = (val[ch[x][0]]+val[ch[x][1]]).merge(x); }
4  inline void pushdown(int x)
5  {
6      if (rev[x])
7      {
8          int &lc = ch[x][0],&rc = ch[x][1];
9          swap(lc,rc);
10         if (lc) rev[lc] ^= 1;
11         if (rc) rev[rc] ^= 1;
12         rev[x] = false;
13     }
14 }
15
16 inline void rotate(int x)
17 {
18     int y = fa[x],z = fa[y],l = ch[y][1] == x,r = l^1;
19     if (!isroot(y)) ch[z][ch[z][1] == y] = x; fa[x] = z;
20     if (ch[x][r]) fa[ch[x][r]] = y; ch[y][1] = ch[x][r];
21     fa[y] = x; ch[x][r] = y; update(y); update(x);
22 }
23 inline void splay(int x)
24 {
25     int top = 0,i;
26     for (i = x;!isroot(i);i = fa[i]) stk[++top] = i; stk[++top] = i;
27     while (top) pushdown(stk[top--]);
28     while (!isroot(x))
29     {
30         int y = fa[x],z = fa[y];
31         if (!isroot(y))
32         {
33             if ((ch[y][0] == x)^(ch[z][0] == y)) rotate(x);

```

```

34         else rotate(y);
35     }
36     rotate(x);
37 }
38 }
39
40 inline int access(int x)
41 {
42     int t = 0;
43     for (t = 0; x; t = x, x = fa[x])
44         splay(x), ch[x][1] = t, update(x);
45     return t;
46 }
47 inline int evert(int x) { int t; rev[t = access(x)] ^= 1; return t; }
48 inline int find(int x)
49 {
50     x = access(x);
51     while (pushdown(x), ch[x][0]) x = ch[x][0];
52     return x;
53 }
54 inline void cut(int x, int y)
55 {
56     evert(x); access(y); splay(y);
57     if (ch[y][0] != x || ch[x][1] != 0) return;
58     ch[y][0] = fa[x] = 0; update(x); update(y);
59 }
60 inline void link(int x, int y) { fa[evert(x)] = y; }
61
62
63 // Magic Forest
64 #include<algorithm>
65 #include<cstring>
66 #include<iostream>
67 #include<cstdio>
68 #include<cstdlib>
69 using namespace std;
70
71 const int maxn = 200010, inf = 1<<29;
72 int N, M, A[maxn], B[maxn], fa[maxn], ch[maxn][2];
73 int stk[maxn], ans = inf; bool rev[maxn];
74
75 struct Value
76 {
77     int ma, mb, id;
78     inline Value(int _ma = 0, int _mb = 0, int _id = 0) : ma(_ma), mb(_mb), id(_id) {}
79     friend inline Value operator +(const Value &a, const Value &b)
80     {
81         Value ret = Value(max(a.ma, b.ma), max(a.mb, b.mb), a.id);
82         if (B[a.id] < B[b.id]) ret.id = b.id;

```

```

83         return ret;
84     }
85     inline Value merge(int i)
86     {
87         Value ret = Value(max(ma,A[i]),max(mb,B[i]),id);
88         if (B[i] > B[id]) ret.id = i;
89         return ret;
90     }
91 }val[maxn];
92
93 inline int gi()
94 {
95     char ch; int ret = 0,f = 1;
96     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
97     if (ch == '-') f = -1,ch = getchar();
98     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
99     return ret*f;
100 }
101
102 struct Edge
103 {
104     int x,y,a,b;
105     inline Edge(int _x = 0,int _y = 0,int _a = 0,int _b = 0):x(_x),y(_y),a(_a),b(_b) {}
106     inline void read() { x = gi(),y = gi(),a = gi(),b = gi(); }
107     friend inline bool operator <(const Edge &s,const Edge &t) { return s.a < t.a; }
108 }edge[maxn];
109
110 inline bool isroot(int a) { return ch[fa[a]][0] != a&&ch[fa[a]][1] != a; }
111
112 inline void update(int x) { val[x] = (val[ch[x][0]]+val[ch[x][1]]).merge(x); }
113 inline void pushdown(int x)
114 {
115     if (rev[x])
116     {
117         int &lc = ch[x][0],&rc = ch[x][1];
118         swap(lc,rc);
119         if (lc) rev[lc] ^= 1;
120         if (rc) rev[rc] ^= 1;
121         rev[x] = false;
122     }
123 }
124
125 inline void rotate(int x)
126 {
127     int y = fa[x],z = fa[y],l = ch[y][1] == x,r = l^1;
128     if (!isroot(y)) ch[z][ch[z][1] == y] = x; fa[x] = z;
129     if (ch[x][r]) fa[ch[x][r]] = y; ch[y][l] = ch[x][r];
130     fa[y] = x; ch[x][r] = y; update(y); update(x);
131 }

```

```

132 inline void splay(int x)
133 {
134     int top = 0,i;
135     for (i = x;!isroot(i);i = fa[i]) stk[++top] = i; stk[++top] = i;
136     while (top) pushdown(stk[top--]);
137     while (!isroot(x))
138     {
139         int y = fa[x],z = fa[y];
140         if (!isroot(y))
141         {
142             if ((ch[y][0] == x)^(ch[z][0] == y)) rotate(x);
143             else rotate(y);
144         }
145         rotate(x);
146     }
147 }
148
149 inline int access(int x)
150 {
151     int t = 0;
152     for (t = 0;x;t = x,x = fa[x])
153         splay(x),ch[x][1] = t,update(x);
154     return t;
155 }
156 inline int evert(int x) { int t; rev[t = access(x)] ^= 1; return t; }
157 inline int find(int x)
158 {
159     x = access(x);
160     while (pushdown(x),ch[x][0]) x = ch[x][0];
161     return x;
162 }
163 inline void cut(int x,int y)
164 {
165     evert(x); access(y); splay(y);
166     if (ch[y][0] != x||ch[x][1] != 0) return;
167     ch[y][0] = fa[x] = 0; update(x); update(y);
168 }
169 inline void link(int x,int y) { fa[evert(x)] = y; }
170
171 inline Value query(int x,int y) { evert(x); return val[access(y)]; }
172
173 int main()
174 {
175     // freopen("D.in","r",stdin);
176     N = gi(),M = gi();
177     for (int i = 1;i <= M;++i) edge[i].read();
178     sort(edge+1,edge+M+1);
179     for (int i = 0;i <= N;++i)
180         A[i] = B[i] = -inf,val[i] = Value(A[i],B[i],i);

```

```

181     for (int i = 1; i <= M; ++i)
182         A[i+N] = edge[i].a, B[i+N] = edge[i].b, val[i+N] = Value(A[i+N], B[i+N], i+N);
183     for (int i = 1; i <= M; ++i)
184     {
185         if (edge[i].x == edge[i].y) continue;
186         if (find(edge[i].x) == find(edge[i].y))
187         {
188             Value res = query(edge[i].x, edge[i].y); int id = res.id - N;
189             if (edge[i].b < edge[id].b)
190             {
191                 cut(edge[id].x, id+N), cut(edge[id].y, id+N);
192                 link(edge[i].x, i+N), link(edge[i].y, i+N);
193             }
194         }
195         else link(edge[i].x, i+N), link(i+N, edge[i].y);
196         if (find(1) == find(N))
197         {
198             Value res = query(1, N);
199             ans = min(ans, res.ma + res.mb);
200         }
201     }
202     if (ans == inf) ans = -1;
203     printf("%d\n", ans);
204     return 0;
205 }

```

3.7 Merge Split Treap

```

1  // jisuanke17123
2  // Warning: 给指针赋值时, 不要赋 this, 因为 this 是临时变量的地址
3  #include<sys/timeb.h>
4  #include<queue>
5  #include<algorithm>
6  #include<cstring>
7  #include<iostream>
8  #include<cstdio>
9  #include<cstdlib>
10 #include<set>
11 using namespace std;
12
13 typedef long long ll;
14 const int maxn = 1000010;
15 int N;
16
17 inline int rand(int n) { int x = rand(); if (x < 0) x = -x; return x%n+1; }
18
19 struct Node
20 {
21     int size, key, val; Node *mn, *ch[2];

```



```

22     inline Node *update()
23     {
24         mn = this; size = 1;
25         if (ch[0])
26         {
27             size += ch[0]->size;
28             if (ch[0]->mn->val < mn->val) mn = ch[0]->mn;
29         }
30         if (ch[1])
31         {
32             size += ch[1]->size;
33             if (ch[1]->mn->val < mn->val) mn = ch[1]->mn;
34         }
35         return this;
36     }
37     inline Node() = default;
38     inline Node(int v, Node *_mn):size(1),key(rand()),val(v),mn(_mn) { ch[0] = ch[1] = NULL; }
39 }pool[maxn*100/4],*root[maxn],*cur;
40 struct Status
41 {
42     int l,r; ll val;
43     inline Status() = default;
44     inline Status(int _l,int _r,ll _val):l(_l),r(_r),val(_val) {}
45     friend inline bool operator <(const Status &a,const Status &b) { return a.val > b.val; }
46 };
47
48 inline int sz(const Node *x) { if (x == NULL) return 0; else return x->size; }
49
50 inline Node *newnode(int v = 0) { *cur = Node(v,cur); return cur++; }
51
52 Node *insert(Node *p,Node *q)
53 {
54     if (p == NULL&&q == NULL) return NULL;
55     if (p == NULL||q == NULL) return p?p:q;
56     Node *u = NULL;
57     if (rand(sz(p)+sz(q)) < sz(p))
58         u = p,u->ch[1] = insert(u->ch[1],q);
59     else u = q,u->ch[0] = insert(p,u->ch[0]);
60     return u->update();
61 }
62
63 Node *merge(Node *p,Node *q)
64 {
65     if (p == NULL&&q == NULL) return NULL;
66     if (p == NULL||q == NULL) return p?p:q;
67     Node *u = newnode();
68     if (rand(sz(p)+sz(q)) < sz(p))
69         *u = *p,u->ch[1] = merge(u->ch[1],q);
70     else *u = *q,u->ch[0] = merge(p,u->ch[0]);

```

```

71     return u->update();
72 }
73
74 Node *split(Node *u, int l, int r)
75 {
76     if (l > r || u == NULL) return 0;
77     Node *x = NULL;
78     if (l == 1 && r == sz(u))
79     {
80         x = newnode(); *x = *u;
81         return x->update();
82     }
83     int lsz = sz(u->ch[0]);
84     if (r <= lsz) return split(u->ch[0], l, r);
85     if (l > lsz+1) return split(u->ch[1], l-lsz-1, r-lsz-1);
86     x = newnode(); *x = *u;
87     x->ch[0] = split(u->ch[0], l, lsz);
88     x->ch[1] = split(u->ch[1], 1, r-lsz-1);
89     return x->update();
90 }
91
92 inline int gi()
93 {
94     char ch; int ret = 0, f = 1;
95     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
96     if (ch == '-') f = -1, ch = getchar();
97     do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
98     return ret*f;
99 }
100
101 int get_pos(Node *rt, Node *mn)
102 {
103     if (rt == mn) return sz(rt->ch[0]);
104     else if (rt->ch[0] && rt->ch[0]->mn == mn)
105         return get_pos(rt->ch[0], mn);
106     else return sz(rt->ch[0])+1+get_pos(rt->ch[1], mn);
107 }
108 inline pair <int, int> Qmin(Node *rt, int l, int r)
109 {
110     if (l > r) return make_pair(-1, -1);
111     Node *v = split(rt, l, r);
112     auto ret = make_pair(v->mn->val, get_pos(v, v->mn)+1);
113     return ret;
114 }
115 inline int get(Node *u, int x) { return split(u, x, x)->val; }
116
117 inline void work(Node *rt, int k)
118 {
119     int n = sz(rt);

```

```

120     set <int> S; S.insert(0); S.insert(n+1);
121     priority_queue <Status> heap;
122     auto tmp = Qmin(rt,1,n);
123     heap.push(Status(tmp.second,tmp.second,tmp.first));
124     while (k--)
125     {
126         auto now = heap.top(); heap.pop();
127         printf("%lld\n",now.val);
128         if (now.l == now.r)
129         {
130             S.insert(now.l);
131             auto it = S.find(now.l);
132             int pre = *(--it);
133             int nxt = *++(++it);
134             auto ls = Qmin(rt,pre+1,now.l-1);
135             auto rs = Qmin(rt,now.l+1,nxt-1);
136             if (ls.first != -1)
137                 heap.push(Status(ls.second,ls.second,ls.first));
138             if (rs.first != -1)
139                 heap.push(Status(rs.second,rs.second,rs.first));
140         }
141         if (now.r < n)
142         {
143             int inc = get(rt,now.r+1);
144             ++now.r; now.val += (ll)inc;
145             heap.push(now);
146         }
147     }
148 }
149
150 inline void init() { N = 0; cur = pool; }
151
152 int main()
153 {
154     struct timeb ttt; ftime(&ttt);
155     srand(ttt.millitm+ttt.time*1000);
156     for (int T = gi();T--;)
157     {
158         init();
159         for (int Q = gi();Q--;)
160         {
161             int opt = gi();
162             if (opt == 1)
163             {
164                 root[++N] = NULL;
165                 for (int n = gi();n--;)
166                     root[N] = insert(root[N],newnode(gi()));
167             }
168             else if (opt == 2)

```

```

169         {
170             root[++N] = NULL;
171             int x = gi(), l1 = gi(), r1 = gi(), y = gi(), l2 = gi(), r2 = gi();
172             Node *ls = split(root[x], l1, r1);
173             Node *rs = split(root[y], l2, r2);
174             root[N] = merge(ls, rs);
175         }
176     else
177     {
178         int x = gi(), k = gi();
179         work(root[x], k);
180     }
181 }
182 // cerr << cur - pool << endl;
183 }
184 return 0;
185 }
186
187 // By zky. To be rewritten.
188 const int mo=1e9+7;
189 int rnd(){
190     static int x=1;
191     return x=(x*23333+233);
192 }
193 int rnd(int n){
194     int x=rnd();
195     if(x<0)x=-x;
196     return x%n+1;
197 }
198 struct node{
199     int siz, key;
200     int val;
201     LL sum;
202     node *c[2];
203     node* rz(){
204         sum=val; siz=1;
205         if(c[0])sum+=c[0]->sum, siz+=c[0]->siz;
206         if(c[1])sum+=c[1]->sum, siz+=c[1]->siz;
207         return this;
208     }
209     node(){ }
210     node(int v){
211         siz=1; key=rnd();
212         val=v; sum=v;
213         c[0]=c[1]=0;
214     }
215
216 }pool[maxn*8], *root, *cur=pool, *old_root, *stop;
217 node *newnode(int v=0){

```

```

218     *cur=node(v);
219     return cur++;
220 }
221 node *old_merge(node *p,node *q){
222     if(!p&&!q)return 0;
223     node *u=0;
224     if(!p||!q)return u=p?p->rz():(q?q->rz():0);
225     if(rnd(sz(p)+sz(q))<sz(p)){
226         u=p;
227         u->c[1]=old_merge(u->c[1],q);
228     }else{
229         u=q;
230         u->c[0]=old_merge(p,u->c[0]);
231     }
232     return u->rz();
233 }
234 node *merge(node *p,node *q){
235     if(!p&&!q)return 0;
236     node *u=newnode();
237     if(!p||!q)return u=p?p->rz():(q?q->rz():0);
238     if(rnd(sz(p)+sz(q))<sz(p)){
239         *u=*p;
240         u->c[1]=merge(u->c[1],q);
241     }else{
242         *u=*q;
243         u->c[0]=merge(p,u->c[0]);
244     }
245     return u->rz();
246 }
247 node *split(node *u,int l,int r){
248     if(l>r||!u)return 0;
249     node *x=0;
250     if(l==1&&r==sz(u)){
251         x=newnode();
252         *x=*u;
253         return x->rz();
254     }
255     int lsz=sz(u->c[0]);
256     if(r<=lsz)
257         return split(u->c[0],l,r);
258     if(l>lsz+1)
259         return split(u->c[1],l-lsz-1,r-lsz-1);
260     x=newnode();
261     *x=*u;
262     x->c[0]=split(u->c[0],l,lsz);
263     x->c[1]=split(u->c[1],1,r-lsz-1);
264     return x->rz();
265 }

```

3.8 Modui Algorithm on Tree

```

1  // 询问树上路径元素 mex, inc dec 复杂度不对, 需要用线段树/set(带 log) 或者分块 (修改 O(1))
2  // 若包括 lca, 每组询问需要把 lca 补 (inc) 上去。
3  #include<cstdio>
4  #include<cstdlib>
5  #include<algorithm>
6  #include<cstring>
7  #include<iostream>
8  using namespace std;
9
10 const int Size = 337,maxn = 200010;
11 int N,Q,cnt,nxt[maxn],side[maxn],len[maxn],toit[maxn],f[maxn][20],key[maxn],timestamp;
12 int dep[maxn],L[maxn],R[maxn],dfn[maxn],ans[maxn],exist[maxn],show[maxn],res;
13
14 inline void add(int a,int b,int c) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
    ↪ len[cnt] = c; }
15 inline void ins(int a,int b,int c) { add(a,b,c); add(b,a,c); }
16
17 void dfs(int now)
18 {
19     dfn[L[now] = ++timestamp] = now;
20     for (int i = 1;(1<<i) <= dep[now];++i) f[now][i] = f[f[now][i-1]][i-1];
21     for (int i = side[now];i;i = nxt[i])
22     {
23         if (toit[i] == f[now][0]) continue;
24         f[toit[i]][0] = now; key[toit[i]] = len[i];
25         dep[toit[i]] = dep[now]+1;
26         dfs(toit[i]);
27     }
28     dfn[R[now] = ++timestamp] = now;
29 }
30
31 inline int jump(int a,int b) { for (int i = 0;b;b >>= 1,++i) if (b&1) a = f[a][i]; return a; }
32 inline int lca(int a,int b)
33 {
34     if (dep[a] < dep[b]) swap(a,b);
35     a = jump(a,dep[a]-dep[b]);
36     if (a == b) return a;
37     for (int i = 0;i >= 0;)
38     {
39         if (f[a][i] == f[b][i]) --i;
40         else a = f[a][i],b = f[b][i],++i;
41     }
42     return f[a][0];
43 }
44
45 struct Node
46 {
47     int a,b,c,id;

```

```

48     Node() = default;
49     Node(int _a,int _b,int _c = 0,int _id = 0):a(_a),b(_b),c(_c),id(_id) {}
50     inline void read(int i)
51     {
52         id = i; scanf("%d %d",&a,&b); c = lca(a,b);
53         if (c == a||c == b) { if (a != c) swap(a,b); a = L[c]+1; b = L[b]; }
54         else { if (L[a] > L[b]) swap(a,b); a = R[a]; b = L[b]; }
55     }
56     friend inline bool operator <(const Node &x,const Node &y) { return x.b < y.b; }
57 }query[maxn];
58
59 inline bool cmp(const Node &x,const Node &y) { return x.a < y.a; }
60
61 inline void inc(int id)
62 {
63     if (key[id] >= maxn) return;
64     ++exist[key[id]];
65     while (exist[res]) ++res;
66 }
67 inline void dec(int id)
68 {
69     if (key[id] >= maxn) return;
70     --exist[key[id]];
71     if (key[id] < res&&!exist[key[id]]) res = key[id];
72 }
73
74 inline void work()
75 {
76     int l = 1,r = 0;
77     for (int i = 1;i <= Q;++i)
78     {
79         while (r < query[i].b)
80         {
81             show[dfn[++r]]++;
82             if (show[dfn[r]] == 2) dec(dfn[r]); else inc(dfn[r]);
83         }
84         while (l > query[i].a)
85         {
86             show[dfn[--l]]++;
87             if (show[dfn[l]] == 2) dec(dfn[l]); else inc(dfn[l]);
88         }
89         while (r > query[i].b)
90         {
91             if (show[dfn[r]] == 1) dec(dfn[r]); else inc(dfn[r]);
92             show[dfn[r--]]--;
93         }
94         while (l < query[i].a)
95         {
96             if (show[dfn[l]] == 1) dec(dfn[l]); else inc(dfn[l]);

```

```

97         show[dfn[l++]]--;
98     }
99     ans[query[i].id] = res;
100 }
101 }
102
103 int main()
104 {
105     freopen("F.in", "r", stdin);
106     scanf("%d %d", &N, &Q);
107     for (int i = 1; i < N; ++i)
108     {
109         int a, b, c;
110         scanf("%d %d %d", &a, &b, &c);
111         ins(a, b, c);
112     }
113     dfs(1);
114     for (int i = 1; i <= Q; ++i) query[i].read(i);
115     sort(query+1, query+Q+1, cmp);
116     for (int i = 1, j; i <= Q; i = j)
117     {
118         for (j = i; j <= Q && query[j].a - query[i].a <= Size; ++j);
119         sort(query+i+1, query+j);
120     }
121     work();
122     for (int i = 1; i <= Q; ++i) printf("%d\n", ans[i]);
123     return 0;
124 }

```

3.9 Modui Algorithm without Deletion

```

1  // r 单调右移, l 只会在  $\sqrt{N}$  中移动, 保证每次 undo 的复杂度可行即可。
2  // CodeForces 620F
3  #include<vector>
4  #include<algorithm>
5  #include<cstring>
6  #include<iostream>
7  #include<cstdio>
8  #include<cstdlib>
9  using namespace std;
10
11 const int maxn = 1000010, len = 200, inf = 1<<29;
12 int N, M, pre[maxn], A[maxn], ans[maxn];
13
14 inline int gi()
15 {
16     char ch; int ret = 0, f = 1;
17     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
18     if (ch == '-') f = -1, ch = getchar();

```



```

19     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
20     return ret*f;
21 }
22
23 inline void upd(int &a,int b) { if (a < b) a = b; }
24
25 struct Trie
26 {
27     int nxt[maxn][2],val[maxn],root,cnt; vector < pair<int,int> > vec;
28     inline int newnode() { val[++cnt] = inf; memset(nxt[cnt],0,8); return cnt; }
29     inline void init() { val[0] = inf; cnt = 0; root = newnode(); }
30
31     inline int query(int key,int num)
32     {
33         int now = root,ret = 0;
34         for (int i = 19;i >= 0;--i)
35         {
36             int dir = !(num&(1<<i));
37             if (val[nxt[now][dir]] <= key)
38                 ret |= (1<<i),now = nxt[now][dir];
39             else now = nxt[now][dir^1];
40         }
41         return ret;
42     }
43
44     inline void insert(int key,int num,int mode) { insert(root,19,key,num,mode); }
45     inline void insert(int &now,int dep,int key,int num,int mode)
46     {
47         if (!now) now = newnode();
48         if (dep < 0)
49         {
50             if (mode) vec.push_back(make_pair(num,val[now]));
51             val[now] = min(val[now],key); return;
52         }
53         insert(nxt[now][(num&(1<<dep)) > 0],dep-1,key,num,mode);
54         val[now] = min(val[nxt[now][0]],val[nxt[now][1]]);
55     }
56
57     inline void change(int now,int dep,int num,int v)
58     {
59         if (dep < 0) { val[now] = v; return; }
60         change(nxt[now][(num&(1<<dep)) > 0],dep-1,num,v);
61         val[now] = min(val[nxt[now][0]],val[nxt[now][1]]);
62     }
63
64     inline void undo()
65     {
66         reverse(vec.begin(),vec.end());
67         for (auto x:vec) change(root,19,x.first,x.second);

```

```

68         vec.clear();
69     }
70 }tree1,tree2;
71
72 struct Query
73 {
74     int l,r,id;
75     inline void read(int i) { l = gi(),r = gi(),id = i; }
76     friend inline bool operator <(const Query &a,const Query &b) { return a.l < b.l; }
77 }query[maxn];
78 inline bool cmp(const Query &a,const Query &b) { return a.r < b.r; }
79
80 inline void work(int l,int r)
81 {
82     int lim = query[r].l;
83     sort(query+l,query+r+1,cmp);
84     tree1.init(); tree2.init();
85     for (int i = l;i <= r;++i)
86     {
87         if (query[i].r <= lim)
88         {
89             for (int j = query[i].l;j <= query[i].r;++j)
90             {
91                 tree1.insert(A[j],pre[A[j]-1],false);
92                 tree2.insert(-A[j],pre[A[j]],false);
93                 upd(ans[query[i].id],tree1.query(A[j],pre[A[j]]));
94                 upd(ans[query[i].id],tree2.query(-A[j],pre[A[j]-1]));
95             }
96             tree1.init(),tree2.init();
97         }
98         else
99         {
100             int pos = lim,mx = 0;
101             for (;i <= r;++i)
102             {
103                 while (pos < query[i].r)
104                 {
105                     ++pos;
106                     tree1.insert(A[pos],pre[A[pos]-1],false);
107                     tree2.insert(-A[pos],pre[A[pos]],false);
108                     upd(mx,tree1.query(A[pos],pre[A[pos]]));
109                     upd(mx,tree2.query(-A[pos],pre[A[pos]-1]));
110                 }
111                 upd(ans[query[i].id],mx);
112                 for (int j = lim;j >= query[i].l;--j)
113                 {
114                     tree1.insert(A[j],pre[A[j]-1],true);
115                     tree2.insert(-A[j],pre[A[j]],true);
116                     upd(ans[query[i].id],tree1.query(A[j],pre[A[j]]));

```

```

117         upd(ans[query[i].id],tree2.query(-A[j],pre[A[j]-1]));
118     }
119     tree1.undo(); tree2.undo();
120 }
121     break;
122 }
123 }
124 }
125
126 int main()
127 {
128     // freopen("A.in","r",stdin);
129     for (int i = 1;i <= 1000000;++i) pre[i] = pre[i-1]^i;
130     N = gi(); M = gi();
131     for (int i = 1;i <= N;++i) A[i] = gi();
132     for (int i = 1;i <= M;++i) query[i].read(i);
133     sort(query+1,query+M+1);
134     for (int i = 1,j;i <= M;i = j)
135     {
136         for (j = i;j <= M&&query[j].l-query[i].l <= len;++j);
137         work(i,j-1);
138     }
139     for (int i = 1;i <= M;++i) printf("%d\n",ans[i]);
140     return 0;
141 }

```

3.10 President Tree

```

1  inline void build(int &now,int l,int r)
2  {
3      now = ++cnt; if (l == r) return;
4      int mid = (l+r)>>1;
5      build(tree[now].ch[0],l,mid); build(tree[now].ch[1],mid+1,r);
6  }
7
8  inline void ins(int &now,int ref,int l,int r,int key)
9  {
10     now = ++cnt; tree[now] = tree[ref];
11     if (l == r) { ++tree[now].sum; return; }
12     int mid = (l+r) >> 1;
13     if (key <= mid) ins(tree[now].ch[0],tree[ref].ch[0],l,mid,key);
14     else ins(tree[now].ch[1],tree[ref].ch[1],mid+1,r,key);
15     tree[now].sum = tree[tree[now].ch[0]].sum+tree[tree[now].ch[1]].sum;
16 }

```

3.11 Splay

```

1  //splay
2

```

```

3  inline int find(int rk)
4  {
5      for (int now = root;;)
6      {
7          if (rk == size[ch[now][0]]+1) return now;
8          else if (rk > size[ch[now][0]]+1)
9              rk -= size[ch[now][1]]+1, now = ch[now][1];
10         else now = ch[now][0];
11     }
12     return 0;
13 }
14
15 inline int upperbound(int x)
16 {
17     int ret = 0;
18     for (int now = root; now;)
19     {
20         if (key[now] > x) ret = now, now = ch[now][0];
21         else now = ch[now][1];
22     }
23     return ret;
24 }
25 inline int lowerbound(int x)
26 {
27     int ret = 0;
28     for (int now = root; now;)
29     {
30         if (key[now] >= x) ret = now, now = ch[now][0];
31         else now = ch[now][1];
32     }
33     return ret;
34 }
35
36 inline void rotate(int x)
37 {
38     int y = fa[x], z = fa[y], l = ch[y][0] != x, r = l^1;
39     if (z) ch[z][ch[z][0] != y] = x; fa[x] = z;
40     if (ch[x][r]) fa[ch[x][r]] = y;
41     ch[y][l] = ch[x][r]; fa[y] = x; ch[x][r] = y;
42     update(y); update(x);
43 }
44 inline void splay(int x, int aim) //aim is x's father.
45 {
46     int top = 0;
47     for (int i = x; i; i = fa[i]) stack[++top] = i;
48     while (top) pushdown(stack[top--]);
49     while (fa[x] != aim)
50     {
51         int y = fa[x], z = fa[y];

```

```

52         if (z != aim)
53         {
54             if ((ch[y][0] == x)^(ch[z][0] == y)) rotate(x);
55             else rotate(y);
56         }
57         rotate(x);
58     }
59     if (!aim) root = x;
60 }
61
62 // 维修数列
63 #include<cassert>
64 #include<queue>
65 #include<algorithm>
66 #include<cstring>
67 #include<iostream>
68 #include<cstdio>
69 #include<cstdlib>
70 using namespace std;
71
72 const int maxn = 500010, inf = 1<<29;
73 int N,M,root,cnt,arr[maxn],tag[maxn],key[maxn],fa[maxn],ch[maxn][2],lb[maxn],rb[maxn];
74 int wb[maxn],sum[maxn],size[maxn],stk[maxn]; bool rev[maxn]; char cmd[20]; queue<int> team;
75
76 inline int gi()
77 {
78     char ch; int ret = 0, f = 1;
79     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
80     if (ch == '-') f = -1, ch = getchar();
81     do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
82     return ret*f;
83 }
84
85 inline int newnode(int x = 0)
86 {
87     int ret;
88     if (!team.empty())
89         ret = team.front(), team.pop();
90     else ret = ++cnt;
91     key[ret] = sum[ret] = lb[ret] = rb[ret] = wb[ret] = x;
92     rev[ret] = false; tag[ret] = inf; size[ret] = 1;
93     return ret;
94 }
95
96 inline void pushdown(int now)
97 {
98     int lc = ch[now][0], rc = ch[now][1];
99     if (rev[now])
100     {

```

```

101     if (lc)
102     {
103         swap(ch[lc][0],ch[lc][1]);
104         swap(lb[lc],rb[lc]); rev[lc] ^= 1;
105     }
106     if (rc)
107     {
108         swap(ch[rc][0],ch[rc][1]);
109         swap(lb[rc],rb[rc]); rev[rc] ^= 1;
110     }
111     rev[now] = false;
112 }
113 if (tag[now] != inf)
114 {
115     if (lc)
116     {
117         key[lc] = tag[lc] = tag[now]; sum[lc] = tag[lc]*size[lc];
118         if (tag[lc] > 0) lb[lc] = rb[lc] = wb[lc] = sum[lc];
119         else lb[lc] = rb[lc] = wb[lc] = tag[lc];
120     }
121     if (rc)
122     {
123         key[rc] = tag[rc] = tag[now]; sum[rc] = tag[rc]*size[rc];
124         if (tag[rc] > 0) lb[rc] = rb[rc] = wb[rc] = sum[rc];
125         else lb[rc] = rb[rc] = wb[rc] = tag[rc];
126     }
127     tag[now] = inf;
128 }
129 }
130
131 inline void update(int now)
132 {
133     // pushdown(now);
134     int lc = ch[now][0],rc = ch[now][1];
135     size[now] = size[lc]+size[rc]+1;
136     sum[now] = sum[lc]+sum[rc]+key[now];
137     if (lc&&rc)
138     {
139         lb[now] = max(lb[lc],max(sum[lc]+key[now],sum[lc]+key[now]+lb[rc]));
140         rb[now] = max(rb[rc],max(sum[rc]+key[now],sum[rc]+key[now]+rb[lc]));
141         wb[now] = max(wb[lc],wb[rc]); wb[now] = max(wb[now],key[now]);
142         wb[now] = max(wb[now],rb[lc]+key[now]); wb[now] = max(wb[now],lb[rc]+key[now]);
143         wb[now] = max(wb[now],rb[lc]+key[now]+lb[rc]);
144     }
145     else if (lc)
146     {
147         lb[now] = max(lb[lc],sum[lc]+key[now]);
148         rb[now] = max(key[now],key[now]+rb[lc]);
149         wb[now] = max(wb[lc],key[now]);

```

```

150         wb[now] = max(wb[now],rb[lc]+key[now]);
151     }
152     else if (rc)
153     {
154         rb[now] = max(rb[rc],sum[rc]+key[now]);
155         lb[now] = max(key[now],key[now]+lb[rc]);
156         wb[now] = max(wb[rc],key[now]);
157         wb[now] = max(wb[now],lb[rc]+key[now]);
158     }
159     else sum[now] = lb[now] = rb[now] = wb[now] = key[now];
160 }
161
162 inline int build(int l,int r)
163 {
164     int mid = (l+r) >> 1,ret = newnode(arr[mid]);
165     if (l < mid) ch[ret][0] = build(l,mid-1),fa[ch[ret][0]] = ret;
166     if (r > mid) ch[ret][1] = build(mid+1,r),fa[ch[ret][1]] = ret;
167     update(ret); return ret;
168 }
169
170 inline void init()
171 {
172     root = newnode(); ch[root][1] = newnode(); fa[2] = 1;
173     for (int i = 1;i <= N;++i) arr[i] = gi();
174     ch[2][0] = build(1,N); fa[ch[2][0]] = 2;
175     update(2); update(1);
176 }
177
178 inline int find(int rk)
179 {
180     for (int now = root;;)
181     {
182         pushdown(now);
183         if (rk == size[ch[now][0]]+1) return now;
184         else if (rk > size[ch[now][0]]+1)
185             rk -= size[ch[now][0]]+1,now = ch[now][1];
186         else now = ch[now][0];
187     }
188     return 0;
189 }
190
191 inline void rotate(int x)
192 {
193     int y = fa[x],z = fa[y],l = ch[y][0] != x,r = l^1;
194     if (z) ch[z][ch[z][0] != y] = x;
195     fa[x] = z; fa[y] = x; fa[ch[x][r]] = y;
196     ch[y][l] = ch[x][r]; ch[x][r] = y;
197     update(y); update(x);
198 }

```

```

199 inline void splay(int x,int aim)
200 {
201     int top = 0;
202     for (int i = x;i;i = fa[i]) stk[++top] = i;
203     while (top) pushdown(stk[top--]);
204     while (fa[x] != aim)
205     {
206         int y = fa[x],z = fa[y];
207         if (z != aim)
208         {
209             if ((ch[y][0] == x)^(ch[z][0] == y)) rotate(x);
210             else rotate(y);
211         }
212         rotate(x);
213     }
214     if (!aim) root = x;
215 }
216
217 inline void Delete(int &now)
218 {
219     if (!now) return;
220     Delete(ch[now][0]);
221     Delete(ch[now][1]);
222     team.push(now); now = 0;
223 }
224
225 inline void print()
226 {
227     for (int i = 1;i <= cnt;++i)
228         printf("%d:%d %d\n",i,ch[i][0],ch[i][1]);
229     for (int i = 1;i <= cnt;++i)
230         printf("%d:%d\n",i,fa[i]);
231 }
232 }
233
234 inline void laydown(int now)
235 {
236     if (!now) return;
237     pushdown(now);
238     laydown(ch[now][0]);
239     printf("%d ",key[now]);
240     laydown(ch[now][1]);
241     update(now);
242 }
243
244 int main()
245 {
246     //freopen("C.in","r",stdin);
247     N = gi(); M = gi(); init();

```



```

248     while (M--)
249     {
250         scanf("%s",cmd);
251         if (cmd[0] == 'I')
252         {
253             int pos = gi(),a = find(pos+1),b = find(pos+2); N = gi();
254             for (int i = 1;i <= N;++i) arr[i] = gi();
255             splay(a,0); splay(b,a);
256             ch[b][0] = build(1,N); fa[ch[b][0]] = b;
257             update(b); update(a);
258         }
259         else if (cmd[0] == 'D')
260         {
261             int pos = gi(); N = gi();
262             int a = find(pos),b = find(pos+N+1);
263             splay(a,0); splay(b,a);
264             Delete(ch[b][0]); update(b); update(a);
265         }
266         else if (cmd[0] == 'M' && cmd[2] == 'K')
267         {
268             int pos = gi(); N = gi();
269             int a = find(pos),b = find(pos+N+1);
270             splay(a,0); splay(b,a);
271             key[ch[b][0]] = tag[ch[b][0]] = gi(); sum[ch[b][0]] = tag[ch[b][0]]*size[ch[b][0]];
272             if (tag[ch[b][0]] > 0) lb[ch[b][0]] = rb[ch[b][0]] = wb[ch[b][0]] = sum[ch[b][0]];
273             else lb[ch[b][0]] = rb[ch[b][0]] = wb[ch[b][0]] = tag[ch[b][0]];
274             update(b); update(a);
275         }
276         else if (cmd[0] == 'R')
277         {
278             int pos = gi(); N = gi();
279             int a = find(pos),b = find(pos+N+1);
280             splay(a,0); splay(b,a);
281             rev[ch[b][0]] ^= 1;
282             swap(ch[ch[b][0]][0],ch[ch[b][0]][1]);
283             swap(lb[ch[b][0]],rb[ch[b][0]]);
284             update(b); update(a);
285         }
286         else if (cmd[0] == 'G')
287         {
288             int pos = gi(); N = gi();
289             int a = find(pos),b = find(pos+N+1);
290             splay(a,0); splay(b,a);
291             printf("%d\n",sum[ch[b][0]]);
292         }
293         else
294         {
295             splay(1,0); splay(2,1);
296             printf("%d\n",wb[ch[2][0]]);

```

```
297         }  
298     }  
299     return 0;  
300 }
```

Chapter 4

Graph Theory

4.1 2-Sat

```
1  // bzoj 1823
2  #include<stack>
3  #include<iostream>
4  #include<cstring>
5  #include<cstdio>
6  #include<cstdlib>
7  using namespace std;
8
9  #define maxn 210
10 #define maxm 2010
11 int n,m,cnt,side[maxn],next[maxm],toit[maxm],dfn[maxn],id[maxn];
12 int tot,low[maxn],d[maxn],DFN;
13 stack <int> S; bool vis[maxn];
14
15 inline void init()
16 {
17     DFN = tot = cnt = 0; memset(vis,false,2*(n+4));
18     memset(side,0,8*(n+4)); memset(dfn,0,8*(n+4));
19 }
20
21 inline void add(int a,int b) { next[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
22
23 inline void dfs(int now)
24 {
25     S.push(now); dfn[now] = low[now] = ++DFN;
26     for (int i = side[now];i;i = next[i])
27     {
28         if (vis[toit[i]]) continue;
29         if (!dfn[toit[i]]) dfs(toit[i]);
30         low[now] = min(low[toit[i]],low[now]);
31     }
32     if (low[now] == dfn[now])
33     {
```

```

34         ++tot;
35         while (S.top() != now) id[S.top()] = tot, vis[S.top()] = true, S.pop();
36         id[S.top()] = tot, vis[S.top()] = true, S.pop();
37     }
38 }
39
40 int main()
41 {
42     freopen("1823.in", "r", stdin);
43     freopen("1823.out", "w", stdout);
44     int T; scanf("%d", &T);
45     while (T--)
46     {
47         scanf("%d %d\n", &n, &m);
48         init();
49         while (m--)
50         {
51             char c1, c2; int a, b; bool o1, o2;
52             scanf("%c%d %c%d\n", &c1, &a, &c2, &b);
53             o1 = c1 == 'h'; o2 = c2 == 'h';
54             add((o1^1)*n+a, o2*n+b);
55             add((o2^1)*n+b, o1*n+a);
56         }
57         int i;
58         for (i = 1; i <= n << 1; ++i) if (!dfn[i]) dfs(i);
59         for (i = 1; i <= n; ++i) if (id[i] == id[i+n]) { printf("BAD\n"); break; }
60         if (i <= n) continue;
61         printf("GOOD\n");
62     }
63     fclose(stdin); fclose(stdout);
64     return 0;
65 }

```

4.2 Bridges and Cut Vertices

```

1 // 求割边和割点
2 const int maxn = 200010;
3 int N, M, cnt, Ts, dfn[maxn], low[maxn], nxt[maxn];
4 int toIt[maxn], side[maxn];
5 bool bridge[maxn], cut[maxn];
6
7 inline void dfs(int now, int fa)
8 {
9     dfn[now] = low[now] = ++Ts; int child = 0;
10    for (int i = side[now]; i; i = nxt[i])
11    {
12        if (toIt[i] == fa) continue;
13        if (!dfn[toIt[i]])
14        {

```

```

15         dfs(toit[i],now); ++child;
16         low[now] = min(low[now],low[toit[i]]);
17         if (low[toit[i]] > dfn[now]) bridge[i] = true;
18         if (low[toit[i]] >= dfn[now]) cut[now] = true;
19     }
20     else low[now] = min(low[now],dfn[toit[i]]);
21 }
22 if (!fa&&child == 1) cut[now] = false;
23 }

```

4.3 Cost Flow

```

1  int side[maxv],nxt[maxe],toit[maxe],cost[maxe],pre[maxv];
2  int cap[maxv],arr[maxv],dis[maxv]; bool in[maxv];
3  int source,sink;
4
5  inline void add(int a,int b,int c,int d) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
   ⇐ cap[cnt] = c; cost[cnt] = d; }
6  inline void ins(int a,int b,int c,int d) { add(a,b,c,d); add(b,a,0,-d); }
7
8  inline bool spfa(int &Flow,int &Cost)
9  {
10     queue<int> team; team.push(source);
11     memset(dis,0x7f,4*(sink+5));
12     dis[source] = 0; in[source] = true;
13     arr[source] = inf; arr[sink] = 0;
14     while (!team.empty())
15     {
16         int now = team.front(); team.pop();
17         for (int i = side[now];i;i = nxt[i])
18         {
19             if (!cap[i]) continue;
20             if (dis[toit[i]] > dis[now]+cost[i])
21             {
22                 arr[toit[i]] = min(cap[i],arr[now]); pre[toit[i]] = i;
23                 dis[toit[i]] = dis[now]+cost[i];
24                 if (!in[toit[i]]) in[toit[i]] = true,team.push(toit[i]);
25             }
26         }
27         in[now] = false;
28     }
29     if (!arr[sink]) return false;
30     Flow += arr[sink];
31     for (int now = sink,i;now != source;now = toit[i^1])
32     {
33         i = pre[now]; Cost += cost[pre[now]]*arr[sink];
34         cap[i] -= arr[sink]; cap[i^1] += arr[sink];
35     }
36     return true;

```

```
37 }
```

4.4 Difference Constraints

```
1 // bzoj2330
2 #include<iostream>
3 #include<stack>
4 #include<queue>
5 #include<cstdio>
6 #include<cstdlib>
7 using namespace std;
8
9 #define maxn 100010
10 #define maxm 200010
11 int cnt,side[maxn],next[maxm],toit[maxm],cost[maxm],d[maxn];
12 int nside[maxn],nnext[maxm],ntoit[maxm],ncost[maxm],m,tot;
13 int dfn[maxn],low[maxn],sum[maxn],id[maxn],arr[maxn],n;
14 bool vis[maxn]; stack <int> S;
15
16 inline void add(int a,int b,int c)
17 {
18     next[++cnt] = side[a]; side[a] = cnt;
19     toit[cnt] = b; cost[cnt] = c;
20 }
21
22 inline void ins(int a,int b,int c)
23 {
24     nnext[++cnt] = nside[a]; nside[a] = cnt;
25     ntoit[cnt] = b; ncost[cnt] = c; ++d[b];
26 }
27
28 inline void dfs(int now)
29 {
30     S.push(now); dfn[now] = low[now] = ++cnt;
31     for (int i = side[now];i;i = next[i])
32         if (!vis[toit[i]])
33         {
34             if (!dfn[toit[i]]) dfs(toit[i]);
35             low[now] = min(low[toit[i]],low[now]);
36         }
37     if (low[now] == dfn[now])
38     {
39         ++tot;
40         while (S.top() != now) id[S.top()] = tot,vis[S.top()] = true,S.pop();
41         id[S.top()] = tot,vis[S.top()] = true,S.pop();
42     }
43 }
44
45 inline bool rebuild()
```

```

46 {
47     cnt = 0;
48     for (int i = 1; i <= n; ++i)
49         for (int j = side[i]; j; j = next[j])
50             {
51                 if (id[toit[j]] == id[i]) sum[id[i]] += cost[j];
52                 else ins(id[i], id[toit[j]], cost[j]);
53             }
54     for (int i = 1; i <= tot; ++i) if (sum[i]) return false;
55     return true;
56 }
57
58 inline void topsort()
59 {
60     queue<int> team;
61     for (int i = 1; i <= tot; ++i) if (!d[i]) team.push(i), arr[i] = 1;
62     while (!team.empty())
63     {
64         int now = team.front(); team.pop();
65         for (int i = nside[now]; i; i = nnext[i])
66             {
67                 arr[ntoit[i]] = max(arr[now] + ncost[i], arr[ntoit[i]]);
68                 if (!--d[ntoit[i]]) team.push(ntoit[i]);
69             }
70     }
71 }
72
73 int main()
74 {
75     freopen("2330.in", "r", stdin);
76     freopen("2330.out", "w", stdout);
77     scanf("%d %d", &n, &m);
78     for (int i = 1; i <= m; ++i)
79     {
80         int x, a, b; scanf("%d %d %d", &x, &a, &b);
81         if (x == 1) add(a, b, 0), add(b, a, 0);
82         else if (x == 2) add(a, b, 1);
83         else if (x == 3) add(b, a, 0);
84         else if (x == 4) add(b, a, 1);
85         else add(a, b, 0);
86     }
87     cnt = 0; for (int i = n; i; --i) if (!dfn[i]) dfs(i);
88     if (!rebuild()) printf("-1"), exit(0);
89     topsort();
90     long long ans = 0;
91     for (int i = 1; i <= n; ++i) ans += (long long)arr[id[i]];
92     printf("%lld", ans);
93     fclose(stdin); fclose(stdout);
94     return 0;

```

```
95 }
```

4.5 Dinic Algorithm

```
1  // dinic
2  int source,sink,cnt = 1;
3  int d[maxv],side[maxv],cur[maxv],side[maxe],nxt[maxe],toit[maxe],cap[maxe]; bool in[maxv];
4
5  inline void add(int a,int b,int c) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
   ↪  cap[cnt] = c; }
6  inline void ins(int a,int b,int c) { add(a,b,c); add(b,a,0); }
7
8  inline bool bfs()
9  {
10     queue <int> team; team.push(source); d[source] = 0;
11     memset(in,false,tot+10); in[source] = true; team.push(source);
12     while (!team.empty())
13     {
14         int now = team.front(); team.pop(); cur[now] = side[now];
15         for (int i = side[now];i;i = nxt[i])
16         {
17             if (!cap[i]) continue;
18             if (!in[toit[i]])
19                 in[toit[i]] = true,d[toit[i]] = d[now]+1,team.push(toit[i]);
20         }
21     }
22     return in[sink];
23 }
24
25 inline int dfs(int now,int f)
26 {
27     if (now == sink||!f) return f;
28     int used = 0,w;
29     for (int &i = cur[now];i;i = nxt[i])
30         if (cap[i]&& d[toit[i]] == d[now]+1)
31         {
32             w = dfs(toit[i],min(cap[i],f-used));
33             used += w; cap[i] -= w; cap[i^1] += w;
34             if (used == f) break;
35         }
36     return used;
37 }
38
39 inline int dinic(int S,int T)
40 {
41     source = S; sink = T; int ret = 0;
42     while (bfs()) ret += dfs(source,inf);
43     return ret;
44 }
```


4.6 Dominator Tree

```

1 //建出来的树点的编号 i 在原图中是 redfn[i]
2 int
   ↳ N,M,Ts,cnt,side[maxn],nxt[maxn],toit[maxn],dfn[maxn],redfn[maxn],idom[maxn],best[maxn],semi[maxn];
3 int ans[maxn],anc[maxn],fa[maxn],child[maxn],size[maxn]; vector <int>
   ↳ prod[maxn],bucket[maxn],son[maxn];
4
5 inline void init()
6 {
7     cnt = 1; memset(side,0,sizeof side); memset(ans,0,sizeof ans);
8     for (int i = 0;i <= N;++i) prod[i].clear(),bucket[i].clear(),son[i].clear();
9 }
10
11 inline void add(int a,int b) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
12
13 inline int gi()
14 {
15     char ch; int ret = 0,f = 1;
16     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
17     if (ch == '-') f = -1,ch = getchar();
18     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
19     return ret*f;
20 }
21
22 inline void dfs(int now)
23 {
24     dfn[now] = ++Ts; redfn[Ts] = now;
25     anc[Ts] = idom[Ts] = child[Ts] = size[Ts] = 0;
26     semi[Ts] = best[Ts] = Ts;
27     for (int i = side[now];i;i = nxt[i])
28     {
29         if (!dfn[toit[i]])
30             dfs(toit[i]),fa[dfn[toit[i]]] = dfn[now];
31         prod[dfn[toit[i]]].push_back(dfn[now]);
32     }
33 }
34
35 inline void compress(int now)
36 {
37     if (anc[anc[now]] != 0)
38     {
39         compress(anc[now]);
40         if (semi[best[now]] > semi[best[anc[now]]])
41             best[now] = best[anc[now]];
42         anc[now] = anc[anc[now]];
43     }
44 }
45
46 inline int eval(int now)

```

```

47 {
48     if (!anc[now]) return now;
49     else
50     {
51         compress(now);
52         return semi[best[anc[now]]] >= semi[best[now]] ? best[now] : best[anc[now]];
53     }
54 }
55
56 inline void link(int v, int w)
57 {
58     int s = w;
59     while (semi[best[w]] < semi[best[child[w]]])
60     {
61         if (size[s] + size[child[child[s]]] >= 2 * size[child[s]])
62             anc[child[s]] = s, child[s] = child[child[s]];
63         else size[child[s]] = size[s], s = anc[s] = child[s];
64     }
65     best[s] = best[w]; size[v] += size[w];
66     if (size[v] < 2 * size[w]) swap(s, child[v]);
67     while (s) anc[s] = v, s = child[s];
68 }
69
70 inline void lengauer_tarjan()
71 {
72     memset(dfn, 0, sizeof dfn); memset(fa, -1, sizeof fa); Ts = 0;
73     dfs(N); fa[1] = 0;
74     for (int w = Ts; w > 1; --w)
75     {
76         for (auto x : prod[w])
77         {
78             int u = eval(x);
79             if (semi[w] > semi[u]) semi[w] = semi[u];
80         }
81         bucket[semi[w]].push_back(w);
82         link(fa[w], w); if (!fa[w]) continue;
83         for (auto x : bucket[fa[w]])
84         {
85             int u = eval(x);
86             if (semi[u] < fa[w]) idom[x] = u;
87             else idom[x] = fa[w];
88         }
89         bucket[fa[w]].clear();
90     }
91     for (int w = 2; w <= Ts; ++w)
92         if (idom[w] != semi[w])
93             idom[w] = idom[idom[w]];
94     idom[1] = 0;
95     for (int i = Ts; i > 1; --i)

```

```

96     {
97         if (fa[i] == -1) continue;
98         son[idom[i]].push_back(i);
99     }
100 }
101
102 // 例题: 询问 i 号点到 N 号点所有必经点编号和
103 #include<algorithm>
104 #include<cstring>
105 #include<iostream>
106 #include<cstdio>
107 #include<cstdlib>
108 using namespace std;
109
110 const int maxn = 100010;
111 int
112     ↪ N,M,Ts,cnt,side[maxn],nxt[maxn],toit[maxn],dfn[maxn],redfn[maxn],idom[maxn],best[maxn],semi[maxn];
113 int ans[maxn],anc[maxn],fa[maxn],child[maxn],size[maxn]; vector<int>
114     ↪ prod[maxn],bucket[maxn],son[maxn];
115
116 inline void init()
117 {
118     cnt = 1; memset(side,0,sizeof side); memset(ans,0,sizeof ans);
119     for (int i = 0;i <= N;++i) prod[i].clear(),bucket[i].clear(),son[i].clear();
120 }
121
122 inline void add(int a,int b) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
123
124 inline int gi()
125 {
126     char ch; int ret = 0,f = 1;
127     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
128     if (ch == '-') f = -1,ch = getchar();
129     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
130     return ret*f;
131 }
132
133 inline void dfs(int now)
134 {
135     dfn[now] = ++Ts; redfn[Ts] = now;
136     anc[Ts] = idom[Ts] = child[Ts] = size[Ts] = 0;
137     semi[Ts] = best[Ts] = Ts;
138     for (int i = side[now];i;i = nxt[i])
139     {
140         if (!dfn[toit[i]])
141             dfs(toit[i]),fa[dfn[toit[i]]] = dfn[now];
142         prod[dfn[toit[i]]].push_back(dfn[now]);
143     }
144 }

```

```

143
144 inline void compress(int now)
145 {
146     if (anc[anc[now]] != 0)
147     {
148         compress(anc[now]);
149         if (semi[best[now]] > semi[best[anc[now]]])
150             best[now] = best[anc[now]];
151         anc[now] = anc[anc[now]];
152     }
153 }
154
155 inline int eval(int now)
156 {
157     if (!anc[now]) return now;
158     else
159     {
160         compress(now);
161         return semi[best[anc[now]]] >= semi[best[now]] ? best[now] : best[anc[now]];
162     }
163 }
164
165 inline void link(int v, int w)
166 {
167     int s = w;
168     while (semi[best[w]] < semi[best[child[w]]])
169     {
170         if (size[s] + size[child[child[s]]] >= 2 * size[child[s]])
171             anc[child[s]] = s, child[s] = child[child[s]];
172         else size[child[s]] = size[s], s = anc[s] = child[s];
173     }
174     best[s] = best[w]; size[v] += size[w];
175     if (size[v] < 2 * size[w]) swap(s, child[v]);
176     while (s) anc[s] = v, s = child[s];
177 }
178
179 inline void lengauer_tarjan()
180 {
181     memset(dfn, 0, sizeof dfn); memset(fa, -1, sizeof fa); Ts = 0;
182     dfs(N); fa[1] = 0;
183     for (int w = Ts; w > 1; --w)
184     {
185         for (auto x : prod[w])
186         {
187             int u = eval(x);
188             if (semi[w] > semi[u]) semi[w] = semi[u];
189         }
190         bucket[semi[w]].push_back(w);
191         link(fa[w], w); if (!fa[w]) continue;

```

```

192     for (auto x:bucket[fa[w]])
193     {
194         int u = eval(x);
195         if (semi[u] < fa[w]) idom[x] = u;
196         else idom[x] = fa[w];
197     }
198     bucket[fa[w]].clear();
199 }
200 for (int w = 2; w <= Ts; ++w)
201     if (idom[w] != semi[w])
202         idom[w] = idom[idom[w]];
203 idom[1] = 0;
204 for (int i = Ts; i > 1; --i)
205 {
206     if (fa[i] == -1) continue;
207     son[idom[i]].push_back(i);
208 }
209 }
210
211 inline void get_ans(int now)
212 {
213     ans[redfn[now]] += redfn[now];
214     for (auto x:son[now])
215         ans[redfn[x]] += ans[redfn[now]], get_ans(x);
216 }
217
218 int main()
219 {
220     //freopen("I.in", "r", stdin);
221     while (scanf("%d %d", &N, &M) != EOF)
222     {
223         init();
224         for (int i = 1; i <= M; ++i)
225             a = gi(), b = gi(), add(a, b);
226         lengauer_tarjan(); get_ans(1);
227         for (int i = 1; i <= N; ++i)
228             printf("%d%c", ans[i], "\n"[i == N]);
229     }
230     return 0;
231 }

```

4.7 Hungary

```

1 //匈牙利算法
2 //Version1
3 inline bool find(int x)
4 {
5     if (cor[x]) return false;
6     for (int i = side[x]; i; i = next[i]) if (!used[toit[i]])

```

```

7      {
8          used[toit[i]] = true;
9          if (!cho[toit[i]] || find(cho[toit[i]]))
10             {
11                 cho[toit[i]] = x; map[x] = toit[i];
12                 return true;
13             }
14     }
15     return false;
16 }
17
18 inline void hungry()
19 {
20     for (int i = 1; i <= p; ++i)
21         memset(used, false, sizeof(used)), find(i);
22     for (int i = 1; i <= m; ++i)
23     {
24         memset(used, false, sizeof(used)), cho[map[i]] = 0;
25         find(i), cor[i] = true;
26     }
27 }
28 //Version2
29 inline int find(int x)
30 {
31     for (int i = 1; i <= n; ++i)
32         if (f[x][i] && !used[i])
33             {
34                 used[i] = true;
35                 if (!cho[i] || find(cho[i])) { cho[i] = x; return true; }
36             }
37     return false;
38 }
39
40 inline int hungry()
41 {
42     int ret = 0;
43     for (int i = 1; i <= n; ++i)
44     {
45         memset(used, false, sizeof(used));
46         if (find(i)) ret++;
47     }
48     return ret;
49 }

```

4.8 Isap Algorithm

```

1 // isap: 有毒
2 inline void bfs()
3 {

```

```

4     queue <int> team; memcpy(cur,side,4*(N+1));
5     team.push(sink); d[sink] = 1; in[sink] = true;
6     while (!team.empty())
7     {
8         int now = team.front(); team.pop(); nd[d[now]]++;
9         for (int i = side[now];i;i = nxt[i])
10            if (cap[i^1] && !in[toit[i]])
11                in[toit[i]] = true,d[toit[i]] = d[now]+1,team.push(toit[i]);
12    }
13    for (int i = 1;i <= N;++i) if (!in[i]) nd[d[i] = N+1]++;
14 }
15 inline int isap()
16 {
17     int res = 0,now = source,ca = inf;
18     bfs();
19     while (d[source] <= N)
20     {
21         if (now == sink)
22         {
23             while (now != source)
24             {
25                 cap[pre[now]] -= ca; cap[pre[now]^1] += ca;
26                 now = toit[pre[now]^1];
27             }
28             res += ca; ca = inf;
29         }
30         bool flag = false; arr[now] = ca;
31         for (int i = cur[now];i;i = nxt[i])
32             if (cap[i]&&d[toit[i]]==d[now]-1)
33             {
34                 cur[now] = pre[toit[i]] = i; ca = min(ca,cap[i]);
35                 now = toit[i]; flag = true; break;
36             }
37         if (flag) continue; if (!--nd[d[now]]) break; int arg = N;
38         for (int i = side[now];i;i = nxt[i])
39             if (cap[i]&&d[toit[i]] < arg) arg = d[toit[i]];
40         ++nd[d[now]=arg+1]; cur[now] = side[now];
41         if (now != source) ca = arr[now = toit[pre[now]^1]];
42     }
43     return res;
44 }
45
46 int source;          // 源点
47 int sink;            // 汇点
48 int p[max_nodes];    // 可增广路上的上一条弧的编号
49 int num[max_nodes];  // 和 t 的最短距离等于 i 的节点数量
50 int cur[max_nodes];  // 当前弧下标
51 int d[max_nodes];    // 残量网络中节点 i 到汇点 t 的最短距离
52 bool visited[max_nodes];

```

```

53
54 // 预处理, 反向 BFS 构造 d 数组
55 bool bfs()
56 {
57     memset(visited, 0, sizeof(visited));
58     queue<int> Q;
59     Q.push(sink);
60     visited[sink] = 1;
61     d[sink] = 0;
62     while (!Q.empty()) {
63         int u = Q.front();
64         Q.pop();
65         for (iterator_t ix = G[u].begin(); ix != G[u].end(); ++ix) {
66             Edge &e = edges[*ix]^1;
67             if (!visited[e.from] && e.capacity > e.flow) {
68                 visited[e.from] = true;
69                 d[e.from] = d[u] + 1;
70                 Q.push(e.from);
71             }
72         }
73     }
74     return visited[source];
75 }
76
77 // 增广
78 int augment()
79 {
80     int u = sink, df = __inf;
81     // 从汇点到源点通过 p 追踪增广路径, df 为一路上最小的残量
82     while (u != source) {
83         Edge &e = edges[p[u]];
84         df = min(df, e.capacity - e.flow);
85         u = edges[p[u]].from;
86     }
87     u = sink;
88     // 从汇点到源点更新流量
89     while (u != source) {
90         edges[p[u]].flow += df;
91         edges[p[u]^1].flow -= df;
92         u = edges[p[u]].from;
93     }
94     return df;
95 }
96
97 int max_flow()
98 {
99     int flow = 0;
100     bfs();
101     memset(num, 0, sizeof(num));

```



```

102     for (int i = 0; i < num_nodes; i++) num[d[i]]++;
103     int u = source;
104     memset(cur, 0, sizeof(cur));
105     while (d[source] < num_nodes) {
106         if (u == sink) {
107             flow += augment();
108             u = source;
109         }
110         bool advanced = false;
111         for (int i = cur[u]; i < G[u].size(); i++) {
112             Edge& e = edges[G[u][i]];
113             if (e.capacity > e.flow && d[u] == d[e.to] + 1) {
114                 advanced = true;
115                 p[e.to] = G[u][i];
116                 cur[u] = i;
117                 u = e.to;
118                 break;
119             }
120         }
121         if (!advanced) { // retreat
122             int m = num_nodes - 1;
123             for (iterator_t ix = G[u].begin(); ix != G[u].end(); ++ix)
124                 if (edges[*ix].capacity > edges[*ix].flow)
125                     m = min(m, d[edges[*ix].to]);
126             if (--num[d[u]] == 0) break; // gap 优化
127             num[d[u] = m+1]++;
128             cur[u] = 0;
129             if (u != source)
130                 u = edges[p[u]].from;
131         }
132     }
133     return flow;
134 }
135 //By mxh
136 #define maxn 1010
137 const int INF=1<<30;
138 int n,m;
139 int S,T;
140 struct Edge
141 {
142     int v,flow,next;
143 } e[510010];
144 int g[maxn],tot=1;//tot 初值必须赋为 1
145 void addedge(int x,int y,int flow)
146 {
147     e[++tot].v=y;e[tot].flow=flow;e[tot].next=g[x];g[x]=tot;
148     e[++tot].v=x;e[tot].flow=0;e[tot].next=g[y];g[y]=tot;
149 }
150 int w[maxn],hash[maxn],d[maxn];

```



```

200         flow=INF;
201     }
202     break;
203 }
204 if (!bo) continue;
205 int minx=n,pos=0;
206 for (int i=g[u];i;i=e[i].next)
207     if (e[i].flow && d[e[i].v]<minx) minx=d[e[i].v],pos=i;
208 p[u]=pos;
209 hash[d[u]]--;
210 if (hash[d[u]]==0) break;
211 d[u]=minx+1;
212 hash[d[u]]++;
213 if (u!=S) u=prel[u],flow=w[u];
214 }
215 return ans;
216 }

```

4.9 Kuhn-Munkres Algorithm

```

1 // Truly  $O(n^3)$ , 最大权匹配
2 // 邻接矩阵, 不能连的边设为  $-INF$ , 求最小权匹配时边权取负, 但不能连的还是  $-INF$ , 使用时先对  $1 \rightarrow n$  调用 hungary(), 再
3 struct KM
4 {
5     int w[maxn][maxn],lx[maxn],ly[maxn],match[maxn],way[maxn],slack[maxn];
6     bool used[maxn];
7
8     inline void init()
9     {
10         for (int i = 1;i <= N;++i)
11             match[i] = lx[i] = ly[i] = way[i] = 0;
12     }
13
14     inline void hungary(int x)
15     {
16         match[0] = x; int j0 = 0;
17         for (int j = 0;j <= N;++j)
18             slack[j] = inf,used[j] = false;
19         do
20         {
21             used[j0] = true;
22             int i0 = match[j0],delta = inf,j1 = 0;
23             for (int j = 1;j <= N;++j)
24                 if (!used[j])
25                 {
26                     int cur = -w[i0][j]-lx[i0]-ly[j];
27                     if (cur < slack[j])
28                         slack[j] = cur,way[j] = j0;
29                     if (slack[j] < delta)

```

```

30         delta = slack[j], j1 = j;
31     }
32     for (int j = 0; j <= N; ++j)
33     {
34         if (used[j]) lx[match[j]] += delta, ly[j] -= delta;
35         else slack[j] -= delta;
36     }
37     j0 = j1;
38 }
39 while (match[j0]);
40 do
41 {
42     int j1 = way[j0];
43     match[j0] = match[j1];
44     j0 = j1;
45 }
46 while (j0);
47 }
48
49 inline void work() { for (int i = 1; i <= N; ++i) hungary(i); }
50
51 inline int get_ans()
52 {
53     int sum = 0;
54     for (int i = 1; i <= N; ++i)
55     {
56         // if (w[match[i]][i] == -inf) ; //无解
57         if (match[i] > 0) sum += w[match[i]][i];
58     }
59     return sum;
60 }
61 }km;
62 //最小权匹配
63 struct KM
64 {
65     int w[maxn][maxn], lx[maxn], ly[maxn], match[maxn], way[maxn], slack[maxn]; bool used[maxn];
66
67     inline void init()
68     {
69         for (int i = 1; i <= N; ++i)
70             match[i] = lx[i] = ly[i] = way[i] = 0;
71     }
72
73     inline void hungary(int x)
74     {
75         match[0] = x; int j0 = 0;
76         for (int j = 0; j <= N; ++j)
77             slack[j] = -inf, used[j] = false;
78         do

```

```

79     {
80         used[j0] = true;
81         int i0 = match[j0], delta = -inf, j1 = 0;
82         for (int j = 1; j <= N; ++j)
83             if (!used[j])
84                 {
85                     int cur = -w[i0][j] - lx[i0] - ly[j];
86                     if (cur > slack[j]) slack[j] = cur, way[j] = j0;
87                     if (slack[j] > delta) delta = slack[j], j1 = j;
88                 }
89         for (int j = 0; j <= N; ++j)
90             {
91                 if (used[j]) lx[match[j]] += delta, ly[j] -= delta;
92                 else slack[j] -= delta;
93             }
94         j0 = j1;
95     }
96     while (match[j0]);
97     do
98     {
99         int j1 = way[j0];
100         match[j0] = match[j1];
101         j0 = j1;
102     }
103     while (j0);
104 }
105
106 inline void work() { for (int i = 1; i <= N; ++i) hungary(i); }
107
108 inline int get_ans()
109 {
110     int sum = 0;
111     for (int i = 1; i <= N; ++i)
112     {
113         // if (w[match[i]][i] == inf) ; // 无解
114         if (match[i] > 0) sum += w[match[i]][i];
115     }
116     return sum;
117 }
118 }km;

```

4.10 Maximal Matching in General Graphs

```

1 // 接口 int matching(), 返回最大匹配数, G 为邻接矩阵
2 inline void push(int x)
3 {
4     team.push(x); check[x] = true;
5     if (!treec[x]) tra[++cnt] = x, treec[x] = true;
6 }

```

```

7  inline int root(int x) { return f[x]?f[x] = root(f[x]):x; }
8
9  inline void clear()
10 {
11     for (int i = 1,j;i <= cnt;++i)
12     {
13         j = tra[i]; father[j] = 0,f[j] = 0;
14         check[j] = treec[j] = false;
15     }
16 }
17
18 inline int lca(int u,int v)
19 {
20     int len = 0;
21     for (;u;u = father[match[u]])
22         pathc[path[++len] = u = root(u)] = true;
23     for (;v = father[match[v]])
24         if (pathc[v = root(v)]) break;
25     for (int i = 1;i <= len;++i)
26         pathc[path[i]] = false;
27     return v;
28 }
29
30 inline void reset(int u,int p)
31 {
32     for (int v;root(u) != p;)
33     {
34         if (!check[v = match[u]]) push(v);
35         if (!f[u]) f[u] = p; if (!f[v]) f[v] = p;
36         u = father[v]; if (root(u) != p) father[u] = v;
37     }
38 }
39
40 inline void flower(int u,int v)
41 {
42     int p = lca(u,v);
43     if (root(u) != p) father[u] = v;
44     if (root(v) != p) father[v] = u;
45     reset(u,p); reset(v,p);
46 }
47
48 inline bool find(int x)
49 {
50     while (!team.empty()) team.pop();
51     cnt = 0; push(x);
52     while (!team.empty())
53     {
54         int i = team.front(); team.pop();
55         for (int j = 1;j <= N;++j)

```

```

56         if (G[i][j]&&root(i) != root(j)&&match[j] != i)
57         {
58             if (match[j]&&father[match[j]]) flower(i,j);
59             else if (!father[j])
60             {
61                 father[tra[++cnt] = j] = i; treec[j] = true;
62                 if (match[j]) push(match[j]);
63                 else
64                 {
65                     for (int k = i,l = j,p;k;l = p,k = father[l])
66                         p = match[k],match[k] = l,match[l] = k;
67                     return true;
68                 }
69             }
70         }
71     }
72     return false;
73 }
74
75 inline int matching()
76 {
77     memset(father,0,sizeof father); memset(f,0,sizeof f); memset(path,0,sizeof path);
78     memset(tra,0,sizeof tra); memset(match,0,sizeof match); memset(check,false,sizeof check);
79     memset(treec,false,sizeof treec); memset(pathc,false,sizeof pathc);
80     int ret = cnt = 0;
81     for (int i = 1;i <= N;++i)
82     {
83         if (match[i]) continue;
84         if (find(i)) ++ret; clear();
85     }
86     return ret;
87 }

```

4.11 Maximal Weighted Matching in General Graphs

```

1  // 接口 int matching(), 返回最大匹配数,G 为邻接矩阵
2  inline void push(int x)
3  {
4      team.push(x); check[x] = true;
5      if (!treec[x]) tra[++cnt] = x,treec[x] = true;
6  }
7  inline int root(int x) { return f[x]?f[x] = root(f[x]):x; }
8
9  inline void clear()
10 {
11     for (int i = 1,j;i <= cnt;++i)
12     {
13         j = tra[i]; father[j] = 0,f[j] = 0;
14         check[j] = treec[j] = false;

```

```

15     }
16 }
17
18 inline int lca(int u,int v)
19 {
20     int len = 0;
21     for (;u;u = father[match[u]])
22         pathc[path[++len] = u = root(u)] = true;
23     for (;v = father[match[v]])
24         if (pathc[v = root(v)]) break;
25     for (int i = 1;i <= len;++i)
26         pathc[path[i]] = false;
27     return v;
28 }
29
30 inline void reset(int u,int p)
31 {
32     for (int v;root(u) != p;)
33     {
34         if (!check[v = match[u]]) push(v);
35         if (!f[u]) f[u] = p; if (!f[v]) f[v] = p;
36         u = father[v]; if (root(u) != p) father[u] = v;
37     }
38 }
39
40 inline void flower(int u,int v)
41 {
42     int p = lca(u,v);
43     if (root(u) != p) father[u] = v;
44     if (root(v) != p) father[v] = u;
45     reset(u,p); reset(v,p);
46 }
47
48 inline bool find(int x)
49 {
50     while (!team.empty()) team.pop();
51     cnt = 0; push(x);
52     while (!team.empty())
53     {
54         int i = team.front(); team.pop();
55         for (int j = 1;j <= N;++j)
56             if (G[i][j]&&root(i) != root(j)&&match[j] != i)
57             {
58                 if (match[j]&&father[match[j]]) flower(i,j);
59                 else if (!father[j])
60                 {
61                     father[tra[++cnt] = j] = i; treec[j] = true;
62                     if (match[j]) push(match[j]);
63                     else

```



```

64         {
65             for (int k = i, l = j, p; k; l = p, k = father[l])
66                 p = match[k], match[k] = l, match[l] = k;
67             return true;
68         }
69     }
70 }
71 }
72 return false;
73 }
74
75 inline int matching()
76 {
77     memset(father, 0, sizeof father); memset(f, 0, sizeof f); memset(path, 0, sizeof path);
78     memset(tra, 0, sizeof tra); memset(match, 0, sizeof match); memset(check, false, sizeof check);
79     memset(treec, false, sizeof treec); memset(pathc, false, sizeof pathc);
80     int ret = cnt = 0;
81     for (int i = 1; i <= N; ++i)
82     {
83         if (match[i]) continue;
84         if (find(i)) ++ret; clear();
85     }
86     return ret;
87 }

```

4.12 Maximum Cardinality Search

```

1  // BZOJ 1006
2  #include <algorithm>
3  #include <queue>
4  #include <cstdio>
5  #include <cstdlib>
6  #include <set>
7  using namespace std;
8
9  #define maxn 10010
10 #define maxc 510
11 #define maxm 1000010
12 int tot, n, m, cnt, color[maxn][maxc], label[maxn], all;
13 int side[maxn], next[maxm*2], toid[maxm*2], per[maxn];
14 bool in[maxn];
15 struct node
16 {
17     int key, ord;
18     friend bool operator < (node a, node b) {return a.key > b.key; }
19 };
20 multiset <node> S;
21
22 inline void add(int a, int b)

```

```

23 {
24     next[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
25 }
26
27 inline void ins(int a,int b){add(a,b); add(b,a);}
28
29 inline void mcs()
30 {
31     int i,u;
32     for (i = 1;i <= n;++i) S.insert((node){0,i});
33     while (all < n)
34     {
35         u = (*S.begin()).ord; S.erase(S.begin()); if (in[u]) continue;
36         in[u] = true; per[++all] = u;
37         for (i = side[u];i;i = next[i])
38             if (!in[toit[i]])
39             {
40                 label[toit[i]]++;
41                 S.insert((node){label[toit[i]],toit[i]});
42             }
43     }
44 }
45
46 inline void paint()
47 {
48     int p,i,j,t;
49     for (p = 1;p <= n;++p)
50     {
51         i = per[p];
52         for (j = 1;j <= tot;++j)
53             if (!color[i][j]) {t = j; break; }
54         if (j == tot + 1) t = ++tot;
55         for (j = side[i];j;j = next[j])
56             color[toit[j]][t] = true;
57     }
58 }
59
60 int main()
61 {
62     freopen("1006.in","r",stdin);
63     freopen("1006.out","w",stdout);
64     scanf("%d %d",&n,&m);
65     for (int i = 1;i <= m;++i)
66     { int a,b; scanf("%d %d",&a,&b); ins(a,b); }
67     mcs();
68     paint();
69     printf("%d",tot);
70     fclose(stdin); fclose(stdout);
71     return 0;

```

72 }

4.13 Network Flow with Lower Bound

1. 无源汇有上下界可行流

设原来源点为 *Source*，汇点是 *Sink*。新建一个超级源 *SuperSource* 和超级汇 *SuperSink*。对于原网络中的每一条边 $u \rightarrow v$ ，上界 U ，下界 L ，将它拆分为三条边：

- (1) $u \rightarrow \text{SuperSink}$ ，容量为 L 。
- (2) $\text{SuperSource} \rightarrow v$ ，容量为 L 。
- (3) $u \rightarrow v$ ，容量为 $U - L$ 。

最后添加边 $\text{Sink} \rightarrow \text{Source}$ ，容量为 $+\infty$ 。在新建的网络上，计算从 *SuperSource* 到 *SuperSink* 的最大流。若每条从 *SuperSource* 发出的边都满流，说明存在可行流，否则不。每条边实际流量为容量下界 + 附加流中它的流量。

2. 有源汇有上下界可行流

在“无源汇有上下界可行流”建图上，新增一条 $\text{Sink} \rightarrow \text{Source}$ 的边，容量为 $+\infty$ 即可。

3. 有源汇有上下界最大流

在“有源汇有上下界可行流”建图上，先判断是否存在可行流，若存在可行流，拆掉 $\text{Sink} \rightarrow \text{Source}$ 的边后，接着在图中 $\text{Source} \rightarrow \text{Sink}$ 最大流增广加上原可行流即为最大流答案。（若存在可行流，去掉下界后最大流即为原图有源汇有上下界最大流）

4. 有源汇有上下界最小流

在“有源汇有上下界可行流”建图上，先判断是否存在可行流，若存在可行流，拆掉 $\text{Sink} \rightarrow \text{Source}$ 的边后，用可行流减去在图中 $\text{Sink} \rightarrow \text{Source}$ 增广的最大流即为最小流答案。

在实现时，可以吧 *SuperSource* 连向同一节点的多条边合成一条（容量合并。从同一节点指向 *SuperSink* 的多条边也应合并）。

对于费用流，只需要改变将网络流算法改成费用流算法。对于原网络中的每一条边 $u \rightarrow v$ ，上界 U ，下界 L ，费用 c ，将它拆分为三条边：

- (1) $u \rightarrow \text{SuperSink}$ ，容量为 L ，费用 c 。
- (2) $\text{SuperSource} \rightarrow v$ ，容量为 L ，费用 0 。
- (3) $u \rightarrow v$ ，容量为 $U - L$ ，费用 c 。

4.14 Point Biconnected Component

```

1 // Source: HackerRank - bonnie-and-clyde
2 #include<algorithm>
3 #include<vector>
4 #include<stack>
5 #include<iostream>
6 #include<cstdio>

```

```

7  #include<cstdlib>
8  using namespace std;
9
10 const int maxn = 400010;
11 int N,M,Q,cnt = 1,side[maxn],toit[maxn],nxt[maxn],f[maxn][25],father[maxn],low[maxn];
12 int tot,dep[maxn],dfn[maxn],nside[maxn],ntoit[maxn],nnxt[maxn]; bool cut[maxn];
13 stack <int> S; vector <int> bel[maxn],bcc[maxn]; bool vis[maxn];
14
15 inline int find(int a) { if (father[a] != a) father[a] = find(father[a]); return father[a]; }
16
17 inline void add(int a,int b) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b; }
18 inline void ins(int a,int b) { add(a,b); add(b,a); }
19 inline void nadd(int a,int b) { nnxt[++cnt] = nside[a]; nside[a] = cnt; ntoit[cnt] = b; }
20 inline void nins(int a,int b) { nadd(a,b); nadd(b,a); }
21
22 inline int gi()
23 {
24     char ch; int ret = 0,f = 1;
25     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
26     if (ch == '-') f = -1, ch = getchar();
27     do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
28     return ret*f;
29 }
30
31 inline void tj(int now,int fa)
32 {
33     dfn[now] = low[now] = ++cnt; int child = 0;
34     for (int i = side[now]; i; i = nxt[i])
35     {
36         if (toit[i] == fa) continue;
37         if (!dfn[toit[i]])
38         {
39             S.push(i>>1); tj(toit[i],now); ++child;
40             low[now] = min(low[now],low[toit[i]]);
41             if (low[toit[i]] >= dfn[now])
42             {
43                 cut[now] = true; ++tot;
44                 while (true)
45                 {
46                     int t = S.top(); S.pop();
47                     bel[toit[t<<1]].push_back(tot); bel[toit[t<<1|1]].push_back(tot);
48                     bcc[tot].push_back(toit[t<<1]); bcc[tot].push_back(toit[t<<1|1]);
49                     if (t == (i>>1)) break;
50                 }
51             }
52         }
53         else low[now] = min(low[now],dfn[toit[i]]);
54     }
55     if (!fa && child == 1) cut[now] = false;

```

```

56 }
57
58 inline void build()
59 {
60     vector<int> cuts; cnt = 1;
61     for (int i = 1; i <= tot; ++i)
62     {
63         sort(bcc[i].begin(), bcc[i].end());
64         bcc[i].erase(unique(bcc[i].begin(), bcc[i].end()), bcc[i].end());
65     }
66     for (int i = 1; i <= N; ++i) if (cut[i]) cuts.push_back(i);
67     for (auto x: cuts)
68     {
69         sort(bel[x].begin(), bel[x].end());
70         bel[x].erase(unique(bel[x].begin(), bel[x].end()), bel[x].end());
71         ++tot; for (auto y: bel[x]) nins(tot, y);
72         bel[x].clear(); bel[x].push_back(tot); bcc[tot].push_back(x);
73     }
74 }
75
76 inline void dfs(int now)
77 {
78     vis[now] = true;
79     for (int i = 1; (1<<i) <= dep[now]; ++i) f[now][i] = f[f[now][i-1]][i-1];
80     for (int i = nside[now]; i; i = nnxt[i])
81     {
82         if (vis[ntoit[i]]) continue; f[ntoit[i]][0] = now;
83         dep[ntoit[i]] = dep[now] + 1; dfs(ntoit[i]);
84     }
85 }
86
87 inline int jump(int a, int b) { for (int i = 0; b; ++i, b >>= 1) if (b&1) a = f[a][i]; return a; }
88 inline int lca(int a, int b)
89 {
90     if (dep[a] < dep[b]) swap(a, b);
91     a = jump(a, dep[a] - dep[b]); if (a == b) return a;
92     for (int i = 0; i >= 0; )
93     {
94         if (f[a][i] != f[b][i]) a = f[a][i], b = f[b][i], ++i;
95         else --i;
96     }
97     return f[a][0];
98 }
99
100 inline bool check(int u, int v, int w)
101 {
102     if (find(u) != find(v) || find(v) != find(w)) return false;
103     if (u == w || v == w) return true; if (u == v) return false;
104     int uu = bel[u][0], vv = bel[v][0], ww = bel[w][0], su, sv;

```

```

105     if (uu == ww || vv == ww) return true;
106     if (lca(uu,ww) == ww) su = jump(uu,dep[uu]-dep[ww]-1); else su = f[ww][0];
107     if (lca(vv,ww) == ww) sv = jump(vv,dep[vv]-dep[ww]-1); else sv = f[ww][0];
108     if (su == sv)
109     {
110         if (!cut[w]) return false;
111         else
112         {
113             if (su == uu || sv == vv) return true; int ssu,ssv;
114             if (lca(su,uu) == su) ssu = jump(uu,dep[uu]-dep[su]-1); else ssu = f[su][0];
115             if (lca(sv,vv) == sv) ssv = jump(vv,dep[vv]-dep[sv]-1); else ssv = f[sv][0];
116             if (ssu == ssv) return false; else return true;
117         }
118     }
119     else return true;
120 }
121
122 int main()
123 {
124     freopen("J.in","r",stdin);
125     freopen("J.out","w",stdout);
126     N = gi(); M = gi(); Q = gi();
127     for (int i = 1;i <= N;++i) father[i] = i;
128     for (int i = 1,a,b;i <= M;++i)
129     {
130         ins(a = gi(),b = gi());
131         a = find(a),b = find(b);
132         if (a != b) father[a] = b;
133     }
134     cnt = 0; for (int i = 1;i <= N;++i) if (!dfn[i]) tj(i,0);
135     build(); for (int i = 1;i <= N;++i) if (!vis[i]) dfs(i);
136     while (Q--)
137     {
138         int u = gi(),v = gi(),w = gi();
139         if (check(u,v,w)) puts("YES"); else puts("NO");
140     }
141     return 0;
142 }

```

4.15 Steiner Tree

```

1  /*
2  *  Steiner Tree: 求,使得指定 K 个点连通的生成树的最小总权值
3  *  st[i] 表示顶点 i 的标记值,如果 i 是指定集合内第 m(0<=m<K) 个点,则 st[i]=1<<m
4  *  endSt=1<<K
5  *  dptree[i][state] 表示以 i 为根,连通状态为 state 的生成树值
6  */
7  inline void update(int &x,int y) { if (x == -1) x = y; else if (x > y) x = y; }
8  inline void spfa(int state)

```

```

9  {
10     while (!team.empty())
11     {
12         int now = team.front(); team.pop();
13         for (int i = side[now]; i; i = nxt[i])
14         {
15             int v = toit[i];
16             if (f[v][st[v]|state] == -1 || f[v][st[v]|state] > f[now][state]+len[i])
17             {
18                 f[v][st[v]|state] = f[now][state]+len[i];
19                 if ((st[v]|state) != state || vis[v][state]) continue;
20                 vis[v][state] = true; team.push(v);
21             }
22         }
23         vis[now][state] = false;
24     }
25 }
26 inline int work()
27 {
28     endSt = 1<<(K<<1);
29     memset(f,-1,sizeof(f)); memset(st,0,sizeof(st)); memset(dp,-1,sizeof(dp));
30     memset(vis,false,sizeof(vis)); memset(side,0,sizeof(side));
31     for (int i = 1; i <= K; ++i) st[i] = 1<<(i-1);
32     for (int i = 1; i <= K; ++i) st[N-K+i] = 1<<(i+K-1);
33     for (int i = 1; i <= N; ++i) f[i][st[i]] = 0;
34     for (int j = 1; j < endSt; ++j)
35     {
36         for (int i = 1; i <= N; ++i)
37         {
38             if (!st[i] || (st[i]&j))
39                 for (int sub = (j-1)&j; sub; sub = (sub-1)&j)
40                 {
41                     int x = sub|st[i], y = (j-sub)|st[i];
42                     if (f[i][x] != -1 && f[i][y] != -1)
43                         update(f[i][j], f[i][x]+f[i][y]);
44                 }
45             if (f[i][j] != -1) team.push(i), vis[i][j] = true;
46         }
47         spfa(j);
48     }
49 }

```

4.16 Stoer Wagner Algorithm

```

1  int G[maxn][maxn], node[maxn], dis[maxn]; bool visit[maxn];
2
3  inline int solve(int n)
4  {
5      if (n == 1) return inf;

```

```

6     int answer = inf;
7     for (int i = 0; i < n; ++i) node[i] = i;
8     while (n > 1)
9     {
10        int mx = 1;
11        for (int i = 0; i < n; ++i)
12        {
13            dis[node[i]] = G[node[0]][node[i]];
14            if (dis[node[i]] > dis[node[mx]]) mx = i;
15        }
16        int prev = 0;
17        memset(visit, false, sizeof visit);
18        visit[node[0]] = true;
19        for (int i = 1; i < n; ++i)
20        {
21            if (i == n-1)
22            {
23                answer = min(answer, dis[node[mx]]);
24                for (int k = 0; k < n; ++k)
25                    G[node[k]][node[prev]] = (G[node[prev]][node[k]] += G[node[k]][node[mx]]);
26                node[mx] = node[--n];
27            }
28            visit[node[mx]] = true; prev = mx; mx = -1;
29            for (int j = 1; j < n; ++j)
30                if (!visit[node[j]])
31                {
32                    dis[node[j]] += G[node[prev]][node[j]];
33                    if (mx == -1 || dis[node[mx]] < dis[node[j]]) mx = j;
34                }
35        }
36    }
37    return answer;
38 }

```

4.17 Strongly Connected Component

```

1  int dfn[maxn], low[maxn], timestamp;
2  stack <int> stk; vector <int> scc[maxn];
3  void tarjan(int now)
4  {
5      dfn[now] = low[now] = ++timestamp;
6      stk.push(now);
7      for (int i = side[now]; i; i = nxt[i])
8      {
9          if (!dfn[toit[i]])
10             tarjan(toit[i]), low[now] = min(low[now], low[toit[i]]);
11          else if (!bel[toit[i]]) low[now] = min(low[now], dfn[toit[i]]);
12      }
13      if (dfn[now] == low[now])

```



```

14     {
15         ++tot;
16         while (stk.top() != now)
17         {
18             scc[tot].push_back(stk.top());
19             bel[stk.top()] = tot; stk.pop();
20         }
21         scc[tot].push_back(stk.top());
22         bel[stk.top()] = tot; stk.pop();
23     }
24 }

```

4.18 Virtual Tree

```

1  int N,cnt,timestamp,dfn[maxn],f[maxn][25],side[maxn],H[maxn];
2  int dep[maxn],toit[maxn],nxt[maxn],last[maxn],cost[maxn],stk[maxn];
3  ll best[maxn],g[maxn];
4
5  inline void add(int a,int b,int c) { nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
   ⇨ cost[cnt] = c; }
6  inline void ins(int a,int b,int c) { add(a,b,c); add(b,a,c); }
7
8  inline void nadd(int a,int b,int idc)
9  {
10     if (a == b) return;
11     if (last[a] != idc) side[a] = 0,last[a] = idc;
12     if (last[b] != idc) side[b] = 0,last[b] = idc;
13     nxt[++cnt] = side[a]; side[a] = cnt; toit[cnt] = b;
14 }
15
16 inline bool cmp(int a,int b) { return dfn[a] < dfn[b]; }
17
18 inline void dfs(int now)
19 {
20     dfn[now] = ++timestamp;
21     for (int i = 1;(1<<i) <= dep[now];++i)
22         f[now][i] = f[f[now][i-1]][i-1];
23     for (int i = side[now];i;i = nxt[i])
24         if (toit[i] != f[now][0])
25         {
26             best[toit[i]] = min(best[now],(ll)cost[i]);
27             dep[toit[i]] = dep[now]+1;
28             f[toit[i]][0] = now; dfs(toit[i]);
29         }
30 }
31
32 inline int jump(int a,int step) { for (int i = 0;step;step >>= 1,++i) if (step&1) a = f[a][i];
   ⇨ return a; }
33 inline int lca(int a,int b)

```

```

34 {
35     if (dep[a] < dep[b]) swap(a,b);
36     a = jump(a,dep[a]-dep[b]);
37     if (a == b) return a;
38     for (int i = 0; i >= 0;)
39     {
40         if (f[a][i] != f[b][i])
41             a = f[a][i], b = f[b][i], ++i;
42         else --i;
43     }
44     return f[a][0];
45 }
46
47 inline void work(int idc)
48 {
49     cnt = 0; int K = gi(), tot, top;
50     for (int i = 1; i <= K; ++i) H[i] = gi();
51     sort(H+1, H+K+1, cmp); H[tot = 1] = H[1];
52     for (int i = 2; i <= K; ++i) if (lca(H[tot], H[i]) != H[tot]) H[++tot] = H[i];
53     stk[top = 1] = 1;
54     for (int i = 1; i <= tot; ++i)
55     {
56         int ans = lca(H[i], stk[top]);
57         while (true)
58         {
59             if (dep[ans] >= dep[stk[top-1]]) { nadd(ans, stk[top--], idc); break; }
60             nadd(stk[top-1], stk[top], idc); --top;
61         }
62         if (stk[top] != ans) stk[++top] = ans;
63         if (stk[top] != H[i]) stk[++top] = H[i];
64     }
65     while (--top) nadd(stk[top], stk[top+1], idc);
66     // dp(1); printf("%lld\n", g[1]);
67 }

```

4.19 Zhu-Liu Algorithm

```

1 struct Directed_MT
2 {
3     struct Edge
4     {
5         int u, v, w;
6         inline Edge() = default;
7         inline Edge(int _u, int _v, int _w) : u(_u), v(_v), w(_w) {}
8     };
9     int n, m, vis[maxn], pre[maxn], id[maxn], in[maxn]; Edge edges[maxn];
10
11     inline void init(int _n) { n = _n; m = 0; }
12     inline void AddEdge(int u, int v, int w) { edges[m++] = Edge(u, v, w); }

```

```

13     inline int work(int root)
14     {
15         int ret = 0;
16         while (true)
17         {
18             // 初始化
19             for (int i = 0; i < n; ++i) in[i] = inf+1;
20             for (int i = 0; i < m; ++i)
21             {
22                 int u = edges[i].u, v = edges[i].v;
23                 // 找寻最小入边, 删除自环
24                 if (edges[i].w < in[v] && u != v)
25                     in[v] = edges[i].w, pre[v] = u;
26             }
27             // 如果没有最小入边, 表示该点不连通, 则最小树形图形成失败
28             for (int i = 0; i < n; ++i)
29             {
30                 if (i == root) continue;
31                 if (in[i] == inf+1) return inf;
32             }
33             int cnt = 0; // 记录缩点
34             memset(id, -1, sizeof id); memset(vis, -1, sizeof vis);
35             in[root] = 0;
36             for (int i = 0; i < n; ++i)
37             {
38                 ret += in[i]; int v = i;
39                 // 找寻自环
40                 while (vis[v] != i && id[v] == -1 && v != root)
41                     vis[v] = i, v = pre[v];
42                 if (v != root && id[v] == -1)
43                 {
44                     // 这里不能从 i 开始找, 因为 i 有可能不在自环内
45                     for (int u = pre[v]; u != v; u = pre[u]) id[u] = cnt;
46                     id[v] = cnt++;
47                 }
48             }
49             // 如果没有自环了, 表示最小树形图成功了
50             if (!cnt) break;
51             // 找到那些不是自环的, 重新给那些点进行标记
52             for (int i = 0; i < n; ++i)
53                 if (id[i] == -1) id[i] = cnt++;
54             for (int i = 0; i < m; ++i)
55             {
56                 int u = edges[i].u, v = edges[i].v;
57                 edges[i].v = id[v]; edges[i].u = id[u];
58                 if (id[u] != id[v]) edges[i].w -= in[v];
59             }
60             // 缩点完后, 点的数量就变了
61             n = cnt; root = id[root];

```

```

62     }
63     return ret;
64 }
65 }MT;

```

4.20 ZKW Cost Flow

```

1  // To be written
2  bool spfa()
3  {
4      memset(mark,0,sizeof(mark));
5      memset(d,0x7,sizeof(d));
6      d[T] = 0; mark[T] = 1;
7      queue<int> team;
8      team.push(T);
9      while (!team.empty())
10     {
11         int now = team.front();
12         team.pop();
13         for (int i = head[now];i;i = e[i].next)
14             if (e[i^1].v&& d[e[i].to] > d[now]-e[i].c)
15             {
16                 d[e[i].to] = d[now]-e[i].c;
17                 if (!mark[e[i].to])
18                 {
19                     mark[e[i].to] = true;
20                     team.push(e[i].to);
21                 }
22             }
23         mark[now] = false;
24     }
25     if (d[0] > 10000000) return false;
26     return true;
27 }
28
29 int dfs(int x,int f)
30 {
31     if (x == T)
32     {
33         mark[T] = 1;
34         return f;
35     }
36     int used = 0,w;
37     mark[x] = true;
38     for (int i = head[x];i;i = e[i].next)
39         if (!mark[e[i].to]&&e[i].v&& d[x]-e[i].c==d[e[i].to])
40         {
41             w = f - used;
42             w = dfs(e[i].to,small(e[i].v,w));

```

```
43         ans += w*e[i].c;
44         e[i].v -= w;
45         e[i^1].v += w;
46         used += w;
47         if (used == f) return f;
48     }
49     return used;
50 }
51
52 void zkw()
53 {
54     while (spfa())
55     {
56         mark[T] = 1;
57         while (mark[T])
58         {
59             memset(mark,0,sizeof(mark));
60             dfs(0,inf);
61         }
62     }
63 }
```

Chapter 5

Number Theory

5.1 Baby Step Giant Step

```
1 // To Be Verified
2 // 求出最小的 t 使得  $X^t = Y \bmod mod$ 
3 inline int bsgs(int X,int Y,int mod)
4 {
5     int m = ceil(sqrt(mod+0.5)),mul = 1,res = 1;
6     if (Y == 1) return 0;
7     hash.clear(); hash[Y] = 0;
8     for (int i = 1;i <= m;++i)
9     {
10         mul = ((ll)mul*(ll)X)%mod;
11         if (mul == Y) return i;
12         hash[(ll)Y*(ll)mul%mod] = i;
13     }
14     res = mul;
15     for (int i = 2;(i-1)*m <= mod;++i)
16     {
17         res = (ll)res*(ll)mul%mod;
18         if (hash.find(res) != hash.end()) return i*m-hash[res];
19     }
20     return -1;
21 }
```

5.2 Chinese Remainder Theorem

```
1 //快速乘
2 inline ll qsc(ll a,ll b,ll mod)
3 {
4     ll ret = 0; a %= mod,b %= mod;
5     for (;b;b >>= 1)
6     {
7         if (b&1)
8         {
```

```

9         ret += a;
10        if (ret >= mod) ret -= mod;
11    }
12    a += a; if (a >= mod) a -= mod;
13 }
14 return ret;
15 }
16
17 inline ll msm(ll a,ll b,ll mod)
18 {
19     ll ret = 1;
20     for (;b;b >>= 1,a = qsc(a,a,mod)) if (b&1) ret = qsc(ret,a,mod);
21     return ret;
22 }
23
24 inline ll crt()
25 {
26     ll lcm = 1,ret = 0;
27     for (int i = 1;i <= K;++i) lcm *= (ll)P[i];
28     for (int i = 1;i <= K;++i)
29     {
30         ll tm = lcm/P[i];
31         ll inv = msm(tm,P[i]-2,P[i]);
32         ret = (ret+qsj(qsj(tm,inv,lcm),res[i],lcm))%lcm;
33     }
34     return ret;
35 }

```

5.3 Extended Euclidean Algorithm

```

1  //By yxj
2  inline ll exgcd(ll a,ll b,ll c) //ax mod b = c
3  {
4      if (a == 0) return -1;
5      else if (c % a == 0) return c/a;
6      ll t = exgcd(b % a,a,((-c % a)+a)%a);
7      if (t == -1) return -1;
8      return (t*b+c)/a;
9  }
10
11 //Input:a,b,&x,&y,ax+by = gcd(a,b)
12 //Output:gcd(a,b)
13 inline int exgcd(int a,int b,int &x,int &y)
14 {
15     if (!b) { x = 1,y = 0; return a; }
16     else
17     {
18         int r = exgcd(b,a%b,y,x);
19         y -= x*(a/b); return r;

```

```

20     }
21 }

```

5.4 Linearly Sieve

```

1  //欧拉函数
2  inline void ready()
3  {
4      phi[1] = 1;
5      for (int i = 2; i < maxn; ++i)
6      {
7          if (!exist[i]) phi[i] = i-1, prime[++tot] = i;
8          for (int j = 1; j <= tot; ++j)
9          {
10             if (i*prime[j] >= maxn) break;
11             exist[i*prime[j]] = true;
12             if (i % prime[j] == 0)
13                 { phi[i*prime[j]] = phi[i]*prime[j]; break; }
14             else phi[i*prime[j]] = phi[i]*phi[prime[j]];
15         }
16     }
17 }
18 //莫比乌斯函数
19 inline void ready()
20 {
21     mu[1] = 1;
22     for (int i = 2; i <= 50000; ++i)
23     {
24         if (!exist[i]) { prime[++tot] = i; mu[i] = -1; }
25         for (int j = 1; j <= tot && prime[j]*i <= 50000; ++j)
26         {
27             exist[i*prime[j]] = true;
28             if (i % prime[j] == 0) { mu[i*prime[j]] = 0; break; }
29             mu[i*prime[j]] = -mu[i];
30         }
31     }
32 }

```

5.5 N-Power Residue

```

1  //Input: p, N, a p is a prime
2  //Output: the solutions to equation  $x^N \equiv a \pmod{p}$  in  $[0, p-1]$ 
3  inline vector<int> residue(int p, int N, int a)
4  {
5      int g = PrimitiveRoot(p); ll m = bsgs(g, a, p);
6      vector<int> ret;
7      if (!a) { ret.push_back(0); return ret; }
8      if (m == -1) return ret;
9      ll A = N, B = p-1, C = m, x, y, d = exgcd(A, B, x, y);

```



```

10     if (C % d) return ret;
11     x *= (C / d)%B;
12     ll delta = B / d;
13     for (int i = 0; i < d; ++i)
14     {
15         x += delta; if (x >= B) x -= B;
16         ret.push_back((int)qsm(g,x,p));
17     }
18     sort(ret.begin(),ret.end());
19     ret.erase(unique(ret.begin(),ret.end()),ret.end());
20     return ret;
21 }

```

5.6 Number Theoretic Transformation

```

1  // The First Version
2  struct node
3  {
4      int a[maxn*2],len;
5      inline void NTT(int loglen,int len,int on)
6      {
7          for (int i = 0,j,t,p;i < len;++i)
8          {
9              for (j = 0,t = i,p = 0;j < loglen;++j,t >>= 1)
10                 p <<= 1,p |= t&1;
11                 if (p > i) swap(a[p],a[i]);
12             }
13             for (int s = 1,k = 2;s <= loglen;++s,k <<= 1)
14             {
15                 int wn; if (on) wn = e[s]; else wn = ine[s];
16                 for (int i = 0;i < len;i += k)
17                 {
18                     int w = 1;
19                     for (int j = 0;j < (k >> 1);++j,w = (ll)wn*w%rhl)
20                     {
21                         int u = a[i+j],v = (ll)w*a[i+j+(k>>1)]%rhl;
22                         a[i+j] = u+v; if (a[i+j] >= rhl) a[i+j] -= rhl;
23                         a[i+j+(k>>1)] = u-v;
24                         if (a[i+j+(k>>1)] < 0) a[i+j+(k>>1)] += rhl;
25                     }
26                 }
27             }
28             if (!on)
29             {
30                 int inv = qsm(len,rhl-2,rhl);
31                 for (int i = 0;i < len;++i) a[i] = (ll)a[i]*inv%rhl;
32             }
33         }
34         friend inline bool operator *(node x,node y)

```

```

35     {
36         int loglen = 0,len;
37         for (;(1<<loglen)<x.len+y.len;++loglen); len = 1<<loglen;
38         x.NTT(loglen,len,1); y.NTT(loglen,len,1);
39         for (int i = 0;i < (1<<loglen);++i) x.a[i] = (ll)x.a[i]*y.a[i]%rhl;
40         x.NTT(loglen,len,0);
41     }
42 };
43
44 int main()
45 {
46     for (int i = 1;i < 20;++i)
47         e[i] = qsm(gg,(rhl-1)>>i,rhl),ine[i] = qsm(e[i],rhl-2,rhl);
48 }
49
50 // The Second Version
51 typedef long long ll;
52 ll e[20],ine[20];
53
54 inline ll qsm(ll a,int b,int c)
55 {
56     ll ret = 1;
57     for (;b>= 1,(a *= a) %= c) if (b&1) (ret *= a) %= c;
58     return ret;
59 }
60
61 inline void NTT(ll *a,int loglen,int len,int on)
62 {
63     for (int i = 0,j,t,p;i < len;++i)
64     {
65         for (j = 0,t = i,p = 0;j < loglen;++j,t >= 1)
66             p <= 1,p |= t&1;
67         if (p > i) swap(a[p],a[i]);
68     }
69     for (int s = 1,k = 2;s <= loglen;++s,k <= 1)
70     {
71         int wn; if (on) wn = e[s]; else wn = ine[s];
72         for (int i = 0;i < len;i += k)
73         {
74             int w = 1;
75             for (int j = 0;j < (k >> 1);++j,w = (ll)wn*w%lhh)
76             {
77                 int u = a[i+j],v = (ll)w*a[i+j+(k>>1)]%lhh;
78                 a[i+j] = u+v; if (a[i+j] >= lhh) a[i+j] -= lhh;
79                 a[i+j+(k>>1)] = u-v;
80                 if (a[i+j+(k>>1)] < 0) a[i+j+(k>>1)] += lhh;
81             }
82         }
83     }

```

```

84     if (!on)
85     {
86         int inv = qsm(len, lhh-2, lhh);
87         for (int i = 0; i < len; ++i) a[i] = a[i]*inv%lhh;
88     }
89 }
90
91 struct Polynomial
92 {
93     int len; ll array[maxn<<2];
94     inline Polynomial(int _len = 0):len(_len) {}
95     inline Polynomial(ll a[], int n):len(n) { for (int i = 0; i < n; ++i) array[i] = a[i]; }
96     inline ll operator [] (int n) const { return array[n]; }
97     inline ll &operator [] (int n) { return array[n]; }
98     inline void set(int n) { len = n; }
99     inline void set(int n, ll a[]) { len = n; for (int i = 0; i < n; ++i) array[i] = a[i]; }
100    inline void extend(int key)
101    {
102        for (int i = len; i < (1<<key); ++i)
103            array[i] = 0;
104    }
105    inline void cut(int key) { len = key; }
106    inline void transform(int loglen, int on) { NTT(array, loglen, 1<<loglen, on); }
107 }; //变量只能定义在全局，不然会 re
108
109 inline Polynomial multiply(Polynomial &pa, Polynomial &ret) // self-multiply
110 {
111     int loglen = 0;
112     while ((1<<loglen) < (pa.len<<1)-1) ++loglen;
113     pa.extend(1<<loglen); pa.transform(loglen, 1);
114     for (int i = 0; i < (1<<loglen); ++i) ret[i] = pa[i]*pa[i]%lhh;
115     ret.transform(loglen, 0); ret.cut((pa.len<<1)-1);
116     return ret;
117 }
118 inline Polynomial multiply(Polynomial &pa, Polynomial &pb, Polynomial &ret)
119 {
120     int loglen = 0;
121     while ((1<<loglen) < (pa.len+pb.len-1)) ++loglen;
122     pa.extend(1<<loglen); pa.transform(loglen, 1);
123     pb.extend(1<<loglen); pb.transform(loglen, 1);
124     for (int i = 0; i < (1<<loglen); ++i) ret[i] = pa[i]*pb[i]%lhh;
125     ret.transform(loglen, 0); ret.cut(pa.len+pb.len-1);
126     return ret;
127 }
128
129 int main()
130 {
131     for (int i = 1; i < 20; ++i)
132         e[i] = qsm(g, (lhh-1)>>i, lhh), ine[i] = qsm(e[i], lhh-2, lhh);

```

```
133 }
```

5.7 Pollard Rho Algorithm

```
1  const int prime[] = {0,2,3,5,7,11,13,17,19,23,29,31};
2
3  inline ll mul(ll a,ll b,ll p) { return (a*b-((ll)((ld)a/p*b+1e-3)*p)+p)%p; }
4
5  inline bool check(ll m)
6  {
7      if (m <= 2) return m == 2;
8      ll tmp = m-1; int t = 0;
9      while (!(tmp&1)) ++t,tmp >>= 1;
10     for (int i = 1;i <= 10;++i)
11     {
12         int a = prime[i];
13         if (a == m) return true;
14         ll w = qsm(a,tmp,m);
15         for (int it = 1;it <= t;++it)
16         {
17             ll pf = mul(w,w,m);
18             if (pf == 1&&(w != 1&&w != m-1)) return false;
19             w = pf;
20         }
21         if (w != 1) return false;
22     }
23     return true;
24 }
25 inline void rho(ll m)
26 {
27     if (check(m)) { fac[++nn] = m; return; }
28     while (true)
29     {
30         ll X = (ll)rand()*rand()%(m-1)+1,Y = X;
31         ll c = (ll)rand()*rand()%(m-1)+1; int i,j;
32         for (i = j = 2;++i)
33         {
34             X = (mul(X,X,m)+c) % m;
35             ll d = __gcd(abs(X-Y),m);
36             if (1 < d&&d < m) { rho(d),rho(m/d); return; }
37             if (X == Y) break; if (i == j) Y = X,j <= 1;
38         }
39     }
40 }
41 inline void factor(ll m) { nn = 0; if (m > 1) rho(m); sort(fac+1,fac+nn+1); }
42
43
44 //__int128 Version
45 typedef __int128 int128;
```

```

46 inline int128 mul(int128 a,int128 b,int128 mod)
47 {
48     int128 ret = 0; a %= mod,b %= mod;
49     for (;b;b >>= 1)
50     {
51         if (b&1)
52         {
53             ret += a;
54             if (ret >= mod) ret -= mod;
55         }
56         a += a; if (a >= mod) a -= mod;
57     }
58     return ret;
59 }
60
61 inline int128 qsm(int128 a,int128 b,int128 mod)
62 {
63     int128 ret = 1;
64     for (;b;b >>= 1,a = mul(a,a,mod)) if (b&1) ret = mul(ret,a,mod);
65     return ret;
66 }
67
68 inline void ready()
69 {
70     for (int i = 2;i <= 100;++i)
71     {
72         if (prime[i]) continue; prime[++tot] = i;
73         for (int j = i*i;j <= 100;j += i) prime[j] = 1;
74     }
75 }
76
77 inline int128 gi()
78 {
79     int128 ret = 0; char ch;
80     do ch = getchar(); while (!(ch >= '0'&&ch <= '9'));
81     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
82     return ret;
83 }
84
85 inline int128 gcd(int128 a,int128 b) { if (b == 0) return a; return gcd(b,a%b); }
86
87 inline int128 Abs(int128 a) { if (a < 0) return -a; return a; }
88
89 inline bool check(int128 m)
90 {
91     if (m <= 2) return m == 2;
92     int128 tmp = m-1; int t = 0;
93     while (!(tmp&1)) ++t,tmp >>= 1;
94     for (int i = 1;i <= tot;++i)

```

```

95     {
96         int a = prime[i];
97         if (a == m) return true;
98         int128 w = qsm(a,tmp,m);
99         for (int it = 1; it <= t; ++it)
100         {
101             int128 pf = mul(w,w,m);
102             if (pf == 1 && (w != 1 && w != m-1)) return false;
103             w = pf;
104         }
105         if (w != 1) return false;
106     }
107     return true;
108 }
109 inline void rho(int128 m)
110 {
111     if (check(m)) { fac[++nn] = m; return; }
112     while (true)
113     {
114         int128 X = (int128)rand()*(int128)rand()%(m-1)+1, Y = X;
115         int128 c = (int128)rand()*(int128)rand()%(m-1)+1; int i,j;
116         for (i = j = 2; ++i)
117         {
118             X = (mul(X,X,m)+c)%m;
119             int128 d = gcd(Abs(X-Y),m);
120             if (1 < d && d < m) { rho(d), rho(m/d); return; }
121             if (X == Y) break; if (i == j) Y = X, j <= 1;
122         }
123     }
124 }
125
126 inline void factor(int128 m) { nn = 0; if (m > 1) rho(m); sort(fac+1,fac+nn+1); }

```

5.8 Primitive Root

```

1  //Input: A prime p
2  //Output: p's primitive root
3  vector <ll> a;
4
5  inline g_test(ll g, ll p)
6  {
7      for (ll i = a.size()-1; i >= 0; --i)
8          if (qsm(g,(p-1)/a[i],p) == 1) return 0;
9      return 1;
10 }
11
12 inline ll PrimitiveRoot(ll p)
13 {
14     ll tmp = p - 1;

```

```

15     for (ll i = 2; i <= tmp/i; ++i)
16     {
17         if (!(tmp % i))
18         {
19             a.push_back(i);
20             while (!(tmp%i)) tmp /= i;
21         }
22         if (tmp != 1) a.push_back(tmp);
23     }
24     for (ll g = 1; ; ++g) if (g_test(g,p)) return g;
25 }

```

5.9 Quadratic Residue

```

1  //判断是否存在  $x$ , 使得  $x^2 \equiv a \pmod n$ , 存在返回最小  $x$ , 否则返回 -1
2  inline int modsqr(int a, int n)
3  {
4      int b, k, i, x;
5      if (n == 2) return a & 1;
6      if (qsm(a, (n-1)>>1, n) == 1)
7      {
8          if (n % 4 == 3) x = qsm(a, (n+1)>>2, n);
9          else
10         {
11             for (b = 1; qsm(b, (n-1)>>1, n) == 1; ++b);
12             i = (n-1)>>1; k = 0;
13             do
14             {
15                 i >>= 1, k >>= 1;
16                 if (!(qsm(a, i, n) * (qsm(b, k, n) + 1) % n)) k += ((n-1)>>1);
17             }
18             while (!(i&1));
19             x = (qsm(a, (i+1)>>1, n) * (qsm(b, k>>1, n)) % n;
20         }
21         if ((x << 1) > n) x = n-x;
22         return x;
23     }
24     return -1;
25 }

```

5.10 Single Variable Modulus Linear Equation

```

1  //Input: a, b, n
2  //Output: All the solutions in  $[0, n)$  to the equation  $ax \equiv b \pmod n$ 
3  inline vector<ll> LineModEquation(ll a, ll b, ll n)
4  {
5      ll x, y, d = exgcd(a, n, x, y); vector<ll> ans;
6      if (!(b % d))
7      {

```

```
8         x %= n; x += n; x % n;
9         ans.push_back(x*(b/d)%n);
10        for (ll i= 1;i < d;++i) ans.push_back((ans[0]+i*n/d)%n);
11        //若找最小的，直接就是 (ans[0]%(n/d))
12    }
13    return ans;
14 }
```


Chapter 6

Numerical Algorithms

6.1 Counting Integral Points under Straight Line

```
1 // \sum_{i=0}^{n-1} (a+bi)/m
2 inline ll count(ll n,ll a,ll b,ll m)
3 {
4     if (!b) return n*(a/m);
5     else if (a >= m) return n*(a/m)+count(n,a/m,b,m);
6     else if (b >= m) return (n-1)*n/2*(b/m)+count(n,a,b/m,m);
7     else return count((a+b*n)/m,(a+b*n)%m,m,b);
8 }
```

6.2 Evaluation of Expression

```
1 #include<bitset>
2 #include<stack>
3 #include<iostream>
4 #include<cstdio>
5 #include<cstdlib>
6 using namespace std;
7
8 const int maxn = 200010;
9 int T,N,M,pri[256],match[maxn]; bitset <maxn> A,B; char s[maxn];
10
11 inline int gi()
12 {
13     char ch; int ret = 0,f = 1;
14     do ch = getchar(); while (!(ch >= '0'&&ch <= '9')&&ch != '-');
15     if (ch == '-') f = -1,ch = getchar();
16     do ret = ret*10+ch-'0',ch = getchar(); while (ch >= '0'&&ch <= '9');
17     return ret*f;
18 }
19
20 inline bitset <maxn> calc(int l,int r)
21 {
```

```

22     if (l > r) return bitset <maxn>();
23     while (match[l] == r) ++l,r--;
24     if (l == r) { if (s[l] == 'A') return A; else return B; }
25     int cur = 0; pair <int,int> mn(1<<30,0);
26     for (int i = l;i <= r;++i)
27     {
28         if (s[i] == '(') cur += 10;
29         else if (s[i] == ')') cur -= 10;
30         else if (pri[s[i]])
31             if (make_pair(cur+pri[s[i]],i) < mn)
32                 mn = make_pair(cur+pri[s[i]],i);
33     }
34     int pos = mn.second; auto L = calc(l,pos-1),R = calc(pos+1,r);
35     if (s[pos] == '+') return L|R;
36     else if (s[pos] == '*') return L&R;
37     else return ~R;
38 }
39
40 int main()
41 {
42     freopen("H.in","r",stdin);
43     freopen("H.out","w",stdout);
44     pri['+'] = 1; pri['*'] = 2; pri['-'] = 3;
45     while (++T)
46     {
47         N = gi(),M = gi(); if (!N) break;
48         A.reset(); B.reset(); printf("Case %d: ",T);
49         for (int K = gi();K--;) A[gi()] = 1;
50         for (int K = gi();K--;) B[gi()] = 1;
51         scanf("%s",s+1); stack <int> S;
52         for (int i = 1;i <= M;++i) match[i] = -1;
53         for (int i = 1;i <= M;++i)
54         {
55             if (s[i] == '(') S.push(i);
56             else if (s[i] == ')')
57             {
58                 int t = S.top(); S.pop();
59                 match[match[t] = i] = t;
60             }
61         }
62         int tot = 0; auto ans = calc(1,M);
63         for (int i = 1;i <= N;++i) tot += ans[i]; printf("%d",tot);
64         for (int i = 1;i <= N;++i) if (ans[i]) printf(" %d",i); putchar('\n');
65     }
66     return 0;
67 }

```

6.3 Fast Fourier Transformation

```

1  // The First Version
2  struct Vir
3  {
4      double re,im;
5      inline Vir(double _re = 0,double _im = 0):re(_re),im(_im) {}
6      friend inline Vir operator*(const Vir &a,const Vir &b) { return
↪   Vir(a.re*b.re-a.im*b.im,a.re*b.im+a.im*b.re); }
7      friend inline Vir operator+(const Vir &a,const Vir &b) { return Vir(a.re+b.re,a.im+b.im); }
8      friend inline Vir operator-(const Vir &a,const Vir &b) { return Vir(a.re-b.re,a.im-b.im); }
9      friend inline Vir operator/(const Vir &a,double r) { return Vir(a.re/r,a.im/r); }
10 }pa[maxn],pb[maxn];
11
12 inline void fft(Vir *a,int loglen,int len,int on)
13 {
14     for (register int i = 0,j,t,p;i < len;++i)
15     {
16         for (p = j = 0,t = i;j < loglen;++j,t >>= 1)
17             p <= 1,p |= (t&1);
18         if (p > i) swap(a[p],a[i]);
19     }
20     for (register int m = 2,s = 1;s <= loglen;++s,m <= 1)
21     {
22         register Vir w(cos(2*pi*on/m),sin(2*pi*on/m));
23         for (int i = 0;i < len;i += m)
24         {
25             register Vir wn(1,0);
26             for (register int j = 0;j < (m>>1);++j,wn = wn*w)
27             {
28                 register Vir u = a[i+j],v = wn*a[i+j+(m>>1)];
29                 a[i+j] = u+v; a[i+j+(m>>1)] = u-v;
30             }
31         }
32     }
33     if (on == -1) for (int i = 0;i < len;++i) a[i] = a[i]/len;
34 }
35
36 inline void work()
37 {
38     int loglen = 0,len;
39     while ((1<<loglen) < len) ++loglen; len = 1 << loglen;
40     fft(pa,loglen,len,1); fft(pb,loglen,len,1);
41     for (int i = 0;i < len;++i) pa[i] = pa[i]*pb[i];
42     fft(pa,loglen,len,-1);
43 }
44
45 //The Second Version
46 const double pi = acos(-1.0);
47 struct Complex

```

```

48 {
49     double re,im;
50     inline Complex() = default;
51     inline Complex(double _re,double _im):re(_re),im(_im) {}
52     friend inline Complex operator*(const Complex &a,const Complex &b) { return
↪ Complex(a.re*b.re-a.im*b.im,a.re*b.im+a.im*b.re); }
53     friend inline Complex operator+(const Complex &a,const Complex &b) { return
↪ Complex(a.re+b.re,a.im+b.im); }
54     friend inline Complex operator-(const Complex &a,const Complex &b) { return
↪ Complex(a.re-b.re,a.im-b.im); }
55     friend inline Complex operator/(const Complex &a,double r) { return Complex(a.re/r,a.im/r);
↪ }
56 };
57
58 inline void FFT(Complex *a,int loglen,int len,int on)
59 {
60     for (register int i = 0,j,t,p;i < len;++i)
61     {
62         for (p = j = 0,t = i;j < loglen;++j,t >>= 1)
63             p <= 1,p |= (t&1);
64         if (p > i) swap(a[p],a[i]);
65     }
66     for (register int m = 2,s = 1;s <= loglen;++s,m <= 1)
67     {
68         register Complex w(cos(2*pi*on/m),sin(2*pi*on/m));
69         for (int i = 0;i < len;i += m)
70         {
71             register Complex wn(1,0);
72             for (register int j = 0;j < (m>>1);++j,wn = wn*w)
73             {
74                 register Complex u = a[i+j],v = wn*a[i+j+(m>>1)];
75                 a[i+j] = u+v; a[i+j+(m>>1)] = u-v;
76             }
77         }
78     }
79     if (on == -1) for (int i = 0;i < len;++i) a[i] = a[i]/len;
80 }
81
82 struct Polynomial
83 {
84     int len; Complex array[maxn<<2];
85     inline Polynomial(int _len = 0):len(_len) {}
86     inline Polynomial(Complex a[],int n):len(n) { for (int i = 0;i < n;++i) array[i] = a[i]; }
87     inline Complex operator [] (int n) const { return array[n]; }
88     inline Complex &operator [] (int n) { return array[n]; }
89     inline void set(int n) { len = n; }
90     inline void set(int n,Complex a[]) { len = n; for (int i = 0;i < n;++i) array[i] = a[i]; }
91     inline void extend(int key)
92     {

```

```

93         for (int i = len; i < (1<<key); ++i)
94             array[i] = Complex(0,0);
95     }
96     inline void cut(int key) { len = key; }
97     inline void transform(int loglen, int on) { FFT(array, loglen, 1<<loglen, on); }
98 }; //变量只能定义在全局, 不然会 re
99
100 inline Polynomial multiply(Polynomial &pa, Polynomial &ret) // self-multiply
101 {
102     int loglen = 0;
103     while ((1<<loglen) < (pa.len<<1)-1) ++loglen;
104     pa.extend(1<<loglen); pa.transform(loglen, 1);
105     for (int i = 0; i < (1<<loglen); ++i) ret[i] = pa[i]*pa[i];
106     ret.transform(loglen, -1); ret.cut((pa.len<<1)-1);
107     return ret;
108 }
109 inline Polynomial multiply(Polynomial &pa, Polynomial &pb, Polynomial &ret)
110 {
111     int loglen = 0;
112     while ((1<<loglen) < (pa.len+pb.len-1)) ++loglen;
113     pa.extend(1<<loglen); pa.transform(loglen, 1);
114     pb.extend(1<<loglen); pb.transform(loglen, 1);
115     for (int i = 0; i < (1<<loglen); ++i) ret[i] = pa[i]*pb[i];
116     ret.transform(loglen, -1); ret.cut(pa.len+pb.len-1);
117     return ret;
118 }

```

6.4 Fast Input and Output

```

1 // Input and Output of Int
2 // Be careful of Max_Int and Min_Int
3 inline int gi()
4 {
5     char ch; int ret = 0, f = 1;
6     do ch = getchar(); while (!(ch >= '0' && ch <= '9') && ch != '-');
7     if (ch == '-') f = -1, ch = getchar();
8     do ret = ret*10+ch-'0', ch = getchar(); while (ch >= '0' && ch <= '9');
9     return ret*f;
10 }
11
12 inline void pi(int a)
13 {
14     if (!a) putchar('0');
15     if (a < 0) a = -a, putchar('-');
16     int num[10], n = 0;
17     while (a) num[n++] = a%10, a /= 10;
18     for (int i = n-1; i >= 0; --i) putchar('0'+num[i]);
19 }

```

6.5 Fraction Class

```

1  typedef long long ll;
2  struct Fraction
3  {
4      ll num,den;
5      inline Fraction(ll a = 0,ll b = 1)
6      {
7          if (den < 0) a = -a,b = -b;
8          assert(b != 0); ll g = gcd(abs(a),b);
9          num = a/g; den = b/g;
10     }
11     friend inline Fraction operator +(const Fraction &a,const Fraction &b) const { return
↪ Fraction(a.num*b.den+b.num*a.den,a.den*b.den); }
12     friend inline Fraction operator -(const Fraction &a,const Fraction &b) const { return
↪ Fraction(a.num*b.den-b.num*a.den,a.den*b.den); }
13     friend inline Fraction operator *(const Fraction &a,const Fraction &b) const { return
↪ Fraction(a.num*b.num,a*den*b.den); }
14     friend inline Fraction operator /(const Fraction &a,const Fraction &b) const { return
↪ Fraction(a.num*b.den,a*den*b.num); }
15     friend inline bool operator <(const Fraction &a,const Fraction &b) const { return
↪ a.num*b.den < a.den*b.num; }
16     friend inline bool operator <=(const Fraction &a,const Fraction &b) const { return
↪ a.num==b.num&& a.den==b.den; }
17 };

```

6.6 Gray Code

```

1  //0-2n-1 的格雷码
2  inline vector <int> GrayCreat(int n)
3  {
4      vector <int> res;
5      for (int i = 0;i < (1<<n);++i) res.push_back(i^(i>>1));
6      return res;
7  }

```

6.7 Numerical Integration

```

1  //self-adapt simpson
2  inline long double simpson(long double l,long double r,long double mid,long double Cl,long
↪ double Cr,long double Cm)
3  {
4      long double tCl = calc((l+mid)/2),tCr = calc((mid+r)/2);
5      long double
↪ ans=(r-l)*(Cl+Cr+4*Cm)/6,lans=(mid-l)*(Cl+Cm+4*tCl)/6,rans=(r-mid)*(Cr+Cm+4*tCr)/6;
6      if (r-l <= 1e-3&&fabs(lans+rans-ans)<eps) return ans;
7      // if (dep > lim&&fabs(lans+rans-ans)<eps) return ans;
8      else return simpson(l,mid,(l+mid)/2,Cl,Cm,tCl)+simpson(mid,r,(mid+r)/2,Cm,Cr,tCr);
9  }

```

```

10
11 //romberg---To Be Verified
12 template <class T>
13 inline double romberg(const T &f, double a, double b, double eps = 1e-8)
14 {
15     vector <double> t; double h = b-a, last, cur;
16     int k = 1, i = 1;
17     t.push_back(h*(f(a)+f(b))/2);
18     do
19     {
20         last = t.back(); cur = 0; double x = a+h/2;
21         for (int j = 0; j < k; ++j) cur += f(x), x += h;
22         cur = (t[0]+h*cur)/2;
23         double k1 = 4.0/3, k2 = 1.0/3;
24         for (int j = 0; j < i; ++j)
25         {
26             double temp = k1*cur-k2*t[j];
27             t[j] = cur; cur = temp; k2 /= 4*k1-k2; k1 = k2+1;
28         }
29         t.push_back(cur); k *= 2; h /= 2; ++i;
30     }
31     while (fabs(last - cur) > eps);
32     return t.back();
33 }

```

6.8 Simplex

6.8.1 Description

有 n 个实数变量 x_1, x_2, \dots, x_n 和 m 条约束，其中第 i 条约束形如 $\sum_{j=1}^n a_{i,j}x_j \leq b_i$ 。

此外这 n 个变量需要满足非负性限制， $x_j \geq 0$ 。

在满足上述所有条件的情况下，你需要指定每个变量 x_j 的取值，使得目标函数 $F = \sum_{j=1}^n c_j x_j$ 的值最大。

6.8.2 Input

第一行三个正整数 n, m, t 。其中 $t \in \{0, 1\}$ 。

第二行有 n 个整数 c_1, c_2, \dots, c_n ，整数间均用一个空格分隔。

接下来 m 行，每行代表一条约束，其中第 i 行有 $n+1$ 个整数 $a_{i1}, a_{i2}, \dots, a_{in}, b_i$ ，整数间均用一个空格分隔。

6.8.3 Output

如果不存在满足所有约束的解，仅输出一行 “Infeasible”。

如果对于任意的 M ，都存在一组解使得目标函数的值大于 M ，仅输出一行 “Unbounded”。

否则，第一行输出一个实数，表示目标函数的最大值 F 。

如果 $t = 1$, 那么你还需要输出第二行, 用空格隔开的 n 个非负实数, 表示此时 x_1, x_2, \dots, x_n 的取值, 如有多组方案请任意输出其中一个。

6.8.4 Code

```

1 // uoj 179
2 #include<iostream>
3 #include<cstdio>
4 #include<cstdlib>
5 using namespace std;
6
7 #define maxn (30)
8 #define eps (1e-8)
9
10 int N,M,op,tot,q[maxn],idx[maxn],idy[maxn]; double a[maxn][maxn],A[maxn];
11
12 inline void pivot(int x,int y)
13 {
14     swap(idy[x],idx[y]);
15     double tmp = a[x][y]; a[x][y] = 1/a[x][y];
16     for (int i = 0;i <= N;++i) if (y != i) a[x][i] /= tmp;
17     tot = 0; for (int i = 0;i <= N;++i) if (i != y&&(a[x][i] > eps||a[x][i] < -eps)) q[++tot] =
    ↪ i;
18     for (int i = 0;i <= M;++i)
19     {
20         if ((x == i)|| (a[i][y] < eps&&a[i][y] > -eps)) continue;
21         for (int j = 1;j <= tot;++j) a[i][q[j]] -= a[x][q[j]]*a[i][y];
22         a[i][y] = -a[i][y]/tmp;
23     }
24 }
25
26 int main()
27 {
28     freopen("179.in","r",stdin);
29     freopen("179.out","w",stdout);
30     scanf("%d %d %d",&N,&M,&op); srand(233);
31     for (int i = 1;i <= N;++i) scanf("%lf",a[0]+i);
32     for (int i = 1;i <= M;++i)
33     {
34         for (int j = 1;j <= N;++j) scanf("%lf",a[i]+j);
35         scanf("%lf",a[i]);
36     }
37     for (int i = 1;i <= N;++i) idx[i] = i;
38     for (int i = 1;i <= M;++i) idy[i] = i+N;
39     while (true)
40     {
41         int x = 0,y = 0;
42         for (int i = 1;i <= M;++i) if (a[i][0] < -eps&&(!x)|| (rand()&1))) x = i; if (!x) break;
43         for (int i = 1;i <= N;++i) if (a[x][i] < -eps&&(!y)|| (rand()&1))) y = i; if (!y) return
    ↪ puts("Infeasible"),0;

```



```

44     pivot(x,y);
45 }
46 while (true)
47 {
48     int x = 0,y = 0; double mn = 1e15;
49     for (int i = 1;i <= N;++i) if (a[0][i] > eps) { y = i; break; } if (!y) break;
50     for (int i = 1;i <= M;++i) if (a[i][y] > eps && a[i][0]/a[i][y] < mn) mn =
↪ a[i][0]/a[i][y],x = i; if (!x) return puts("Unbounded"),0;
51     pivot(x,y);
52 }
53 printf("%.8lf\n",-a[0][0]); if (!op) return 0;
54 for (int i = 1;i <= M;++i) if (idy[i] <= N) A[idy[i]] = a[i][0];
55 for (int i = 1;i <= N;++i) printf("%.8lf ",A[i]);
56 fclose(stdin); fclose(stdout);
57 return 0;
58 }

```

6.9 Solutions of Equation of Higher Order

```

1  // vector <double> solve(vector <double> coef,int n)
2  // coef 方程的系数; n 方程的系数
3  // 输出所有实数解
4  const double EPS = 1e-15,inf = 1e12;
5
6  inline int sign(double x) { return x < -EPS?-1:x > EPS; }
7
8  inline double get(const vector <double> &coef,double x)
9  {
10     double e = 1,s = 0;
11     for (int i = 0;i < coef.size();++i) s += coef[i]*e,e *= x;
12     return s;
13 }
14
15 inline double find(const vector <double> &coef,int n,double lo,double hi)
16 {
17     double sign_lo,sign_hi;
18     if ((sign_lo = sign(get(coef,lo)))== 0) return lo;
19     if ((sign_hi = sign(get(coef,hi)))== 0) return hi;
20     if (sign_lo*sign_hi > 0) return inf;
21     for (int step = 0;step < 100&&hi-lo > EPS;++step)
22     {
23         double m = (lo+hi)/2; int sign_mid = sign(get(coef,m));
24         if (sign_mid == 0) return m;
25         else if (sign_lo*sign_mid < 0) hi = m;
26         else lo = m;
27     }
28     return (lo+hi)/2;
29 }
30

```

```
31 inline vector <double> solve(const vector <double> &coef, int n)
32 {
33     vector <double> ret;
34     if (n == 1)
35     {
36         if (sign(coef[1])) ret.push_back(-coef[0]/coef[1]);
37         return ret;
38     }
39     vector <double> dcoef(n);
40     for (int i = 0; i < n; ++i) dcoef[i] = coef[i+1]*(i+1);
41     vector <double> droot = solve(dcoef, n-1);
42     droot.insert(droot.begin(), -inf);
43     droot.push_back(inf);
44     for (int i = 0; i+1 < droot.size(); ++i)
45     {
46         double tmp = find(coef, n, droot[i], droot[i+1]);
47         if (tmp < inf) ret.push_back(tmp);
48     }
49     return ret;
50 }
```

Chapter 7

String Algorithms

7.1 Aho-Corasick Automaton

```
1 // ac 自动机
2 inline int newnode()
3 {
4     memset(nxt[L],-1,sizeof(nxt[L]));
5     return ++L-1;
6 }
7 inline void init() { L = 0; root = newnode(); }
8 inline void insert()
9 {
10     int len = strlen(buf),now = root;
11     for (int i = 0;i < len;++i)
12     {
13         if (nxt[now][buf[i]-'0'] == -1)
14             nxt[now][buf[i]-'0'] = newnode();
15         now = nxt[now][buf[i]-'0'];
16     }
17     end[now] = true;
18 }
19 inline void build()
20 {
21     int now = root; queue <int> team;
22     fail[root] = root;
23     for (int i = 0;i < 10;++i)
24     {
25         if (nxt[now][i] == -1) nxt[now][i] = root;
26         else fail[nxt[now][i]] = root,team.push(nxt[now][i]);
27     }
28     while (!team.empty())
29     {
30         now = team.front(); team.pop();
31         for (int i = 0;i < 10;++i)
32         {
33             if (nxt[now][i] == -1)
```

```

34         nxt[now][i] = nxt[fail[now]][i];
35     else
36     {
37         fail[nxt[now][i]] = nxt[fail[now]][i];
38         team.push(nxt[now][i]);
39     }
40 }
41 }
42 }

```

7.2 Knuth-Morris-Pratt Algorithm

```

1  // To Be Verified
2  void cal_next(char *str, int *next, int len)
3  {
4      int i,j;
5      next[0] = -1;
6      for (int i = 1; i < len; i++)
7      {
8          j = next[i - 1];
9          while (str[j+1] != str[i] && (j >= 0)) j = next[j];
10         if (str[i] == str[j+1]) next[i] = j + 1;
11         else next[i] = -1;
12     }
13 }
14
15 int KMP(char *str,int slen, char *ptr,int plen,int *next)
16 {
17     int s_i = 0,p_i = 0;
18     while (s_i < slen && p_i < plen)
19     {
20         if (str[s_i] == ptr[p_i]) s_i++,p_i++;
21         else
22         {
23             if (!p_i) s_i++;
24             else p_i = next[p_i-1] + 1;
25         }
26     }
27     return (p_i == plen)?(s_i - plen):-1;
28 }

```

7.3 Manacher Algorithm

```

1  // Correct but to Be Rewritten
2  inline void ready()
3  {
4      for (int i = 1; i <= 2*l1+1; ++i)
5          { if (i & 1) bac[i] = '#'; else bac[i] = s[i>>1]; }
6      bin[0] = 1;

```

```

7     for (int i = 1; i <= l1; ++i)
8         hash[i] = hash[i-1]*37+s[i]-'A'+1, bin[i] = 37*bin[i-1];
9 }
10
11 inline void manacher()
12 {
13     rad[1] = 1; int best = 1;
14     for (int i = 2; i <= 2*l1+1; ++i)
15     {
16         int j;
17         if (best+rad[best]-1 < i) j = 1;
18         else j = min(rad[2*best-i], best+rad[best]-i)+1;
19         while (i-j+1 && i+j-1 <= 2*l1+1 && bac[i-j+1] == bac[i+j-1])
20         {
21             if (bac[i+j-1] != '#')
22             {
23                 ull h = (hash[(i+j-1)>>1] - hash[((i-j+1)>>1)-1]*bin[j]);
24                 if (!exist1[h%rh11] || !exist2[h%rh12] || !exist3[h%rh13])
25                 {
26                     exist1[h%rh11] = exist2[h%rh12] = exist3[h%rh13] = true;
27                     ++tot, have[tot][0] = (i-j+1)>>1;
28                     have[tot][1] = (i+j-1)>>1;
29                 }
30             }
31             ++j;
32         }
33         rad[i] = j-1;
34         if (i+rad[i] > best+rad[best]) best = i;
35     }
36 }

```

7.4 Palindrome Automaton

```

1  // Correct but to Be Rewritten
2  struct pat
3  {
4      int next[maxn][26], fail[maxn], cnt[maxn], len[maxn], s[maxn], last, n, p;
5      inline int newnode(int l) { cnt[p] = 0; len[p] = 1; return p++; }
6      inline void init() { last = n = p = 0; newnode(0); newnode(-1); s[0] = -1; fail[0] = 1; }
7      inline int getfail(int x) { while (s[n-len[x]-1] != s[n]) x = fail[x]; return x; }
8      inline void add(int c)
9      {
10         c -= 'a'; s[++n] = c; int cur = getfail(last);
11         if (!next[cur][c])
12         {
13             int now = newnode(len[cur]+2);
14             fail[now] = next[getfail(fail[cur])][c];
15             next[cur][c] = now;
16         }

```

```

17         last = next[cur][c]; cnt[last]++;
18     }
19 }

```

7.5 Suffix Array

```

1  // 记得最后填一个字符集中没有的字符
2  inline void build(char *buf, int *Sa, int *Rank, int *Height, int n, int now, int m)
3  {
4      int i, j, k, *x = t1, *y = t2;
5      memset(c, 0, 4*m);
6      for (i = 0; i < n; ++i) c[x[i] - 'A']++;
7      for (i = 1; i < m; ++i) c[i] += c[i-1];
8      for (i = n-1; i >= 0; --i) Sa[--c[x[i]]] = i;
9      for (k = 1; k < n; k <= 1)
10     {
11         int p = 0;
12         for (i = n-k; i < n; ++i) y[p++] = i;
13         for (i = 0; i < n; ++i) if (Sa[i] >= k) y[p++] = Sa[i] - k;
14         memset(c, 0, 4*m);
15         for (i = 0; i < n; ++i) c[x[y[i]]]++;
16         for (i = 1; i < m; ++i) c[i] += c[i-1];
17         for (i = n-1; i >= 0; --i) Sa[--c[x[y[i]]]] = y[i];
18         swap(x, y); p = 1; x[Sa[0]] = 0;
19         for (i = 1; i < n; ++i)
20             x[Sa[i]] = y[Sa[i-1]] == y[Sa[i]] && y[Sa[i-1]+k] == y[Sa[i]+k] ? p-1 : p++;
21         if (p >= n) break; m = p;
22     }
23     for (i = 0; i < n; ++i) Rank[Sa[i]] = i;
24     for (i = k = 0; i < n; ++i)
25     {
26         if (k) --k; if (!Rank[i]) continue;
27         j = Sa[Rank[i]-1];
28         while (i+k < n && j+k < n && buf[i+k] == buf[j+k]) ++k;
29         Height[Rank[i]] = k;
30     }
31 }

```

7.6 Suffix Automaton

```

1  // Correct but to Be Rewritten
2  struct SAM
3  {
4      int tot, tail, cnt, p, np, q, nq, sz[maxn], arr[maxn], step[maxn], tran[maxn][26], parent[maxn];
5      inline SAM() { tail = tot = 1; }
6      inline void insert(int c)
7      {
8          p = tail; np = tail = ++tot; step[np] = step[p]+1;
9          for (; !tran[p][c]; p = parent[p]) tran[p][c] = np;

```

```

10     if (!p) parent[np] = 1;
11     else
12     {
13         q = tran[p][c];
14         if (step[p]+1 == step[q]) parent[np] = q;
15         else
16         {
17             nq = ++tot; step[nq] = step[p]+1;
18             memcpy(tran[nq],tran[q],104);
19             parent[nq] = parent[q]; parent[np] = parent[q] = nq;
20             for (;tran[p][c] == q;p = parent[p]) tran[p][c] = nq;
21         }
22     }
23     sz[np] = 1;
24 }
25
26 inline void dfs(int now)
27 {
28     if (vis[now]) return; vis[now] = true;
29     for (int i = 0;i < 26;++i)
30         if (tran[now][i]) dfs(tran[now][i]),arr[now] += arr[tran[now][i]];
31     arr[now] += sz[now];
32 }
33
34 inline void build()
35 {
36     if (!mode) for (int i = 1;i <= tot;++i) sz[i] = 1;
37     else
38     {
39         for (int i = 2;i <= tot;++i) ++d[parent[i]];
40         queue<int> team; for (int i = 1;i <= tot;++i) if (!d[i]) team.push(i);
41         while (!team.empty())
42         {
43             int now = team.front(); team.pop();
44             sz[parent[now]] += sz[now];
45             if (--d[parent[now]]) team.push(parent[now]);
46         }
47     }
48     sz[1] = 0; dfs(1);
49 }
50 inline void work()
51 {
52     int now = 1,l = 0,rank = 0; memset(s,0,N+1);
53     if (K > arr[1]) puts("-1");
54     else
55     {
56         while (true)
57         {
58             rank += sz[now]; if (rank >= K) break;

```

```
59         for (int i = 0; i < 26; ++i)
60         {
61             if (rank+arr[tran[now][i]] < K) rank += arr[tran[now][i]];
62             else { s[++l] = 'a'+i; now = tran[now][i]; break; }
63         }
64     }
65     printf("%s", s+1);
66 }
67 }
68 }sam;
```


Chapter 8

Others

8.1 Calculation of Date

```
1  //ya 年 ma 月 da 日与 yb 年 mb 月 db 日相差几天
2  const int days = 365, s[] = {0,31,28,31,30,31,30,31,31,30,31,30,31};
3  inline bool isleap(int y)
4  {
5      if ((!(y%400)||y%100)&&!(y%4)) return true;
6      return false;
7  }
8
9  inline int leap(int y)
10 {
11     if (!y) return 0;
12     return y/4-y/100+y/400;
13 }
14
15 inline int calc(int day,int mon,int year)
16 {
17     int res = (year-1)*days+leap(year-1);
18     for (int i = 1;i < mon;++i) res += s[i];
19     if (isleap(year)&&mon > 2) res++;
20     res += day; return res;
21 }
22
23 inline int count_day(int da,int ma,int ya,int db,int mb,int yb)
24 {
25     int resa = calc(da,ma,ya);
26     int resb = calc(db,mb,yb);
27     return abs(resa-resb);
28 }
```

8.2 Java Hints

```

1  // Code 1
2  import java.io.*;
3  import java.math.*;
4  import java.util.*;
5
6  public class Main
7  {
8      final static int lhh = 998244353,maxn = 1655;
9      static long jc[] = new long [maxn];
10
11     static int calc(BigInteger N)
12     {
13         if (N.compareTo(BigInteger.ONE) <= 0) return 0;
14         // System.out.println(N);
15         int l = 2,r = 1650,mid;
16         while (l <= r)
17         {
18             mid = (l+r)>>1;
19             if (((BigInteger.valueOf(mid)).pow(mid)).compareTo(N) <= 0) l = mid+1;
20             else r = mid-1;
21         }
22         // System.out.println(l+" "+r);
23         int ret = (int)jc[r]-1,d = 1; if (ret < 0) ret += lhh;
24         int digit[] = new int[d]; BigInteger _d = BigInteger.valueOf(l);
25         for (int i = 0;i < d;++i)
26         {
27             digit[i] = N.mod(_d).intValue();
28             N = N.divide(_d);
29         }
30         // for (int i = d-1;i >= 0;--i) System.out.print(digit[i]);
31         // System.out.println();
32         boolean cho[] = new boolean[d],safe = false,exist = true;
33         Arrays.fill(cho,false);
34         int per[] = new int [d];
35         for (int i = d-1;i >= 0;--i)
36         {
37             int cur = -1;
38             if (safe)
39             {
40                 int down = i == d-1?1:0;
41                 for (int j = d-1;j >= down;--j)
42                 {
43                     if (cho[j] == true) continue;
44                     cur = j; break;
45                 }
46                 if (cur == -1) { exist = false; break; }
47                 cho[cur] = true; per[i] = cur;
48             }

```

```

49         else
50         {
51             if (cho[digit[i]] == true)
52             {
53                 // System.out.println(i+": "+digit[i]);
54                 while (i < d)
55                 {
56                     cur = -1;
57                     int down = i == d-1?1:0;
58                     for (int j = digit[i]-1; j >= down; --j)
59                     {
60                         if (cho[j] == true) continue;
61                         cur = j; break;
62                     }
63                     // System.out.println(cur+": "+i);
64                     if (cur == -1) { ++i; if (i < d) cho[per[i]] = false; }
65                     else { cho[cur] = true; per[i] = cur; break; }
66                 }
67
68                 if (cur == -1) { exist = false; break; }
69                 safe = true;
70             }
71             else
72             {
73                 if (digit[i] == 0 && i == d-1) { exist = false; break; }
74                 per[i] = digit[i];
75                 cho[digit[i]] = true;
76             }
77         }
78     }
79     // for (int i = d-1; i >= 0; --i) System.out.print(per[i]);
80     // System.out.println();
81     if (!exist) return ret;
82     for (int i = d-1; i >= 0; --i)
83     {
84         int tmp = per[i];
85         for (int j = d-1; j > i; --j)
86             if (per[j] < per[i]) --tmp;
87         ret += jc[i]*tmp%lhh;
88         if (ret >= lhh) ret -= lhh;
89     }
90     ret++; if (ret >= lhh) ret -= lhh;
91     ret -= jc[d-1]; if (ret < 0) ret += lhh;
92     // System.out.println(ret);
93     return ret;
94 }
95
96 public static void main(String args[])
97 {

```

```

98     jc[0] = 1;
99     for (int i = 1; i <= 1650; ++i)
100         jc[i] = jc[i-1]*(long)i%lhh;
101     Scanner cin = new Scanner(System.in);
102     int T = cin.nextInt();
103
104     while (T-- > 0)
105     {
106         BigInteger l = cin.nextBigInteger(), r = cin.nextBigInteger();
107         int ans = calc(r) - calc(l.subtract(BigInteger.ONE));
108         if (ans < 0) ans += lhh; System.out.println(ans);
109     }
110     // calc(BigInteger.valueOf(123455));
111 }
112 }
113
114 //Code 2
115 import java.io.*;
116 import java.util.*;
117 import java.math.*;
118 public class Main
119 {
120     static BigDecimal ratio[] = new BigDecimal[110];
121     public static void main(String[] args)
122     {
123         Scanner cin = new Scanner(System.in);
124         int T = cin.nextInt();
125         for (int Case = 1; Case <= T; ++Case)
126         {
127             int N = cin.nextInt();
128             for (int i = 1; i <= N; ++i)
129             {
130                 String S = cin.next();
131                 String[] str = S.split(":");
132                 BigDecimal a = new BigDecimal(str[0]), b = new BigDecimal(str[1]);
133                 ratio[i] = a.divide(a.add(b), 30, BigDecimal.ROUND_HALF_EVEN);
134             }
135             Arrays.sort(ratio, 1, N+1);
136             BigDecimal res = new BigDecimal(0), _1 = new BigDecimal(1); int ans = 0;
137             for (int i = 1; i <= N; ++i)
138             {
139                 res = res.add(ratio[i]);
140                 if (res.compareTo(_1) < 0) ans = i;
141                 else break;
142             }
143             System.out.println("Case #" + Case + ": " + ans);
144         }
145     }
146 }

```

```

147
148 // Code 3
149 import java.math.*;
150 import java.util.*;
151 public class Main
152 {
153     static BigInteger d,ret,temp,yy;
154     static int n,dd;
155     static boolean mark = true;
156     static BigInteger[] a = new BigInteger[20];
157     public static void main(String[] args)
158     {
159         Scanner in = new Scanner (System.in);
160         n = in.nextInt();
161         temp = BigInteger.ONE;
162         ret = BigInteger.ZERO;
163         for (int i = 0; i < n; ++i)
164         {
165             int k = in.nextInt();
166             a[i] = BigInteger.valueOf(k);
167             d = temp.gcd(a[i]);
168             temp = temp.multiply(a[i]).divide(d);
169         }
170         for (int i = 1; i < (1<n); ++i)
171         {
172             mark = false; yy = BigInteger.ONE;
173             for (int j = 0; j < n; ++j) if (((1 < j) & i) > 0) { mark = !mark; d = a[j].gcd(yy);
↪ yy = yy.multiply(a[j]).divide(d); }
174             if (mark) ret = ret.add(temp.divide(yy));
175             else ret = ret.subtract(temp.divide(yy));
176         }
177         d = ret.gcd(temp);
178         System.out.println(ret.divide(d));
179         System.out.println(temp.divide(d));
180     }
181 }
182
183 // Code 4
184 import java.io.*;
185 import java.math.*;
186 import java.util.*;
187
188 public class Main
189 {
190     public static String reverse(String str) { return new
↪ StringBuffer(str).reverse().toString(); }
191
192     public static void main(String args[])
193     {

```

```

194 Scanner cin = new Scanner(System.in);
195 int T = cin.nextInt(); BigInteger zero = BigInteger.valueOf(0);
196 while (T-- > 0)
197 {
198     int base1 = cin.nextInt(), base2 = cin.nextInt();
199     String S = cin.next(); int len = S.length();
200     System.out.println(base1+" "+S);
201     BigInteger res = BigInteger.valueOf(0), b1 = BigInteger.valueOf(base1), b2 =
↪ BigInteger.valueOf(base2);
202     for (int i = 0; i < len; ++i)
203     {
204         res = res.multiply(b1);
205         int rep = 0;
206         if (S.charAt(i) >= '0' && S.charAt(i) <= '9') rep = S.charAt(i) - '0';
207         else if (S.charAt(i) >= 'A' && S.charAt(i) <= 'Z') rep = 10 + S.charAt(i) - 'A';
208         else rep = 36 + S.charAt(i) - 'a';
209         res = res.add(BigInteger.valueOf(rep));
210     }
211     String ret = new String();
212     // System.out.println(res);
213     if (res.compareTo(zero) == 0) ret += '0';
214     else
215         while (res.compareTo(zero) > 0)
216         {
217             long val = res.remainder(b2).longValue();
218             // System.out.println(val);
219             if (val < 10) ret += (char)(val + '0');
220             else if (val < 36) ret += (char)(val + 'A' - 10);
221             else ret += (char)(val + 'a' - 36);
222             res = res.divide(b2);
223         }
224     System.out.println(base2+" "+reverse(ret)+"\n");
225 }
226 }
227 }

```

8.3 Emacs Configuration-Full

```

1  ;;-----General-----
2  (global-set-key (kbd "M-n") 'forward-paragraph)
3  (global-set-key (kbd "M-p") 'backward-paragraph)
4  (global-set-key (kbd "<C-f12>") 'print-buffer)
5  (global-set-key (kbd "C-`") 'set-mark-command)
6  (global-set-key (kbd "<f5>") 'eshell)
7  ;; 修改透明度
8  (set-frame-parameter (selected-frame) 'alpha (list 78 78))
9  (add-to-list 'default-frame-alist (cons 'alpha (list 78 78)))
10 ;; set the cursor
11 (setq-default cursor-type 'bar)

```

```

12 ;; comment-dwim
13 (defun strong-comment-dwim-line (&optional arg)
14
15   ↪ "Replacement for the comment-dwim command. If no region is selected and current line is not blank and we a
16   (interactive "*P")
17   (comment-normalize-vars)
18   (if (and (not (region-active-p)) (not (looking-at "[\t]*$")))
19       (comment-or-uncomment-region (line-beginning-position) (line-end-position))
20       (comment-dwim arg)))
21 (global-set-key (kbd "M-;") 'strong-comment-dwim-line)
22 ;; Remove tool bar
23 (tool-bar-mode -1)
24 ;; 不要滚动栏，现在都用滚轴鼠标了，可以不用滚动栏了
25 (scroll-bar-mode -1)
26 ;; 设置行号
27 (global-linum-mode t)
28 ;; Change the Title
29 (setq frame-title-format "%b@lmxyy'-emacs")
30 ;; 滚动页面时比较舒服，不要整页的滚动
31 (setq scroll-step 1
32       scroll-margin 3
33       scroll-conservatively 10000)
34 ;; 设置界面 start
35 (if window-system
36     (setq default-frame-alist
37           (append
38             '( (top . 0)
39               (left . 0)
40               (width . 300)
41               (height . 300))
42             default-frame-alist))
43     )
44 ;; 允许 emacs 和外部其他程序的粘贴
45 (setq x-select-enable-clipboard t)
46 ;; 去掉菜单栏，我将 F10 绑定为显示菜单栏，万一什么东西忘了，需要菜单栏了可以摁 F10 调出，再摁 F10 就去掉菜单
47 (menu-bar-mode -1)
48 ;; 显示列号
49 (setq column-number-mode t)
50 ;; 开启语法高亮。
51 (global-font-lock-mode 1)
52 ;; Auto Indent
53 (global-set-key (kbd "RET") 'newline-and-indent)
54
55 ;; -----Tex Mode-----
56 ;; Emacs 加载 Auctex
57 (load "auctex.el" nil t t)
58 (load "preview-latex.el" nil t t)
59 (setq Tex-auto-save t)

```

```

60 (setq Tex-parse-self t)
61 (setq-default Tex-master nil)
62 ;; 设置编译信息
63 (defun compile-xelatex ()
64   (interactive)
65   (compile (format "xelatex -shell-escape %s" (buffer-name))))
66 (global-set-key (kbd "<f6>") 'compile-xelatex)
67 (defun compile-latex ()
68   (interactive)
69   (compile (format "latex -shell-escape %s" (buffer-name))))
70 (global-set-key (kbd "C-<f6>") 'compile-latex)
71
72 ;; -----C++ Mode-----
73 ;; 设置编译信息
74 (defun compile-cpp ()
75   (interactive)
76   (compile (format "g++ -o %s %s -g -lm -Wall -std=c++11" (file-name-sans-extension
77     ↪ (buffer-name))(buffer-name))))
78 (global-set-key (kbd "<f9>") 'compile-cpp)
79 (defun compile-cpp-02 ()
80   (interactive)
81   (compile (format "g++ -o %s %s -g -lm -Wall -std=c++11 -02" (file-name-sans-extension
82     ↪ (buffer-name))(buffer-name))))
83 (global-set-key (kbd "C-<f9>") 'compile-cpp-02)
84 ;; 设置一键调试
85 (global-set-key (kbd "<f8>") 'gud-gdb)
86 ;; 设置 tab 为 4 个空格的宽度
87 (setq c-basic-offset 4)
88 (setq default-tab-width 4)
89
90 ;; -----Java Mode-----
91 ;; 设置编译信息
92 (defun compile-java ()
93   (interactive)
94   (compile (format "javac %s" (buffer-name))))
95 (global-set-key (kbd "<f7>") 'compile-java)
96
97 ;; -----Org Mode-----
98 (setq org-startup-indented t)
99 ;; The following lines are always needed. Choose your own keys.
100 (add-to-list 'auto-mode-alist '("\\.org\\'" . org-mode))
101 (add-hook 'org-mode-hook 'turn-on-font-lock) ; not needed when global-font-lock-mode is on
102 (global-set-key "\C-cl" 'org-store-link)
103 (global-set-key "\C-ca" 'org-agenda)
104 (global-set-key "\C-cb" 'org-iswitchb)
105 ;; Auto-line-breaking
106 ;; 这一句定义一个函数
107 (defun my-org-mode() (setq truncate-lines nil))
108 ;; 把这个函数加入到 `org-mode-hook' 中，这样每次打开 org 文件时都会先执行这个函数

```



```

107 (add-hook 'org-mode-hook 'my-org-mode)
108
109 ;; -----Ido Mode-----
110 ;; 启用 ido 模式
111 (ido-mode t)
112
113 ;; -----Verilog Mode-----
114 ;; 设置编译信息
115 (defun compile-verilog ()
116   (interactive)
117   (compile (format "iverilog -o %s %s" (file-name-sans-extension (buffer-name))(buffer-name))))
118 (global-set-key (kbd "<f12>") 'compile-verilog)
119
120
121 ;; -----Custom Sets-----
122 (custom-set-variables
123   ;; custom-set-variables was added by Custom.
124   ;; If you edit it by hand, you could mess it up, so be careful.
125   ;; Your init file should contain only one such instance.
126   ;; If there is more than one, they won't work right.
127   '(column-number-mode t)
128   '(cua-mode t nil (cua-base))
129   '(inhibit-startup-screen t)
130   '(menu-bar-mode nil)
131   '(tool-bar-mode nil))
132 (custom-set-faces
133   ;; custom-set-faces was added by Custom.
134   ;; If you edit it by hand, you could mess it up, so be careful.
135   ;; Your init file should contain only one such instance.
136   ;; If there is more than one, they won't work right.
137   '(default ((t (:family "Courier 10 Pitch" :foundry "bitstream" :slant normal :weight bold
138   ↪   :height 151 :width normal)))))

```

8.4 Emacs Configuration-Competition

```

1  ;; Default Font: Courier 10 Pitch Bold   Size: 15
2  ;; Remember to set CUA-mode and save your options.
3  (global-set-key (kbd "M-n") 'forward-paragraph)
4  (global-set-key (kbd "M-p") 'backward-paragraph)
5  (global-linum-mode t)
6  (defun compile-cpp ()
7    (interactive)
8    (compile (format "g++ -o %s %s -g -lm -Wall -std=c++11" (file-name-sans-extension
9    ↪   (buffer-name))(buffer-name))))
9  (global-set-key (kbd "<f9>") 'compile-cpp)
10 (global-set-key (kbd "<f8>") 'gud-gdb)
11 (setq default-tab-width 4)
12 (setq c-basic-offset 4)
13 (global-set-key (kbd "RET") 'newline-and-indent)

```