

SOUTH CHINA UNIVERSITY OF TECHNOLOGY

SCUT\_GUGUGU

# TEMPLATE



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# Contents

<b>1</b>	<b>Graph Theory</b>	<b>3</b>
1.1	Shortest Path . . . . .	3
1.1.1	Dijkstra . . . . .	3
1.1.2	SPFA . . . . .	3
1.2	Network Flow . . . . .	4
1.2.1	ISAP . . . . .	4
1.2.2	HLPP . . . . .	5
1.2.3	Dinic . . . . .	6
1.2.4	MCMF . . . . .	7
1.3	Tree Related . . . . .	8
1.3.1	Kruskal . . . . .	8
1.3.2	Prim . . . . .	9
1.3.3	Tree Divide and Conquer . . . . .	9
1.4	LCA . . . . .	11
1.4.1	Tree Decomposition LCA . . . . .	11
1.4.2	Tarjan LCA . . . . .	11
1.5	Tarjan . . . . .	12
1.5.1	SCC . . . . .	12
1.5.2	BCC . . . . .	12
<b>2</b>	<b>Data Structures</b>	<b>14</b>
2.1	Basic Structures . . . . .	14
2.2	Tree Structures . . . . .	14
2.2.1	Tree Decomposition . . . . .	14
2.2.2	Link-Cut Tree . . . . .	16
2.3	Sequence Structures . . . . .	18
2.3.1	Segment Tree . . . . .	18
2.3.2	Splay Tree . . . . .	19
2.4	Persistent Data Structures . . . . .	19
2.4.1	Chairman Tree . . . . .	19
<b>3</b>	<b>String</b>	<b>20</b>
3.1	Basics . . . . .	20
3.1.1	Hash . . . . .	20
3.1.2	KMP && exKMP . . . . .	20
3.1.3	AC Automaton . . . . .	21
3.2	Suffix Related . . . . .	22
3.2.1	Suffix Array . . . . .	22
3.2.2	Suffix Automaton . . . . .	23
3.3	Palindrome Related . . . . .	23
3.3.1	Manacher . . . . .	23

3.3.2	Palindromic Tree . . . . .	23
<b>4</b>	<b>Math</b>	<b>24</b>
4.1	Algebra . . . . .	24
4.1.1	FFT . . . . .	24
4.1.2	NTT . . . . .	24
4.2	Math Theory . . . . .	25
4.2.1	CRT && exCRT . . . . .	25
<b>5</b>	<b>Computational Geometry</b>	<b>27</b>
5.1	Commonly Definition and Functions . . . . .	27
5.1.1	Const and Functions . . . . .	27
5.1.2	Point Definition . . . . .	27
5.1.3	Line Definition . . . . .	27
5.1.4	Get Area . . . . .	28
5.1.5	Get Circumference . . . . .	28
5.2	Convex Hull . . . . .	28
5.3	Half Plane Intersection . . . . .	29
5.4	Min Circle Cover . . . . .	29
<b>6</b>	<b>Others</b>	<b>31</b>
6.1	sample . . . . .	31
6.1.1	vimrc . . . . .	31
6.1.2	FastIO . . . . .	31
6.2	Offline Algorithm . . . . .	32
6.2.1	CDQ Divide and Conquer . . . . .	32
6.2.2	Mo's Algorithm . . . . .	33
6.2.3	Mo's Algorithm On Tree . . . . .	33
6.3	Randomized Algorithm . . . . .	33
6.3.1	Simulated Annealing . . . . .	33

# 1 Graph Theory

## 1.1 Shortest Path

### 1.1.1 Dijkstra

```

1  typedef pair<int, int> P;
2  struct Edge {
3      int to, nxt;
4      LL w;
5  }e[MAXM];
6  int head[MAXN], ecnt;
7  LL d[MAXN];
8  priority_queue<P, vector<P>, greater<P> > q;
9  inline void addEdge(int x, int y, LL w) {
10     e[++ecnt] = (Edge) {y, head[x], w}; head[x] = ecnt;
11 }
12 void dijkstra(int st) {
13     memset(d, 0x3f, sizeof(d));
14     d[st] = 0;
15     q.push(make_pair(0, st));
16     while(!q.empty()) {
17         P x = q.top(); q.pop();
18         int u = x.second;
19         for(int i = head[u], v; i; i = e[i].nxt) {
20             v = e[i].to;
21             if(d[v] > d[u] + e[i].w) {
22                 d[v] = d[u] + e[i].w;
23                 q.push(make_pair(d[v], v));
24             }
25         }
26     }
27 }

```

### 1.1.2 SPFA

```

1  struct Edge {
2      int to, nxt;
3      LL w;
4  }e[MAXE];
5  int head[MAXN], ecnt;
6  LL d[MAXN];
7  bool exist[MAXN];
8  queue<int> q;
9  inline void addEdge(int x, int y, LL w) {
10     e[++ecnt] = (Edge) {y, head[x], w}; head[x] = ecnt;
11 }
12 void SPFA(int st) {
13     memset(d, 0x3f, sizeof(d));
14     d[st] = 0;
15     q.push(st);
16     exist[st] = 1;
17     while(!q.empty()) {
18         int u = q.front(); q.pop();
19         exist[u] = 0;
20         for(int i = head[u], v; i; i = e[i].nxt) {
21             v = e[i].to;
22             if(d[v] > d[u] + e[i].w) {

```

```

23         d[v] = d[u] + e[i].w;
24         //pre[v] = u;
25         if(!exist[v]) {
26             q.push(v);
27             exist[v] = 1;
28         }
29     }
30 }
31 }
32 }

```

## 1.2 Network Flow

### 1.2.1 ISAP

```

1 namespace NWF {
2     struct Edge{
3         int to, nxt; LL f;
4     }e[MAXM << 1];
5     int S, T, tot;
6     int ecnt, head[MAXN], cur[MAXN], pre[MAXN], num[MAXN], dis[MAXN];
7     queue<int> q;
8     void init(int _S, int _T, int _tot){
9         ecnt = 1; S = _S; T = _T; tot = _tot;
10        memset(num, 0, (tot + 1) * sizeof(int));
11        memset(head, 0, (tot + 1) * sizeof(int));
12    }
13    inline void addEdge(int u, int v, LL f) {
14        e[++ecnt] = (Edge) {v, head[u], f}; head[u] = ecnt;
15        e[++ecnt] = (Edge) {u, head[v], 0}; head[v] = ecnt;
16    }
17    void bfs() {
18        memset(dis, 0, (tot + 1) * sizeof(int));
19        q.push(T);
20        dis[T] = 1;
21        while(!q.empty()) {
22            int u = q.front(), v; q.pop();
23            num[dis[u]]++;
24            for(int i = cur[u] = head[u]; i; i = e[i].nxt) {
25                if(!dis[v = e[i].to]) {
26                    dis[v] = dis[u] + 1;
27                    q.push(v);
28                }
29            }
30        }
31    }
32    LL augment() {
33        LL flow = INF;
34        for(int i = S; i != T; i = e[cur[i]].to)
35            flow = min(flow, e[cur[i]].f);
36        for(int i = S; i != T; i = e[cur[i]].to) {
37            e[cur[i]].f -= flow;
38            e[cur[i] ^ 1].f += flow;
39        }
40        return flow;
41    }
42    LL isap() {
43        bfs();
44        int u = S, v;

```

```

45     LL flow = 0;
46     while(dis[S] <= tot) {
47         if(u == T) {
48             flow += augment();
49             u = S;
50         }
51         bool fg = 0;
52         for(int i = cur[u]; i; i = e[i].nxt) {
53             if(e[i].f && dis[u] > dis[v = e[i].to]) {
54                 pre[v] = u;
55                 cur[u] = i;
56                 u = v;
57                 fg = 1;
58                 break;
59             }
60         }
61         if(fg) continue;
62         if(!--num[dis[u]]) break;
63         int maxDis = tot;
64         for(int i = head[u]; i; i = e[i].nxt) {
65             if(e[i].f && maxDis > dis[v = e[i].to]) {
66                 maxDis = dis[v];
67                 cur[u] = i;
68             }
69         }
70         num[dis[u] = maxDis + 1]++;
71         if(u != S) u = pre[u];
72     }
73     return flow;
74 }
75 }

```

### 1.2.2 HLPP

```

1 namespace NWF{
2     struct Edge{
3         int to,nxt;LL f;
4     }e[MAXM << 1];
5     int S, T, tot;
6     int ecnt, head[MAXN], dis[MAXN], num[MAXN];
7     LL sumf[MAXN];
8     queue<int> q;
9     list<int> dep[MAXN];
10    void init(int _S,int _T,int _tot){
11        ecnt = 1;S = _S;T = _T;tot = _tot;
12        memset(num, 0, (tot + 1) * sizeof(int));
13        memset(head, 0, (tot + 1) * sizeof(int));
14        memset(sumf, 0, (tot + 1) * sizeof(LL));
15    }
16    void addEdge(int u,int v,LL f){
17        e[++ecnt] = (Edge) {v, head[u], f};head[u] = ecnt;
18        e[++ecnt] = (Edge) {u, head[v], 0};head[v] = ecnt;
19    }
20    void bfs(){
21        memset(dis, 0, (tot + 1) * sizeof(int));
22        q.push(T); dis[T] = 1;
23        while(!q.empty()){
24            int u=q.front(), v; q.pop();
25            for(int i = head[u]; i; i = e[i].nxt)
26                if(!dis[v = e[i].to]){

```

```

27         dis[v] = dis[u] + 1;
28         q.push(v);
29     }
30 }
31 }
32 LL hlpp(){
33     bfs();
34     dis[S] = tot + 1;
35     for(int i = 1; i <= tot; ++i) num[dis[i]]++;
36     for(int i = tot + 1; ~i; --i) dep[i].clear();
37     int maxd = dis[S]; LL f;
38     dep[maxd].push_back(S); sumf[S] = INF;
39     for(;;){
40         while(maxd && dep[maxd].empty()) maxd--;
41         if(!maxd) break;
42         int u = dep[maxd].back(), v; dep[maxd].pop_back();
43         int minDis = tot + 1;
44         for(int i = head[u]; i; i = e[i].nxt)
45             if(e[i].f){
46                 if(dis[u] > dis[v = e[i].to]){
47                     f = min(sumf[u], e[i].f);
48                     e[i].f -= f; e[i^1].f += f;
49                     if(sumf[u] != INF) sumf[u] -= f;
50                     if(sumf[v] != INF) sumf[v] += f;
51                     if(v != S && v != T && sumf[v] == f){
52                         maxd = max(maxd, dis[v]);
53                         dep[dis[v]].push_back(v);
54                     }
55                     if(!sumf[u]) break;
56                 } else minDis = min(minDis, dis[v] + 1);
57             }
58         if(sumf[u]){
59             if(--num[dis[u]]){
60                 for(int i = dis[u]; i <= maxd; ++i){
61                     while(!dep[i].empty()){
62                         --num[i];
63                         dis[dep[i].back()] = tot + 1;
64                         dep[i].pop_back();
65                     }
66                 }
67                 maxd = dis[u] - 1; dis[u] = tot + 1;
68             } else {
69                 dis[u] = minDis;
70                 if(minDis > tot) continue;
71                 num[minDis]++;
72                 maxd = max(maxd, minDis);
73                 dep[minDis].push_back(u);
74             }
75         }
76     }
77     return sumf[T];
78 }
79 }

```

### 1.2.3 Dinic

```

1 namespace NWF {
2     struct Edge {
3         int to, nxt; LL f;
4     } e[MAXM << 1];

```

```

5  int S, T, tot;
6  int ecnt, head[MAXN], cur[MAXN], dis[MAXN];
7  queue<int> q;
8  void init(int _S, int _T, int _tot){
9      ecnt = 1; S = _S; T = _T; tot = _tot;
10     memset(head, 0, (tot + 1) * sizeof(int));
11 }
12 void addEdge(int u, int v, LL f) {
13     e[++ecnt] = (Edge) {v, head[u], f}; head[u] = ecnt;
14     e[++ecnt] = (Edge) {u, head[v], 0}; head[v] = ecnt;
15 }
16 bool bfs() {
17     memset(dis, 0, (tot + 1) * sizeof(int));
18     q.push(S); dis[S] = 1;
19     while (!q.empty()) {
20         int u = q.front(), v; q.pop();
21         for (int i = cur[u] = head[u]; i; i = e[i].nxt) {
22             if (e[i].f && !dis[v = e[i].to]) {
23                 q.push(v);
24                 dis[v] = dis[u] + 1;
25             }
26         }
27     }
28     return dis[T];
29 }
30 LL dfs(int u, LL maxf) {
31     if (u == T) return maxf;
32     LL sumf = maxf;
33     for (int &i = cur[u]; i; i = e[i].nxt) {
34         if (e[i].f && dis[e[i].to] > dis[u]) {
35             LL tmpf = dfs(e[i].to, min(sumf, e[i].f));
36             e[i].f -= tmpf; e[i ^ 1].f += tmpf;
37             sumf -= tmpf;
38             if (!sumf) return maxf;
39         }
40     }
41     return maxf - sumf;
42 }
43 LL dinic() {
44     LL ret = 0;
45     while (bfs()) ret += dfs(S, INF);
46     return ret;
47 }
48 }

```

#### 1.2.4 MCMF

```

1  namespace NWF{
2      struct Edge {
3          int to, nxt; LL f, c;
4      } e[MAXM << 1];
5      int S, T, tot;
6      int ecnt, head[MAXN], cur[MAXN]; LL dis[MAXN];
7      bool exist[MAXN];
8      queue<int> q;
9      void init(int _S, int _T, int _tot){
10         ecnt = 1; S = _S; T = _T; tot = _tot;
11         memset(head, 0, (tot + 1) * sizeof(int));
12     }
13     void addEdge(int u, int v, LL f, LL c) {

```



```

14     e[++ecnt] = (Edge) {v, head[u], f, c}; head[u] = ecnt;
15     e[++ecnt] = (Edge) {u, head[v], 0, -c}; head[v] = ecnt;
16 }
17 bool spfa() {
18     for(int i = 0; i <= tot; ++i){
19         dis[i] = INF; exist[i] = cur[i] = 0;
20     }
21     q.push(S); dis[S] = 0; exist[S] = 1;
22     while(!q.empty()) {
23         int u = q.front(), v; q.pop(); exist[u] = 0;
24         for(int i = head[u]; i; i = e[i].nxt) {
25             if(e[i].f && dis[v = e[i].to] > dis[u] + e[i].c) {
26                 dis[v] = dis[u] + e[i].c;
27                 cur[v] = i;
28                 if(!exist[v]) {
29                     q.push(v);
30                     exist[v] = 1;
31                 }
32             }
33         }
34     }
35     return dis[T] != INF;
36 }
37 LL mcmf() {
38     LL cost = 0;
39     while(spfa()) {
40         LL flow = INF;
41         for(int i = T; i != S; i = e[cur[i] ^ 1].to)
42             flow = min(flow, e[cur[i]].f);
43         for(int i = T; i != S; i = e[cur[i] ^ 1].to) {
44             e[cur[i]].f -= flow;
45             e[cur[i] ^ 1].f += flow;
46         }
47         cost += flow * dis[T];
48     }
49     return cost;
50 }
51 }

```

## 1.3 Tree Related

### 1.3.1 Kruskal

```

1 namespace MST{
2     struct Edge{
3         int u,v; LL w;
4         bool operator < (const Edge& x) const { return w < x.w; }
5     }e[MAXM];
6     int ecnt, fa[MAXN];
7     void addEdge(int u, int v, LL w) {
8         e[++ecnt] = (Edge){v, u, w}; headp[u] = ecnt;
9     }
10    int Find(int x) { return x == fa[x] ? x : fa[x] = Find(fa[x]); }
11    LL kruskal(int n) {
12        sort(e + 1, e + ecnt + 1);
13        for(int i = 1; i <= n; i++) fa[i] = i;
14        LL sum = 0;
15        for (int i = 1; i <= ecnt; i++){
16            int fu = Find(e[i].u), fv = Find(e[i].v);

```

```

17         if(fu != fv){
18             fa[fu] = fv;
19             sum += e[i].w;
20         }
21     }
22     return sum;
23 }
24 }

```

### 1.3.2 Prim

```

1 namespace MST {
2     struct Edge{
3         int to,nxt; LL w;
4     }e[MAXM];
5     int ecnt, head[MAXN], vis[MAXN]; // pre[MAXN];
6     LL dis[MAXN];
7     void addEdge(int u, int v, LL w){
8         e[++ecnt] = (Edge){v, head[u], w}; head[u] = ecnt;
9         e[++ecnt] = (Edge){u, head[v], w}; head[v] = ecnt;
10    }
11    LL Prim(int n){
12        for (int i = 1; i <= n; i++){
13            //pre[i] = 0;
14            vis[i] = 0;
15            dis[i] = INF;
16        }
17        vis[1] = 1;
18        LL sum = 0;
19        for (int i = head[1]; i; i = e[i].nxt)
20            dis[e[i].to] = min(dis[e[i].to], e[i].w);
21        for (int j = 1; j < n; j++){
22            int u; LL minDis = INF;
23            for (int i = 1; i <= n; ++i)
24                if (!vis[i] && dis[i] < minDis){
25                    minDis = dis[i];
26                    u = i;
27                }
28            if (minDis == INF) return -1;
29            vis[u] = 1;
30            sum += minDis;
31            for (int i = head[u], v; i; i = e[i].nxt)
32                if (!vis[v = e[i].to] && e[i].w < dis[v]){
33                    //pre[u] = v;
34                    dis[v] = e[i].w;
35                }
36        }
37        return sum;
38    }
39 }

```

### 1.3.3 Tree Divide and Conquer

```

1 struct Edge {
2     int to, nxt, w;
3 }e[MAXM];
4 int head[MAXN], ecnt;
5 int sz[MAXN];

```

```

6  int d[MAXN], t[5], ans;
7  bool vis[MAXN];
8  inline void add_edge(int u, int v, int w) {
9      e[++ecnt] = (Edge) {v, h[u], w}; head[u] = ecnt;
10     e[++ecnt] = (Edge) {u, h[v], w}; head[v] = ecnt;
11 }
12 int getsz(int x, int fa) {
13     sz[x] = 1;
14     for(int i = h[x]; i; i = e[i].nxt) {
15         int y = e[i].to;
16         if(vis[y] || y == fa) continue;
17         sz[x] += getsz(y, x);
18     }
19     return sz[x];
20 }
21 int getrt(int x) {
22     int tot = getsz(x, 0) >> 1;
23     while(1) {
24         int u = -1;
25         for(int i = h[x]; i; i = e[i].nxt) {
26             int y = e[i].to;
27             if(vis[y] || sz[y] > sz[x]) continue;
28             if(u == -1 || sz[y] > sz[u]) u = y;
29         }
30         if(~u && sz[u] > tot) x = u;
31         else break;
32     }
33     return x;
34 }
35 void getdep(int x, int fa) {
36     t[d[x]]++;
37     for(int i = h[x]; i; i = e[i].nxt) {
38         int y = e[i].to;
39         if(vis[y] || y == fa) continue;
40         d[y] = (d[x] + e[i].w) % 3;
41         getdep(y, x);
42     }
43 }
44 int cal(int x, int v) {
45     t[0] = t[1] = t[2] = 0;
46     d[x] = v % 3;
47     getdep(x, 0);
48     return t[0] * t[0] + t[1] * t[2] * 2;
49 }
50 void solve(int x) {
51     vis[x] = 1;
52     ans += cal(x, 0);
53     for(int i = h[x]; i; i = e[i].nxt) {
54         int y = e[i].to;
55         if(vis[y]) continue;
56         ans -= cal(y, e[i].w);
57         solve(getrt(y));
58     }
59 }
60 int main() {
61     solve(getrt(1));
62 }

```

## 1.4 LCA

### 1.4.1 Tree Decomposition LCA

```

1  int sz[MAXN], dep[MAXN], top[MAXN], fa[MAXN], son[MAXN], num[MAXN], totw;
2  struct Edge {
3      int to, nxt;
4  } e[MAXN << 1];
5  int head[MAXN], ecnt;
6  inline void add_edge(int x, int y) {
7      e[++ecnt] = (Edge) {y, head[x]}; head[x] = ecnt;
8  }
9  void dfs1(int x) {
10     sz[x] = 1; son[x] = 0;
11     for(int i = head[x]; i; i = e[i].nxt) {
12         int v = e[i].to;
13         if(v == fa[x]) continue;
14         fa[v] = x;
15         dep[v] = dep[x] + 1;
16         dfs1(v);
17         sz[x] += sz[v];
18         if(sz[v] > sz[son[x]]) son[x] = v;
19     }
20 }
21 void dfs2(int x) {
22     B[num[x]] = A[x];
23     if(son[x]) {
24         top[son[x]] = top[x];
25         num[son[x]] = ++totw;
26         dfs2(son[x]);
27     }
28     for(int i = head[x]; i; i = e[i].nxt) {
29         int v = e[i].to;
30         if(v == fa[x] || v == son[x]) continue;
31         top[v] = v;
32         num[v] = ++totw;
33         dfs2(v);
34     }
35 }
36 int lca(int u, int v) {
37     if(u == v) return u;
38     while(top[u] != top[v]) {
39         if(dep[top[u]] > dep[top[v]]) swap(u, v);
40         v = fa[top[v]];
41     }
42     if(dep[u] > dep[v]) swap(u, v);
43     return u;
44 }
45 inline void init() {
46     memset(head, 0, sizeof(head)); ecnt = 0;
47     fa[1] = 0; dep[1] = 1; top[1] = 1; num[1] = 1; totw = 1;
48 }
49 inline void pre() {
50     dfs1(1); dfs2(1);
51 }

```

### 1.4.2 Tarjan LCA

## 1.5 Tarjan

### 1.5.1 SCC

```

1 namespace SCC{
2     vector<int> G[MAXN];
3     int dfs_clock, scc_cn, dfn[MAXN], low[MAXN], sccno[MAXN];
4     stack<int> S;
5     void addEdge(int u, int v) {
6         G[u].push_back(v);
7     }
8     void tarjan(int u) {
9         dfn[u] = low[u] = ++dfs_clock;
10        S.push(u);
11        for(auto v : G[u]) {
12            if(!dfn[v]) {
13                tarjan(v);
14                low[u] = min(low[u], low[v]);
15            } else if(!sccno[v]) {
16                low[u] = min(low[u], dfn[v]);
17            }
18        }
19        if(dfn[u] == low[u]) {
20            scc_cnt++;
21            for(;;) {
22                int v = S.top(); S.pop();
23                sccno[v] = scc_cnt;
24                if(v == u) break;
25            }
26        }
27    }
28    void findSCC(int n) {
29        for(int i = 1; i <= n; i++)
30            if(!dfn[i]) tarjan(i);
31    }
32    void init(int n){
33        dfs_clock = scc_cnt = 0;
34        for(int i = 0; i <= n; ++i){
35            dfn[i] = low[i] = sccno[i] = 0;
36            G[i].clear();
37        }
38    }
39 }

```

### 1.5.2 BCC

```

1 struct Edge {
2     int to, nxt;
3 }e[MAXE];
4 struct Node {
5     int u, v;
6 };
7 int head[MAXN], ecnt;
8 int pre[MAXN], low[MAXN], iscut[MAXN], bccno[MAXN], dfs_clock, bcc_cnt;
9 vector<int> bcc[MAXN];
10 stack<Node> S;
11 inline void add_edge(int x, int y) {
12     e[++ecnt] = (Edge) {y, head[x]}; head[x] = ecnt;
13     e[++ecnt] = (Edge) {x, head[y]}; head[y] = ecnt;

```

```

14 }
15 inline void init() {
16     memset(pre, 0, sizeof(pre));
17     memset(low, 0, sizeof(low));
18     memset(bccno, 0, sizeof(bccno));
19     memset(iscut, 0, sizeof(iscut));
20     memset(head, 0, sizeof(head)); ecnt = 0;
21     dfs_clock = bcc_cnt = 0;
22 }
23 void tarjan(int u, int fa) {
24     low[u] = pre[u] = ++dfs_clock;
25     int ch = 0;
26     for(int i = head[u]; i; i = e[i].nxt) {
27         int v = e[i].to;
28         if(!pre[v]) {
29             S.push((Node) {u, v});
30             ch++;
31             tarjan(v, u);
32             low[u] = min(low[u], low[v]);
33             if(low[v] >= pre[u]) {
34                 iscut[u] = 1;
35                 bcc[bcc_cnt++].clear();
36                 for(;;) {
37                     Node x = S.top(); S.pop();
38                     if(bccno[x.u] != bcc_cnt) {
39                         bcc[bcc_cnt].push_back(x.u);
40                         bccno[x.u] = bcc_cnt;
41                     }
42                     if(bccno[x.v] != bcc_cnt) {
43                         bcc[bcc_cnt].push_back(x.v);
44                         bccno[x.v] = bcc_cnt;
45                     }
46                     if(x.u == u && x.v == v) break;
47                 }
48             }
49         }
50         else if(pre[v] < pre[u] && v != fa) {
51             S.push((Node) {u, v});
52             low[u] = min(low[u], pre[v]);
53         }
54     }
55     if(u == fa && ch <= 1) iscut[u] = 0;
56 }

```

## 2 Data Structures

### 2.1 Basic Structures

### 2.2 Tree Structures

#### 2.2.1 Tree Decomposition

```

1  int sz[MAXN], dep[MAXN], top[MAXN], fa[MAXN], son[MAXN], num[MAXN], totw;
2  struct Edge {
3      int to, nxt;
4  }e[MAXN << 1];
5  int head[MAXN], ecnt;
6  int n, m, Q;
7  #define Ls(x) (x << 1)
8  #define Rs(x) (x << 1 | 1)
9  struct Tree {
10     int l, r, lazy;
11     LL sum, mx;
12 }tree[MAXN << 2];
13 int A[MAXN], B[MAXN];
14 void push_up(int x) {
15     tree[x].sum = tree[Ls(x)].sum + tree[Rs(x)].sum;
16     tree[x].mx = max(tree[Ls(x)].mx, tree[Rs(x)].mx);
17 }
18 void push_down(int x) {
19     if(tree[x].lazy) {
20         tree[Ls(x)].sum += tree[x].lazy * (tree[Ls(x)].r - tree[Ls(x)].l + 1);
21         tree[Rs(x)].sum += tree[x].lazy * (tree[Rs(x)].r - tree[Rs(x)].l + 1);
22         tree[Ls(x)].mx += tree[x].lazy;
23         tree[Rs(x)].mx += tree[x].lazy;
24         tree[Ls(x)].lazy += tree[x].lazy;
25         tree[Rs(x)].lazy += tree[x].lazy;
26         tree[x].lazy = 0;
27     }
28 }
29 void build(int x, int L, int R) {
30     tree[x].lazy = 0;
31     tree[x].l = L; tree[x].r = R;
32     if(L == R) {
33         tree[x].sum = B[L];
34         tree[x].mx = B[L];
35         return;
36     }
37     int mid = (L + R) >> 1;
38     build(Ls(x), L, mid);
39     build(Rs(x), mid + 1, R);
40     push_up(x);
41 }
42 void update(int x, int L, int R, LL val) {
43     if(tree[x].l >= L && tree[x].r <= R) {
44         tree[x].lazy += val;
45         tree[x].sum += val * (tree[x].r - tree[x].l + 1);
46         tree[x].mx += val;
47         return;
48     }
49     push_down(x);

```

```

50     int mid = (tree[x].l + tree[x].r) >> 1;
51     if(L <= mid) update(Ls(x), L, R, val);
52     if(R > mid) update(Rs(x), L, R, val);
53     push_up(x);
54 }
55 LL query(int x, int L, int R) {
56     if(tree[x].l >= L && tree[x].r <= R)
57         return tree[x].sum;
58     push_down(x);
59     int mid = (tree[x].l + tree[x].r) >> 1;
60     LL res = 0;
61     if(L <= mid) res += query(Ls(x), L, R);
62     if(R > mid) res += query(Rs(x), L, R);
63     return res;
64 }
65 LL query2(int x, int L, int R) {
66     if(tree[x].l >= L && tree[x].r <= R)
67         return tree[x].mx;
68     push_down(x);
69     int mid = (tree[x].l + tree[x].r) >> 1;
70     LL res = -INF;
71     if(L <= mid) res = max(res, query2(Ls(x), L, R));
72     if(R > mid) res = max(res, query2(Rs(x), L, R));
73     return res;
74 }
75 inline void add_edge(int x, int y) {
76     e[++ecnt] = (Edge) {y, head[x]}; head[x] = ecnt;
77 }
78 void dfs1(int x) {
79     sz[x] = 1; son[x] = 0;
80     for(int i = head[x]; i; i = e[i].nxt) {
81         int v = e[i].to;
82         if(v == fa[x]) continue;
83         fa[v] = x;
84         dep[v] = dep[x] + 1;
85         dfs1(v);
86         sz[x] += sz[v];
87         if(sz[v] > sz[son[x]]) son[x] = v;
88     }
89 }
90 void dfs2(int x) {
91     B[num[x]] = A[x];
92     if(son[x]) {
93         top[son[x]] = top[x];
94         num[son[x]] = ++totw;
95         dfs2(son[x]);
96     }
97     for(int i = head[x]; i; i = e[i].nxt) {
98         int v = e[i].to;
99         if(v == fa[x] || v == son[x]) continue;
100         top[v] = v;
101         num[v] = ++totw;
102         dfs2(v);
103     }
104 }
105 void up(int a, int b, int c) {
106     int f1 = top[a], f2 = top[b];
107     while(f1 != f2) {
108         if(dep[f1] < dep[f2]) { swap(a, b); swap(f1, f2); }
109         update(1, num[f1], num[a], c);
110         a = fa[f1];

```



```

111     f1 = top[a];
112 }
113 if(dep[a] > dep[b]) swap(a, b);
114 update(1, num[a], num[b], c);
115 }
116 int qsum(int a, int b) {
117     if(a == b) return query(1, num[a], num[a]);
118     int f1 = top[a], f2 = top[b];
119     int res = 0;
120     while(f1 != f2) {
121         if(dep[f1] < dep[f2]) { swap(a, b); swap(f1, f2); }
122         res += query(1, num[f1], num[a]);
123         a = fa[f1];
124         f1 = top[a];
125     }
126     if(dep[a] > dep[b]) swap(a, b);
127     res += query(1, num[a], num[b]);
128     return res;
129 }
130 int qmax(int a, int b) {
131     if(a == b) return query2(1, num[a], num[a]);
132     int f1 = top[a], f2 = top[b];
133     int res = -1000000000;
134     while(f1 != f2) {
135         if(dep[f1] < dep[f2]) { swap(a, b); swap(f1, f2); }
136         res = max(res, query2(1, num[f1], num[a]));
137         a = fa[f1];
138         f1 = top[a];
139     }
140     if(dep[a] > dep[b]) swap(a, b);
141     res = max(res, query2(1, num[a], num[b]));
142     return res;
143 }
144 inline void init() {
145     memset(head, 0, sizeof(head)); ecnt = 0;
146     fa[1] = 0; dep[1] = 1; top[1] = 1; num[1] = 1; totw = 1;
147 }
148 inline void pre() {
149     dfs1(1); dfs2(1); build(1, 1, totw);
150 }

```

## 2.2.2 Link-Cut Tree

```

1 namespace LCT {
2     int fa[MAXN], rev[MAXN], tr[MAXN][2];
3     int s[MAXN], val[MAXN];
4     void push_up(int x) {
5         int l = tr[x][0], r = tr[x][1];
6         s[x] = s[l] + s[r] + val[x];
7     }
8     void Rev(int x) {
9         rev[x] ^= 1; swap(tr[x][0], tr[x][1]);
10    }
11    void push_down(int x) {
12        if(!rev[x]) return;
13        int l = tr[x][0], r = tr[x][1];
14        rev[x] = 0;
15        if(l) Rev(l); if(r) Rev(r);
16    }
17    bool isroot(int x) {

```

```

18     return tr[fa[x]][0] != x && tr[fa[x]][1] != x;
19 }
20 void pre(int x) {
21     if(!isroot(x)) pre(fa[x]);
22     push_down(x);
23 }
24 void rotate(int x) {
25     int y = fa[x]; int z = fa[y];
26     int l = tr[y][1] == x;
27     int r = l ^ 1;
28     if(!isroot(y)) tr[z][tr[z][1] == y] = x;
29     fa[x] = z; fa[y] = x; fa[tr[x][r]] = y;
30     tr[y][l] = tr[x][r]; tr[x][r] = y;
31     push_up(y);
32 }
33 void splay(int x) {
34     pre(x);
35     int y, z;
36     while(!isroot(x)) {
37         y = fa[x]; z = fa[y];
38         if(!isroot(y)) {
39             if((tr[z][0] == y) == (tr[y][0] == x)) rotate(y);
40             else rotate(x);
41         }
42         rotate(x);
43     }
44     push_up(x);
45 }
46 void access(int x) {
47     int y = 0;
48     while(x) {
49         splay(x); tr[x][1] = y;
50         push_up(x);
51         y = x; x = fa[x];
52     }
53 }
54 void makeroot(int x) {
55     access(x); splay(x); Rev(x);
56 }
57 void lnk(int x, int y) {
58     makeroot(x); fa[x] = y;
59 }
60 void cut(int x, int y) {
61     makeroot(x); access(y); splay(y);
62     tr[y][0] = fa[x] = 0; push_up(y);
63 }
64 void update(int x, int y) {
65     makeroot(x); val[x] = y; push_up(x);
66 }
67 int query(int x, int y) {
68     makeroot(x); access(y); splay(y);
69     return s[y];
70 }
71 bool check(int x, int y) {
72     int tmp = y;
73     makeroot(x); access(y); splay(x);
74     while(!isroot(y)) y = fa[y];
75     splay(tmp);
76     return x == y;
77 }
78 }

```

## 2.3 Sequence Structures

### 2.3.1 Segment Tree

```

1  #define Ls(x) (x << 1)
2  #define Rs(x) (x << 1 | 1)
3  struct Tree {
4      int l, r, lazy;
5      LL sum, mx;
6  } tree[MAXN << 2];
7  int A[MAXN];
8  void push_up(int x) {
9      tree[x].sum = tree[Ls(x)].sum + tree[Rs(x)].sum;
10     tree[x].mx = max(tree[Ls(x)].mx, tree[Rs(x)].mx);
11 }
12 void push_down(int x) {
13     if(tree[x].lazy) {
14         tree[Ls(x)].sum += tree[x].lazy * (tree[Ls(x)].r - tree[Ls(x)].l + 1);
15         tree[Rs(x)].sum += tree[x].lazy * (tree[Rs(x)].r - tree[Rs(x)].l + 1);
16         tree[Ls(x)].mx += tree[x].lazy;
17         tree[Rs(x)].mx += tree[x].lazy;
18         tree[Ls(x)].lazy += tree[x].lazy;
19         tree[Rs(x)].lazy += tree[x].lazy;
20         tree[x].lazy = 0;
21     }
22 }
23 void build(int x, int L, int R) {
24     tree[x].lazy = 0;
25     tree[x].l = L; tree[x].r = R;
26     if(L == R) {
27         tree[x].sum = A[L];
28         tree[x].mx = A[L];
29         return;
30     }
31     int mid = (L + R) >> 1;
32     build(Ls(x), L, mid);
33     build(Rs(x), mid + 1, R);
34     push_up(x);
35 }
36 void update(int x, int L, int R, LL val) {
37     if(tree[x].l >= L && tree[x].r <= R) {
38         tree[x].lazy += val;
39         tree[x].sum += val * (tree[x].r - tree[x].l + 1);
40         tree[x].mx += val;
41         return;
42     }
43     push_down(x);
44     int mid = (tree[x].l + tree[x].r) >> 1;
45     if(L <= mid) update(Ls(x), L, R, val);
46     if(R > mid) update(Rs(x), L, R, val);
47     push_up(x);
48 }
49 LL query(int x, int L, int R) {
50     if(tree[x].l >= L && tree[x].r <= R)
51         return tree[x].sum;
52     push_down(x);
53     int mid = (tree[x].l + tree[x].r) >> 1;
54     LL res = 0;
55     if(L <= mid) res += query(Ls(x), L, R);
56     if(R > mid) res += query(Rs(x), L, R);

```

```

57     return res;
58 }
59 LL query2(int x, int L, int R) {
60     if(tree[x].l >= L && tree[x].r <= R)
61         return tree[x].mx;
62     push_down(x);
63     int mid = (tree[x].l + tree[x].r) >> 1;
64     LL res = -INF;
65     if(L <= mid) res = max(res, query2(Ls(x), L, R));
66     if(R > mid) res = max(res, query2(Rs(x), L, R));
67     return res;
68 }

```

### 2.3.2 Splay Tree

## 2.4 Persistent Data Structures

### 2.4.1 Chairman Tree

```

1 struct Node {
2     int l, r;
3     LL sum;
4 } t[MAXN * 40];
5 int cnt, n;
6 int rt[MAXN];
7 void update(int pre, int &x, int l, int r, int v) {
8     x = ++cnt; t[x] = t[pre]; t[x].sum++;
9     if(l == r) return;
10    int mid = (l + r) >> 1;
11    if(v <= mid) update(t[pre].l, t[x].l, l, mid, v);
12    else update(t[pre].r, t[x].r, mid + 1, r, v);
13 }
14 int query(int x, int y, int l, int r, int v) {
15     if(l == r) return l;
16     int mid = (l + r) >> 1;
17     int sum = t[t[y].l].sum - t[t[x].l].sum;
18     if(sum >= v) return query(t[x].l, t[y].l, l, mid, v);
19     else return query(t[x].r, t[y].r, mid + 1, r, v - sum);
20 }

```

## 3 String

### 3.1 Basics

#### 3.1.1 Hash

```

1  const LL p1 = 201, p2 = 301, mod1 = 1200000319, mod2 = 2147483647;
2  struct Hash {
3      LL a, b;
4      void append(Hash pre, int v) {
5          a = (pre.a * p1 + v) % mod1;
6          b = (pre.b * p2 + v) % mod2;
7      }
8      void init(string S) {
9          a = b = 0;
10         for(int i = 0; i < S.size(); i++) append(*this, S[i]);
11     }
12     bool operator == (const Hash &x) const {
13         return a == x.a && b == x.b;
14     }
15     bool operator < (const Hash &x) const {
16         return a < x.a || (a == x.a && b < x.b);
17     }
18 };

```

#### 3.1.2 KMP && exKMP

```

1  namespace KMP {
2      int f[MAXN];
3      void get_fail(string A) {
4          f[0] = 0; f[1] = 0;
5          for(int i = 1; i < A.size(); i++) {
6              int j = f[i];
7              while(j && A[i] != A[j]) j = f[j];
8              f[i + 1] = A[i] == A[j] ? j + 1 : 0;
9          }
10     }
11
12     void kmp(string A, string B) {
13         get_fail(B);
14         int j = 0;
15         for(int i = 0; i < A.size(); i++) {
16             while(j && B[j] != A[i]) j = f[j];
17             if(B[j] == A[i]) j++;
18             if(j == B.size()) {
19                 ans++;
20                 j = f[j];
21             }
22         }
23     }
24 }
25 namespace exKMP {
26     int nxt[MAXN], ext[MAXN];
27     void get_nxt(string T) {
28         int j = 0, mx = 0;
29         int m = T.size();
30         nxt[0] = m;
31         for(int i = 1; i < m; i++) {

```

```

32         if(i >= mx || i + nxt[i - j] >= mx) {
33             if(i >= mx) mx = i;
34             while(mx < m && T[mx] == T[mx - i]) mx++;
35             nxt[i] = mx - i;
36             j = i;
37         }
38         else nxt[i] = nxt[i - j];
39     }
40 }
41 void exkmp(string S, string T) {
42     int j = 0, mx = 0;
43     get_nxt(T);
44     int n = S.size(), m = T.size();
45     for(int i = 0; i < n; i++) {
46         if(i >= mx || i + nxt[i - j] >= mx) {
47             if(i >= mx) mx = i;
48             while(mx < n && mx - i < m && S[mx] == T[mx - i]) mx++;
49             ext[i] = mx - i;
50             j = i;
51         }
52         else ext[i] = nxt[i - j];
53     }
54 }
55 }

```

### 3.1.3 AC Automaton

```

1 namespace AC {
2     int ch[MAXN][sigma_size], last[MAXN];
3     int val[MAXN], f[MAXN], sz;
4     inline void init() { sz = 1; memset(ch[0], 0, sizeof(ch[0])); }
5     inline int idx(char c) { return c - 'a'; }
6     void insert(string s, int v) {
7         int u = 0;
8         for(int i = 0; i < s.size(); i++) {
9             int c = idx(s[i]);
10            if(!ch[u][c]) {
11                memset(ch[sz], 0, sizeof(ch[sz]));
12                val[sz] = 0;
13                ch[u][c] = sz++;
14            }
15            u = ch[u][c];
16        }
17        val[u] = v;
18    }
19    void get_fail() {
20        queue<int> q;
21        f[0] = 0;
22        for(int c = 0; c < sigma_size; c++) {
23            int u = ch[0][c];
24            if(u) { f[u] = 0; q.push(u); last[u] = 0; }
25        }
26        while(!q.empty()) {
27            int r = q.front(); q.pop();
28            for(int c = 0; c < sigma_size; c++) {
29                int u = ch[r][c];
30                if(!u) { ch[r][c] = ch[f[r]][c]; continue; }
31                q.push(u);
32                int v = f[r];
33                while(v && !ch[v][c]) v = f[v];

```

```

34         f[u] = ch[v][c];
35         last[u] = val[f[u]] ? f[u] : last[f[u]];
36     }
37 }
38 }
39 inline void solve(int j) {
40     if(j) {
41         ans += val[j];
42         solve(last[j]);
43     }
44 }
45 void find(string T) {
46     int j = 0;
47     for(int i = 0; i < T.size(); i++) {
48         int c = idx(T[i]);
49         j = ch[j][c];
50         if(val[j]) solve(j);
51         else if(last[j]) solve(last[j]);
52     }
53 }
54 }

```

## 3.2 Suffix Related

### 3.2.1 Suffix Array

```

1 namespace SA {
2     char s[MAXN];
3     int sa[MAXN], rank[MAXN], height[MAXN];
4     int t[MAXN], t2[MAXN], c[MAXN], n;
5     void clear() { n = 0; memset(sa, 0, sizeof(sa)); }
6     void build(int m) {
7         int *x = t, *y = t2;
8         for(int i = 0; i < m; i++) c[i] = 0;
9         for(int i = 0; i < n; i++) c[x[i] = s[i]]++;
10        for(int i = 1; i < m; i++) c[i] += c[i - 1];
11        for(int i = n - 1; i >= 0; i--) sa[--c[x[i]]] = i;
12        for(int k = 1; k <= n; k <= 1) {
13            int p = 0;
14            for(int i = n - k; i < n; i++) y[p++] = i;
15            for(int i = 0; i < n; i++) if(sa[i] >= k) y[p++] = sa[i] - k;
16            for(int i = 0; i < m; i++) c[i] = 0;
17            for(int i = 0; i < n; i++) c[x[y[i]]]++;
18            for(int i = 1; i < m; i++) c[i] += c[i - 1];
19            for(int i = n - 1; i >= 0; i--) sa[--c[x[y[i]]]] = y[i];
20            swap(x, y);
21            p = 1; x[sa[0]] = 0;
22            for(int i = 1; i < n; i++)
23                x[sa[i]] = y[sa[i - 1]] == y[sa[i]] && y[sa[i - 1] + k] == y[sa[i] + k]
24                    ? p - 1 : p++;
25            if(p >= n) break;
26            m = p;
27        }
28    }
29    void buildHeight() {
30        int k = 0;
31        for(int i = 0; i < n; i++) rank[sa[i]] = i;
32        for(int i = 0; i < n; i++) {
33            if(k) k--;

```

```

33         int j = sa[rank[i] - 1];
34         while(s[i + k] == s[j + k]) k++;
35         height[rank[i]] = k;
36     }
37 }
38 void init() {
39     n = strlen(s) + 1;
40     build('z' + 1);
41     buildHeight();
42 }
43 }

```

### 3.2.2 Suffix Automaton

## 3.3 Palindrome Related

### 3.3.1 Manacher

```

1 namespace Palindrome {
2     char s1[MAXN], s2[MAXN];
3     int len1, len2, ans;
4     int p[MAXN]; //p[i] - 1
5     void init() {
6         len1 = strlen(s1);
7         s2[0] = '$';
8         s2[1] = '#';
9         for(int i = 0; i < len1; i++) {
10             s2[2 * i + 2] = s1[i];
11             s2[2 * i + 3] = '#';
12         }
13         len2 = len1 * 2 + 2;
14         s2[len2] = '&';
15     }
16     void manacher() {
17         int id = 0, mx = 0;
18         for(int i = 1; i < len2; i++) {
19             if(mx > i) p[i] = min(p[2 * id - i], mx - i);
20             else p[i] = 1;
21             while(s2[i + p[i]] == s2[i - p[i]]) p[i]++;
22             if(i + p[i] > mx) {
23                 mx = i + p[i];
24                 id = i;
25             }
26         }
27     }
28 }

```

### 3.3.2 Palindromic Tree



## 4 Math

### 4.1 Algebra

#### 4.1.1 FFT

```

1  const double pi = acos(-1.0);
2  const int MAXN = 300003;
3  struct comp {
4      double x, y;
5      comp operator + (const comp a) const { return (comp) {x + a.x, y + a.y}; }
6      comp operator - (const comp a) const { return (comp) {x - a.x, y - a.y}; }
7      comp operator * (const comp a) const { return (comp) {x * a.x - y * a.y, x * a.y + y
      * a.x}; }
8  };
9  int rev[MAXN], T;
10 comp tmp;
11 void fft(comp *a, int r) {
12     if(r == -1) for(int i = 0; i < T; i++) A[i] = A[i] * A[i];
13     for(int i = 0; i < T; i++) if(rev[i] > i) swap(a[rev[i]], a[i]);
14     for(int i = 2, mid = 1; i <= T; mid = i, i <= 1) {
15         comp step = (comp) {cos(pi / mid), r * sin(pi / mid)};
16         for(int j = 0; j < T; j += i) {
17             comp cur = (comp) {1, 0};
18             for(int k = j; k < j + mid; k++, cur = cur * step) {
19                 tmp = a[k + mid] * cur;
20                 a[k + mid] = a[k] - tmp;
21                 a[k] = a[k] + tmp;
22             }
23         }
24     }
25     if(r == -1) for(int i = 0; i < T; i++) a[i].y = (int)(a[i].y / T / 2 + 0.5);
26 }
27 int n, m;
28 comp A[MAXN];
29 void init() {
30     for(T = 1; T <= n + m; T <= 1);
31     for(int i = 1; i < T; i++) {
32         if(i & 1) rev[i] = (rev[i >> 1] >> 1) ^ (T >> 1);
33         else rev[i] = rev[i >> 1] >> 1;
34     }
35 }

```

#### 4.1.2 NTT

```

1  const int MAXN = 300005, G = 3, mod = 998244353; //or (479LL<<21) + 1
2  int rev[MAXN], T;
3  LL qpow(LL x, LL y) {
4      LL res = 1;
5      while(y) {
6          if(y & 1) res = res * x % mod;
7          x = x * x % mod;
8          y >>= 1;
9      }
10     return res;
11 }
12 void ntt(LL *a, int r) {
13     if(r == -1) for(int i = 0; i < T; i++) A[i] = A[i] * B[i] % mod;

```

```

14 for(int i = 0; i < T; i++) if(rev[i] > i) swap(a[rev[i]], a[i]);
15 for(int i = 2, mid = 1; i <= T; mid = i, i <= 1) {
16     LL gn = qpow(G, (mod - 1) / i);
17     if(r == -1) gn = qpow(gn, mod - 2);
18     for(int j = 0; j < T; j += i) {
19         LL cur = 1, tmp;
20         for(int k = j; k < j + mid; k++, cur = cur * gn % mod) {
21             tmp = a[k + mid] * cur % mod;
22             a[k + mid] = ((a[k] - tmp) % mod + mod) % mod;
23             a[k] = (a[k] + tmp) % mod;
24         }
25     }
26 }
27 if(r == -1) {
28     LL inv = qpow(T, mod - 2);
29     for(int i = 0; i < T; i++) a[i] = a[i] * inv % mod;
30 }
31 }
32 int n, m;
33 LL A[MAXN], B[MAXN];
34 void init() {
35     for(T = 1; T <= n + m; T <= 1);
36     for(int i = 0; i < T; i++) {
37         if(i & 1) rev[i] = (rev[i >> 1] >> 1) ^ (T >> 1);
38         else rev[i] = rev[i >> 1] >> 1;
39     }
40 }

```

## 4.2 Math Theory

### 4.2.1 CRT && exCRT

```

1 namespace CRT {
2     LL m[MAXN], a[MAXN]; //x_i = a[i] (mod m[i])
3     LL exgcd(LL _a, LL _b, LL &x, LL &y) {
4         if(!_b) {
5             x = 1; y = 0;
6             return _a;
7         }
8         LL d = exgcd(_b, _a % _b, y, x);
9         y -= (_a / _b) * x;
10        return d;
11    }
12    LL crt(int n) {
13        LL M = 1, tmp, res = 0, x, y;
14        for(int i = 1; i <= n; i++) M *= m[i];
15        for(int i = 1; i <= n; i++) {
16            tmp = M / m[i];
17            exgcd(tmp, m[i], x, y);
18            x = (x + m[i]) % m[i];
19            res = (a[i] * x % M * tmp % M + res) % M;
20        }
21        return res;
22    }
23 }
24 namespace EXCRT {
25     LL m[MAXN], a[MAXN];
26     LL exgcd(LL _a, LL _b, LL &x, LL &y) {
27         if(!_b) {

```

```
28         x = 1; y = 0;
29         return _a;
30     }
31     LL d = exgcd(_b, _a % _b, y, x);
32     y -= (_a / _b) * x;
33     return d;
34 }
35 LL excrt(int n) {
36     LL M = m[1], A = a[1], x, y, d, tmp;
37     for(int i = 2; i <= n; i++) {
38         d = exgcd(M, m[i], x, y);
39         if((A - a[i]) % d) return -1; //No solution
40         tmp = M / d; M *= m[i] / d;
41         y = (A - a[i]) / d % M * y % M;
42         y = (y + tmp) % tmp;
43         A = (m[i] % M * y % M + a[i]) % M;
44         A = (A + M) % M;
45     }
46     return A;
47 }
48 }
```

## 5 Computational Geometry

### 5.1 Commonly Definition and Functions

#### 5.1.1 Const and Functions

```

1 namespace CG{
2     #define Point Vector
3     const double pi=acos(-1.0);
4     const double inf=1e100;
5     const double eps=1e-9;
6     template <typename T> inline T Abs(T x){return x>0?x:-x;}
7     template <typename T> inline bool operator == (T x,T y){return Abs(x-y)<eps;}
8     int sgn(double x){
9         if (Abs(x)<eps) return 0;
10        if (x>0) return 1;
11        else return -1;
12    }
13 }

```

#### 5.1.2 Point Definition

```

1 namespace CG{
2     struct Point{
3         double x,y;
4         Point(double x=0,double y=0):x(x),y(y){}
5     };
6     Vector operator + (const Vector a,const Vector b){return Vector(a.x+b.x,a.y+b.y);}
7     Vector operator - (const Vector a,const Vector b){return Vector(a.x-b.x,a.y-b.y);}
8     Vector operator * (const Vector a,const double k){return Vector(a.x*k,a.y*k);}
9     Vector operator / (const Vector a,const double k){return Vector(a.x/k,a.y/k);}
10    bool operator < (const Vector a,const Vector b) {return a.x==b.x?a.y<b.y:a.x<b.x;}
11    bool operator == (const Vector a,const Vector b) {return a.x==b.x && a.y==b.y;}
12    double Dot(const Vector a,const Vector b){return a.x*b.x+a.y*b.y;}
13    double Cross(const Vector a,const Vector b){return a.x*b.y-a.y*b.x;}
14    double Norm(const Vector a){return sqrt(Dot(a,a));}
15    double Angle(const Vector a,const Vector b){return acos(Dot(a,b)/Norm(a)/Norm(b));}
16    Vector Rotate(const Vector a,const double theta){return Vector(a.x*cos(theta)-a.y*
17        sin(theta),a.x*sin(theta)+a.y*cos(theta));}
18    boolToLeftTest(const Vector a,const Vector b){return Cross(a,b)<0;}
19    double DisPP(const Vector a,const Vector b){return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)
20        *(a.y-b.y));}
21 }

```

#### 5.1.3 Line Definition

```

1 namespace CG{
2     struct Line{
3         Point p0,v,p1;
4         double t,theta;
5         Line(Point _p0=0,Point _v=0,double _t=1):p0(_p0),v(_v),t(_t){p1=p0+v*t; theta=
6             atan2(v.y,v.x);}
7         // Line(Point _p0=0,Point _v=0,double _t=1):p0(_p0),p1(_v){v=(p1-p0)/t; theta=
8             atan2(v.y,v.x);}
9     };
10    bool operator < (const Line n,const Line m) {return n.theta<m.theta;}

```

```

9   Point GetIntersection(const Line n,const Line m){return n.p0+n.v*Cross(m.v,(n.p0-m.
    p0))/Cross(n.v,m.v);}
10  bool OnLine(const Vector a,const Line l){return Cross(l.p0-a,l.p1-a)==0;}
11  bool OnSegment(const Point a,const Line l){return sgn(Cross(l.p0-a,l.p1-a))==0 &&
    sgn(Dot(l.p0-a,l.p1-a))<0;}
12  double DisPL(const Point a,const Line l){return Abs(Cross(l.p1-l.p0,a-l.p0)/Norm(l.
    p1-l.p0));}
13  double DisPS(const Point a,const Line l){
14      if (l.p0==l.p1) return Norm(a-l.p0);
15      Vector v1=l.p1-l.p0,v2=a-l.p0,v3=a-l.p1;
16      if (sgn(Dot(v1,v2))<0) return Norm(v2);
17      if (sgn(Dot(v1,v3))>0) return Norm(v3);
18      return DisPL(a,l);
19  }
20  Point GetProjection(const Point a,const Line l){
21      Vector v=l.p1-l.p0;
22      return l.p0+v*(Dot(v,a-l.p0)/Dot(v,v));
23  }
24  bool SegmentIntersection(const Line n,const Line m,bool p){
25      double c1=Cross(n.p1-n.p0,m.p1-m.p0);
26      double c2=Cross(n.p1-n.p0,m.p1-n.p0);
27      double c3=Cross(m.p1-m.p0,n.p0-m.p0);
28      double c4=Cross(m.p1-m.p0,n.p1-m.p0);
29      if (p){
30          if (!sgn(c1) || !sgn(c2) || !sgn(c3) || !sgn(c4)){
31              return OnSegment(n.p0,m) || OnSegment(n.p1,m) || OnSegment(m.p0,n) ||
                OnSegment(m.p1,n);
32          }
33      }
34      return (sgn(c1)*sgn(c2)<0 && sgn(c3)*sgn(c4)<0);
35  }
36  }
37  }

```

#### 5.1.4 Get Area

```

1  namespace CG{
2      double GetArea(Point *p,int n){
3          double area=Cross(p[n],p[1]);
4          for (int i=2;i<=n;i++) area+=0.5*Cross(p[i-1],p[i]);
5          return Abs(area);
6      }
7  }

```

#### 5.1.5 Get Circumference

```

1  namespace CG{
2      double GetCircumference(Point *p,int n){
3          double Circumference=DisPP(p[n],p[1]);
4          for (int i=2;i<=n;i++) Circumference+=DisPP(p[i-1],p[i]);
5          return Circumference;
6      }
7  }

```

### 5.2 Convex Hull

```

1 namespace CG{
2     Point p[MAXN],s[MAXN];
3     int ConvexHull(Point *p,int n){
4         sort(p+1,p+1+n);
5         int m=0;
6         for (int i=1;i<=n;i++){
7             for (;m>=2 && !ToLeftTest(s[m]-s[m-1],p[i]-s[m-1]);m--);
8             s[++m]=p[i];
9         }
10        int k=m;
11        for (int i=n-1;i;i--){
12            for (;m>=k+1 && !ToLeftTest(s[m]-s[m-1],p[i]-s[m-1]);m--);
13            s[++m]=p[i];
14        }
15        return m-1;
16    }
17 }

```

### 5.3 Half Plane Intersection

```

1 namespace CG{
2     void HalfPlaneIntersection(Line l[],int n){
3         deque <Point> p;
4         sort(l+1,l+1+n);
5         deque <Line> q;
6         q.push_back(l[1]);
7         for (int i=2;i<=n;i++){
8             for (;!p.empty() && !ToLeftTest(p.back()-l[i].p0,l[i].v);q.pop_back(),p.
9                 pop_back());
10            for (;!p.empty() && !ToLeftTest(p.front()-l[i].p0,l[i].v);q.pop_front(),p.
11                pop_front());
12            if (sgn(Cross(l[i].v,q.back().v))==0)
13                if (ToLeftTest(l[i].p0-q.back().p0),q.back().v){
14                    q.pop_back();
15                    if (!p.empty()) p.pop_back();
16                }
17            if (!q.empty()) p.push_back(GetIntersection(q.back(),l[i]));
18            q.push_back(l[i]);
19        }
20        for (;!p.empty() && !ToLeftTest(p.back()-q.front().p0,q.front().v);q.pop_back(),
21            p.pop_back());
22        p.push_back(GetIntersection(q.back(),q.front()));
23        double area=0.5*Cross(p.back(),p.front()); Point last=p.front();
24        for (p.pop_front();!p.empty();last=p.front(),p.pop_front()) area+=0.5*Cross(last
25            ,p.front());
26        printf("%.1f",Abs(area));
27    }
28 }

```

### 5.4 Min Circle Cover

```

1 namespace CG{
2     Point GetCircleCenter(const Point a,const Point b,const Point c){
3         Point p=(a+b)/2.0,q=(a+c)/2.0;
4         Vector v=Rotate(b-a,pi/2.0),w=Rotate(c-a,pi/2.0);
5         if (sgn(Norm(Cross(v,w)))==0){
6             if (sgn(Norm(a-b)+Norm(b-c)-Norm(a-c))==0) return (a+c)/2;
7             if (sgn(Norm(b-a)+Norm(a-c)-Norm(b-c))==0) return (b+c)/2;

```

```

8         if (sgn(Norm(a-c)+Norm(c-b)-Norm(a-b))==0) return (a+c)/2;
9     }
10    return GetIntersection(Line(p,v),Line(q,w));
11 }
12 void MinCircleCover(Point p[],int n){
13     random_shuffle(p+1,p+1+n);
14     Point c=p[1];
15     double r=0;
16     for (int i=2;i<=n;i++){
17         if (sgn(Norm(c-p[i])-r)>0){
18             c=p[i],r=0;
19             for (int j=1;j<i;j++){
20                 if (sgn(Norm(c-p[j])-r)>0){
21                     c=(p[i]+p[j])/2.0;
22                     r=Norm(c-p[i]);
23                     for (int k=1;k<j;k++){
24                         if (sgn(Norm(c-p[k])-r)>0){
25                             c=GetCircleCenter(p[i],p[j],p[k]);
26                             r=Norm(c-p[i]);
27                         }
28                     }
29                 }
30             }
31             printf("%.10f\n%.10f %.10f",r,c.x,c.y);
32 }

```

## 6 Others

### 6.1 sample

#### 6.1.1 vimrc

```

1  set nocompatible
2  source $VIMRUNTIME/vimrc_example.vim
3  source $VIMRUNTIME/mswin.vim
4  nunmap <c-v>
5  set cindent
6  set number
7  set mouse=a
8  set tabstop=4
9  set shiftwidth=4
10 set cursorline
11 set guifont=Consolas:h14
12 inoremap kj <esc>
13 inoremap jk <esc>
14 inoremap { {}<left>
15 syntax enable
16 func! Compile()
17     exec "w"
18     exec "! g++ % -o %< -Wall -Wextra -Wshadow -Wconversion --std=c++14 -O2"
19     exec "! ./%<"
20 endfunc
21 func! Debug()
22     exec "w"
23     exec "! g++ % -o %< -g -Wall --std=c++14 && gdb %<"
24 endfunc
25 func! AddTitle()
26     call append(0,"// Cease to struggle and you cease to live")
27     call append(1,"#include <bits/stdc++.h>")
28     call append(2,"using namespace std;")
29     call append(4,"int main() {"
30     call append(5,"    ios::sync_with_stdio(0); cin.tie(0); cout.precision(6); cout <<
        fixed;")
31     call append(7,"    return 0;")
32     call append(8,"}")
33 endfunc
34 map <F9> :call Compile()<CR>
35 map <F5> :call Debug()<CR>
36 map <F8> :call AddTitle()<CR>

```

#### 6.1.2 FastIO

```

1 namespace IO {
2     const int MB = 1048576;
3     const int RMAX = 16 * MB;
4     const int WMAX = 16 * MB;
5     #define getchar() *(rp++)
6     #define putchar(x) (*(wp++) = (x))
7     char rb[RMAX], *rp = rb, wb[WMAX], *wp = wb;
8     inline void init() {
9         fread(rb, sizeof(char), RMAX, stdin);
10    }
11    template <class _T> inline void read(_T &a) {
12        _a = 0; register bool _f = 0; register int _c = getchar();

```



```

13     while (_c < '0' || _c > '9') _f != _c == '-', _c = getchar();
14     while (_c >= '0' && _c <= '9') _a = _a * 10 + (_c ^ '0'), _c = getchar();
15     _a = _f ? -_a : _a;
16 }
17 template <class _T> inline void write(_T _a) {
18     static char buf[20], *top = buf;
19     if (_a) {
20         while (_a) {
21             register _T tm = _a / 10;
22             *(++top) = char(_a - tm * 10) | '0';
23             _a = tm;
24         }
25         while (top != buf) putchar(*(top--));
26     }
27     else putchar('0');
28 }
29 void output() {
30     fwrite(wb, sizeof(char), wp - wb, stdout);
31 }
32 }

```

## 6.2 Offline Algorithm

### 6.2.1 CDQ Divide and Conquer

```

1 struct Node {
2     int x, y, z, ans;
3     Node() {}
4     Node(int _x, int _y, int _z):x(_x), y(_y), z(_z) {}
5     bool operator < (const Node &b) const {
6         if(y == b.y) {
7             if(z == b.z) return x < b.x;
8             return z < b.z;
9         }
10        return y < b.y;
11    }
12 } A[MAXN], B[MAXN], C[MAXN];
13 int bit[MAXN];
14 void add(int k, int v) {
15     for(; k <= m; k += k & -k) bit[k] = max(bit[k], v);
16 }
17 void clear(int k) {
18     for(; k <= m; k += k & -k) bit[k] = 0;
19 }
20 int sum(int k) {
21     int res = 0;
22     for(; k; k -= k & -k) res = max(res, bit[k]);
23     return res;
24 }
25 void solve(int l, int r) {
26     if(l == r) {
27         B[l] = A[l];
28         return;
29     }
30     int mid = (l + r) >> 1;
31     solve(l, mid);
32     for(int i = mid + 1; i <= r; i++) B[i] = A[i];
33     //sort(B + l, B + mid + 1);
34     sort(B + mid + 1, B + r + 1);

```

```

35     int L = l;
36     for(int R = mid + 1; R <= r; R++) {
37         while(L <= mid && B[L].y < B[R].y) add(B[L].z, B[L].ans), L++;
38         A[B[R].x].ans = max(A[B[R].x].ans, sum(B[R].z - 1) + 1);
39         B[R].ans = A[B[R].x].ans;
40     }
41     for(int i = l; i <= L; i++) clear(B[i].z);
42     solve(mid + 1, r);
43     L = l;
44     int p = l, q = mid + 1;
45     while(p <= mid || q <= r) {
46         if(q > r || (p <= mid && B[p].y <= B[q].y)) C[L++] = B[p++];
47         else C[L++] = B[q++];
48     }
49     for(int i = l; i <= r; i++) B[i] = C[i];
50 }

```

## 6.2.2 Mo' s Algorithm

```

1 struct Node{
2     int l, r, t, id;
3     bool operator < (const Node& a) const {
4         if(l / sz == a.l / sz) {
5             if(r == a.r) return t < a.t;
6             return r < a.r;
7         }
8         return l / sz < a.l / sz;
9     }
10 }q[MAXN];
11 void solve() {
12     while (t < q[i].t) addTime(t++, 1);
13     while (t > q[i].t) addTime(--t, -1);
14     while(L < q[i].l) add(L++, -1);
15     while(L > q[i].l) add(--L, 1);
16     while(R < q[i].r) add(++R, 1);
17     while(R > q[i].r) add(R--, -1);
18 }

```

## 6.2.3 Mo's Algorithm On Tree

## 6.3 Randomized Algorithm

### 6.3.1 Simulated Annealing

```

1 void solve() {
2     while(T > eps) {
3         double alpha = ((rand() % 30001) / 15000.0) * pi;
4         double theta = ((rand() % 10001) / 10000.0) * pi;
5         tmp.x = cur.x + T * sin(theta) * cos(alpha);
6         tmp.y = cur.y + T * sin(theta) * sin(alpha);
7         tmp.z = cur.z + T * cos(theta);
8         tmp.dis = cal(tmp);
9         if(tmp.dis < cur.dis || (tmp.dis * 0.999 < cur.dis && (rand() & 7) == 7)) cur = tmp;
10         //if(exp((cur.d - tmp.d) / T) > ((double)rand() / RAND_MAX)) cur = tmp;

```

```
11  
12      T *= 0.999;  
13  }  
14 }
```