模板

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目录

1 字符串算法

1.1 最小表示

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1000001;
int n, x, y, t, ans;
char s[N + 10];
int main() {
    scanf("%s", s + 1);
    n = strlen(s + 1);
    x = 1;
    y = 2;
    for (int i = 0; x <= n && y <= n && i <= n; ) {
        t = s[(x + i - 1) % n + 1] - s[(y + i - 1) % n + 1];
        if (!t)
            i++;
        else {
            t > 0 ? x += i + 1 : y += i + 1;
            if (x == y)
                y++;
            i = 0;
        }
    }
    ans = min(x, y);
    for (int i = ans; i <= n; i++)
        putchar(s[i]);
    for (int i = 1; i < ans; i++)
        putchar(s[i]);
    puts("");
    return 0;
}
```

1.2 Manacher

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1000001;
int n, ans, p[N << 1];
char c, s[N << 1];
int main() {
    s[0] = '$';
    while ((c = getchar()) != '\n') {
        s[++n] = '#';
        s[++n] = c;
    }
    s[++n] = '#';
    for (int i = 1, j = 0; i <= n; i++) {
        p[i] = i < j + p[j] ? min(p[(j << 1) - i], j + p[j] - i) : 1;
        while (s[i + p[i]] == s[i - p[i]])
            p[i]++;
        if (i + p[i] > j + p[j])
            j = i;
        ans = max(ans, p[i] - 1);
    }
    printf("%d\n", ans);
    return 0;
}
```

1.3 Knuth-Morris-Pratt

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1000001;
int n, m, num, p[N], ans[N];
char a[N + 10], b[N + 10];
int main() {
```

```
7        scanf("%s%s", a + 1, b + 1);
8        n = strlen(a + 1);
9        m = strlen(b + 1);
10       for (int i = 2, j = 0; i <= m; i++) {
11           for (; j > 0 && b[j + 1] != b[i]; j = p[j]);
12           if (b[j + 1] == b[i])
13               j++;
14           p[i] = j;
15       }
16       for (int i = 1, j = 0; i <= n; i++) {
17           for (; j > 0 && b[j + 1] != a[i]; j = p[j]);
18           if (b[j + 1] == a[i])
19               j++;
20           if (j == m) {
21               ans[++num] = i − j + 1;
22               j = p[j];
23           }
24       }
25       for (int i = 1; i < num; i++)
26           printf("%d␣", ans[i]);
27       printf("%d\n", ans[num]);
28       return 0;
29   }
```

1.4 扩展 Knuth-Morris-Pratt

```
1    #include <bits/stdc++.h>
2    using namespace std;
3    const int N = 1000001;
4    int n, m, p[N], ex[N];
5    char a[N + 10], b[N + 10];
6    int main() {
7        scanf("%s%s", a + 1, b + 1);
8        n = strlen(a + 1);
9        m = strlen(b + 1);
10       for (int i = 2, j = 0; i <= m; i++) {
11           p[i] = i < j + p[j] ? min(p[i − j + 1], j + p[j] − i) : 0;
12           for (; i + p[i] <= m && b[i + p[i]] == b[p[i] + 1]; p[i]++);
13           if (i + p[i] > j + p[j])
14               j = i;
15       }
16       for (int i = 1, j = 0; i <= n; i++) {
17           ex[i] = i <= j + ex[j] ? min(p[i − j + 1], j + ex[j] − i) : 0;
18           for (; i + ex[i] <= n && ex[i] < m && a[i + ex[i]] == b[ex[i] + 1]; ex[i]++);
19           if (i + ex[i] > j + ex[j])
20               j = i;
21       }
22       for (int i = 1; i < n; i++)
23           printf("%d␣", ex[i]);
24       printf("%d\n", ex[n]);
25       return 0;
26   }
```

1.5 Aho-Corasick

```
1    #include <bits/stdc++.h>
2    using namespace std;
3    const int N = 1000001;
4    int n, t, tmp, now, pos, ans, son[N][26], num[N], p[N];
5    char a[N + 10], b[N + 10];
6    queue<int> q;
7    void Insert(char s[]) {
8        int p = 1, t;
9        for (int i = 0; s[i]; i++) {
10           t = s[i] − 97;
11           if (!son[p][t])
12               son[p][t] = ++pos;
13           p = son[p][t];
14       }
```

```cpp
        num[p]++;
}
int main() {
    pos = 1;
    scanf("%s%d", a, &n);
    for (int i = 1; i <= n; i++) {
        scanf("%s", b);
        Insert(b);
    }
    q.push(1);
    while (!q.empty()) {
        now = q.front();
        q.pop();
        for (int i = 0; i < 26; i++)
            if (son[now][i]) {
                for (t = p[now]; t > 0 && son[t][i] == 0; t = p[t]);
                p[son[now][i]] = t ? son[t][i] : 1;
                q.push(son[now][i]);
            }
    }
    t = 1;
    for (int i = 0; a[i]; i++) {
        tmp = a[i] − 97;
        for (; t > 0 && son[t][tmp] == 0; t = p[t]);
        t = t ? son[t][tmp] : 1;
        for (int j = t; j > 1 && num[j] > −1; j = p[j]) {
            ans += num[j];
            num[j] = −1;
        }
    }
    printf("%d\n", ans);
    return 0;
}
```

1.6 后缀数组

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 100001;
int n, a[N], b[N], sum[N], tmp[N], id[N], rk[N + 10];
char s[N + 10];
void Sort(int a[], int m) {
    memset(sum, 0, sizeof(sum));
    for (int i = 1; i <= n; i++)
        sum[a[i]]++;
    for (int i = 1; i <= m; i++)
        sum[i] += sum[i − 1];
    for (int i = n; i; i−−)
        tmp[id[i]] = sum[a[id[i]]]−−;
    for (int i = 1; i <= n; i++)
        id[tmp[i]] = i;
}
int main() {
    scanf("%s", s + 1);
    n = strlen(s + 1);
    for (int i = 1; i <= n; i++)
        a[id[i] = i] = s[i] − 96;
    Sort(a, 26);
    for (int i = 1, t = 0; i <= n; i++)
        rk[id[i]] = a[id[i]] == a[id[i − 1]] ? t : ++t;
    for (int i = 1; i <= n; i <<= 1) {
        for (int j = 1; j <= n; j++) {
            a[j] = rk[j];
            b[j] = rk[min(i + j, n + 1)];
        }
        Sort(b, n);
        Sort(a, n);
        for (int j = 1, t = 0; j <= n; j++)
            rk[id[j]] = a[id[j]] == a[id[j − 1]] && b[id[j]] == b[id[j − 1]] ? t : ++t;
    }
    for (int i = 1; i < n; i++)
```

```
36        printf("%d␣", rk[i]);
37    printf("%d\n", rk[n]);
38    return 0;
39 }
```

2 图算法

2.1 拓扑排序

```
1  #include <bits/stdc++.h>
2  using namespace std;
3  const int N = 1000001, M = 1000001;
4  int n, m, u, v, tot, num, Head[N], Next[M], Link[M], ans[N];
5  bool flag[N];
6  inline void AddEdge(int u, int v) {
7      Next[++tot] = Head[u];
8      Link[tot] = v;
9      Head[u] = tot;
10 }
11 void DFS(int x) {
12     flag[x] = true;
13     for (int i = Head[x], j; i; i = Next[i])
14         if (!flag[j = Link[i]])
15             DFS(j);
16     ans[++num] = x;
17 }
18 int main() {
19     scanf("%d%d", &n, &m);
20     for (int i = 1; i <= m; i++) {
21         scanf("%d%d", &u, &v);
22         AddEdge(u, v);
23     }
24     for (int i = 1; i <= n; i++)
25         if (!flag[i])
26             DFS(i);
27     for (int i = n; i > 1; i--)
28         printf("%d␣", ans[i]);
29     printf("%d\n", ans[1]);
30     return 0;
31 }
```

2.2 Floyd-Warshall

```
1  #include <bits/stdc++.h>
2  using namespace std;
3  const int N = 101;
4  int n, m, u, v, c, d[N][N];
5  int main() {
6      scanf("%d%d", &n, &m);
7      for (int i = 1; i <= n; i++)
8          for (int j = 1; j <= n; j++)
9              d[i][j] = i == j ? 0 : INT_MAX >> 1;
10     for (int i = 1; i <= m; i++) {
11         scanf("%d%d%d", &u, &v, &c);
12         d[u][v] = d[v][u] = min(d[u][v], c);
13     }
14     for (int k = 1; k <= n; k++)
15         for (int i = 1; i <= n; i++)
16             for (int j = 1; j <= n; j++)
17                 d[i][j] = min(d[i][j], d[i][k] + d[k][j]);
18     for (int i = 1; i <= n; i++) {
19         for (int j = 1; j < n; j++)
20             printf("%d␣", d[i][j] == INT_MAX >> 1 ? -1 : d[i][j]);
21         printf("%d\n", d[i][n] == INT_MAX >> 1 ? -1 : d[i][n]);
22     }
23     return 0;
24 }
```

2.3 Floyd-Warshall（最小环）

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 101;
int n, m, u, v, c, t, num, Min, a[N][N], d[N][N], p[N][N], ans[N];
int main() {
    scanf("%d%d", &n, &m);
    for (int i = 1; i <= n; i++)
        for (int j = 1; j <= n; j++) {
            a[i][j] = i == j ? 0 : INT_MAX / 3;
            p[i][j] = i;
        }
    for (int i = 1; i <= m; i++) {
        scanf("%d%d%d", &u, &v, &c);
        a[u][v] = a[v][u] = min(a[u][v], c);
    }
    memcpy(d, a, sizeof(d));
    Min = INT_MAX / 3;
    for (int k = 1; k <= n; k++) {
        for (int i = 1; i < k; i++)
            for (int j = 1; j < i; j++)
                if (d[i][j] + a[i][k] + a[k][j] < Min) {
                    Min = d[i][j] + a[i][k] + a[k][j];
                    for (num = 0, t = j; t != i; t = p[i][t])
                        ans[++num] = t;
                    ans[++num] = i;
                    ans[++num] = k;
                }
        for (int i = 1; i <= n; i++)
            for (int j = 1; j <= n; j++)
                if (d[i][k] + d[k][j] < d[i][j]) {
                    d[i][j] = d[i][k] + d[k][j];
                    p[i][j] = p[k][j];
                }
    }
    printf("%d\n", Min);
    for (int i = 1; i < num; i++)
        printf("%d ", ans[i]);
    printf("%d\n", ans[num]);
    return 0;
}
```

2.4 Bellman-Ford+ 队列

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 100001, M = 100001;
int n, m, s, u, v, c, now, tot, Head[N], Next[M << 1], Link[M << 1], Cost[M << 1], d[N];
bool flag[N];
queue<int> q;
inline void AddEdge(int u, int v, int c) {
    Next[++tot] = Head[u];
    Link[tot] = v;
    Cost[tot] = c;
    Head[u] = tot;
}
int main() {
    scanf("%d%d%d", &n, &m, &s);
    for (int i = 1; i <= m; i++) {
        scanf("%d%d%d", &u, &v, &c);
        AddEdge(u, v, c);
        AddEdge(v, u, c);
    }
    for (int i = 1; i <= n; i++)
        d[i] = INT_MAX;
    d[s] = 0;
    q.push(s);
    flag[s] = true;
    while (!q.empty()) {
        now = q.front();
```

```
27          q.pop();
28          flag[now] = false;
29          for (int i = Head[now], j; i; i = Next[i])
30              if (d[now] + Cost[i] < d[j = Link[i]]) {
31                  d[j] = d[now] + Cost[i];
32                  if (!flag[j]) {
33                      q.push(j);
34                      flag[j] = true;
35                  }
36              }
37      }
38      for (int i = 1; i < n; i++)
39          printf("%d␣", d[i]);
40      printf("%d\n", d[n]);
41      return 0;
42  }
```

2.5   Dijkstra+ 堆

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001, M = 100001;
4   int n, m, s, u, v, c, now, tot, d[N], Head[N], Next[M << 1], Link[M << 1], Cost[M << 1];
5   bool flag[N];
6   priority_queue<pair<int, int> > q;
7   inline void AddEdge(int u, int v, int c) {
8       Next[++tot] = Head[u];
9       Link[tot] = v;
10      Cost[tot] = c;
11      Head[u] = tot;
12  }
13  int main() {
14      scanf("%d%d%d", &n, &m, &s);
15      for (int i = 1; i <= m; i++) {
16          scanf("%d%d%d", &u, &v, &c);
17          AddEdge(u, v, c);
18          AddEdge(v, u, c);
19      }
20      for (int i = 1; i <= n; i++)
21          d[i] = INT_MAX;
22      q.push(make_pair(d[s] = 0, s));
23      while (!q.empty()) {
24          now = q.top().second;
25          q.pop();
26          if (flag[now])
27              continue;
28          flag[now] = true;
29          for (int i = Head[now], j; i; i = Next[i])
30              if (d[now] + Cost[i] < d[j = Link[i]]) {
31                  d[j] = d[now] + Cost[i];
32                  q.push(make_pair(-d[j], j));
33              }
34      }
35      for (int i = 1; i < n; i++)
36          printf("%d␣", d[i] == INT_MAX ? -1 : d[i]);
37      printf("%d\n", d[n] == INT_MAX ? -1 : d[n]);
38      return 0;
39  }
```

2.6   Prim+ 堆

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001, M = 100001;
4   int n, m, s, u, v, c, now, ans, tot, Head[N], Next[M << 1], Link[M << 1], Cost[M << 1], d[N];
5   bool flag[N];
6   priority_queue<pair<int, int> > q;
7   inline void AddEdge(int u, int v, int c) {
8       Next[++tot] = Head[u];
```

```
9        Link[tot] = v;
10       Cost[tot] = c;
11       Head[u] = tot;
12   }
13   int main() {
14       scanf("%d%d", &n, &m);
15       for (int i = 1; i <= m; i++) {
16           scanf("%d%d%d", &u, &v, &c);
17           AddEdge(u, v, c);
18           AddEdge(v, u, c);
19       }
20       for (int i = 1; i <= n; i++)
21           d[i] = INT_MAX;
22       q.push(make_pair(d[1] = 0, 1));
23       while (!q.empty()) {
24           now = q.top().second;
25           q.pop();
26           if (flag[now])
27               continue;
28           ans += d[now];
29           flag[now] = true;
30           for (int i = Head[now], j; i; i = Next[i])
31               if (Cost[i] < d[j = Link[i]]) {
32                   d[j] = Cost[i];
33                   q.push(make_pair(-d[j], j));
34               }
35       }
36       printf("%d\n", ans);
37       return 0;
38   }
```

2.7 Tarjan（强连通分量）

```
1    #include <bits/stdc++.h>
2    using namespace std;
3    const int N = 1000001, M = 1000001;
4    int n, m, u, v, tot, num, idx, Head[N], Next[M], Link[M], dfn[N], low[N];
5    bool flag[N];
6    stack<int> s;
7    vector<int> sub[N];
8    inline void AddEdge(int u, int v) {
9        Next[++tot] = Head[u];
10       Link[tot] = v;
11       Head[u] = tot;
12   }
13   void DFS(int x) {
14       s.push(x);
15       flag[x] = true;
16       low[x] = dfn[x] = ++idx;
17       for (int i = Head[x], j; i; i = Next[i])
18           if (!dfn[j = Link[i]]) {
19               DFS(j);
20               low[x] = min(low[x], low[j]);
21           } else if (flag[j])
22               low[x] = min(low[x], dfn[j]);
23       if (low[x] == dfn[x]) {
24           int t;
25           num++;
26           do {
27               t = s.top();
28               s.pop();
29               flag[t] = false;
30               sub[num].push_back(t);
31           } while (t != x);
32       }
33   }
34   int main() {
35       scanf("%d%d", &n, &m);
36       for (int i = 1; i <= m; i++) {
37           scanf("%d%d", &u, &v);
38           AddEdge(u, v);
```

```
39          }
40          for (int i = 1; i <= n; i++)
41              if (!dfn[i])
42                  DFS(i);
43          printf("%d\n", num);
44          for (int i = 1; i <= num; i++) {
45              for (int j = 0; j < sub[i].size() − 1; j++)
46                  printf("%d␣", sub[i][j]);
47              printf("%d\n", sub[i][sub[i].size() − 1]);
48          }
49          return 0;
50      }
```

2.8 Tarjan（点双连通分量）

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 1000001, M = 1000001;
4   int n ,m, u, v, tot, num, idx, Head[N], Next[M << 1], Link[M << 1], dfn[N], low[N];
5   bool flag[N];
6   stack<int> s;
7   vector<int> sub[N];
8   inline void AddEdge(int u, int v) {
9       Next[++tot] = Head[u];
10      Link[tot] = v;
11      Head[u] = tot;
12  }
13  void DFS(int x, int y) {
14      s.push(x);
15      flag[x] = true;
16      low[x] = dfn[x] = ++idx;
17      for (int i = Head[x], j; i; i = Next[i]) {
18          if ((j = Link[i]) == y)
19              continue;
20          if (!dfn[j]) {
21              DFS(j, x);
22              low[x] = min(low[x], low[j]);
23          } else if (flag[j])
24              low[x] = min(low[x], dfn[j]);
25      }
26      if (x != y && low[x] >= dfn[y]) {
27          int t;
28          num++;
29          do {
30              t = s.top();
31              s.pop();
32              flag[t] = false;
33              sub[num].push_back(t);
34          } while (t != y);
35          s.push(y);
36          flag[y] = true;
37      }
38  }
39  int main() {
40      scanf("%d%d", &n, &m);
41      for (int i = 1; i <= m; i++) {
42          scanf("%d%d", &u, &v);
43          AddEdge(u, v);
44          AddEdge(v, u);
45      }
46      for (int i = 1; i <= n; i++)
47          if (!dfn[i]) {
48              DFS(i, i);
49              s.pop();
50              flag[i] = false;
51          }
52      printf("%d\n", num);
53      for (int i = 1; i <= num; i++) {
54          for (int j = 0; j < sub[i].size() − 1; j++)
55              printf("%d␣", sub[i][j]);
56          printf("%d\n", sub[i][sub[i].size() − 1]);
```

```
57        }
58        return 0;
59    }
```

2.9 Tarjan（边双连通分量）

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 1000001, M = 1000001;
4   int n, m, u, v, tot, num, idx, Head[N], Next[M << 1], Link[M << 1], dfn[M << 1], low[N];
5   bool flag[N];
6   stack<int> s;
7   vector<int> sub[N];
8   inline void AddEdge(int u, int v) {
9       Next[++tot] = Head[u];
10      Link[tot] = v;
11      Head[u] = tot;
12  }
13  void DFS(int x, int y) {
14      s.push(x);
15      flag[x] = true;
16      low[x] = dfn[x] = ++idx;
17      for (int i = Head[x], j; i; i = Next[i]) {
18          if ((j = Link[i]) == y)
19              continue;
20          if (!dfn[j]) {
21              DFS(j, x);
22              low[x] = min(low[x], low[j]);
23          } else if (flag[j])
24              low[x] = min(low[x], dfn[j]);
25      }
26      if (low[x] > dfn[y]) {
27          int t;
28          num++;
29          do {
30              t = s.top();
31              s.pop();
32              flag[t] = false;
33              sub[num].push_back(t);
34          } while (t != x);
35      }
36  }
37  int main() {
38      scanf("%d%d", &n, &m);
39      for (int i = 1; i <= m; i++) {
40          scanf("%d%d", &u, &v);
41          AddEdge(u, v);
42          AddEdge(v, u);
43      }
44      for (int i = 1; i <= n; i++)
45          if (!dfn[i]) {
46              DFS(i, i);
47              num++;
48              while (!s.empty()) {
49                  flag[s.top()] = false;
50                  sub[num].push_back(s.top());
51                  s.pop();
52              }
53          }
54      printf("%d\n", num);
55      for (int i = 1; i <= num; i++) {
56          for (int j = 0; j < sub[i].size() − 1; j++)
57              printf("%d␣", sub[i][j]);
58          printf("%d\n", sub[i][sub[i].size() − 1]);
59      }
60      return 0;
61  }
```

2.10 匈牙利

11

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1001, M = 10001;
int n, m, k, u, v, tot, ans, Head[N], Next[M], Link[M], p[N];
bool flag[N];
inline void AddEdge(int u, int v) {
    Next[++tot] = Head[u];
    Link[tot] = v;
    Head[u] = tot;
}
bool DFS(int x) {
    for (int i = Head[x], j; i; i = Next[i])
        if (!flag[j = Link[i]]) {
            flag[j] = true;
            if (p[j] == 0 || DFS(p[j])) {
                p[j] = x;
                return true;
            }
        }
    return false;
}
int main() {
    scanf("%d%d%d", &n, &m, &k);
    for (int i = 1; i <= k; i++) {
        scanf("%d%d", &u, &v);
        AddEdge(u, v);
    }
    for (int i = 1; i <= n; i++) {
        memset(flag, false, sizeof(flag));
        if (DFS(i))
            ans++;
    }
    printf("%d\n", ans);
    return 0;
}
```

2.11   Kuhn-Munkres

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 101;
int n, m, t, ans, a[N][N], lx[N], ly[N], slack[N], p[N];
bool fx[N], fy[N];
bool DFS(int x) {
    fx[x] = true;
    for (int i = 1, t; i <= m; i++)
        if (!fy[i]) {
            t = lx[x] + ly[i] - a[x][i];
            if (!t) {
                fy[i] = true;
                if (p[i] == 0 || DFS(p[i])) {
                    p[i] = x;
                    return true;
                }
            } else
                slack[i] = min(slack[i], lx[x] + ly[i] - a[x][i]);
        }
    return false;
}
bool Find(int x) {
    memset(fx, false, sizeof(fx));
    memset(fy, false, sizeof(fy));
    return DFS(x);
}
int main() {
    scanf("%d%d", &n, &m);
    for (int i = 1; i <= n; i++)
        for (int j = 1; j <= m; j++)
            scanf("%d", &a[i][j]);
    for (int i = 1; i <= n; i++) {
```

```
33          lx[i] =  INT_MIN;
34          for (int j = 1; j <= m; j++)
35              lx[i] = max(lx[i], a[i][j]);
36      }
37      for (int i = 1; i <= n; i++) {
38          for (int j = 1; j <= m; j++)
39              slack[j] = INT_MAX;
40          while (!Find(i)) {
41              t = INT_MAX;
42              for (int j = 1; j <= m; j++)
43                  if (!fy[j])
44                      t = min(t, slack[j]);
45              for (int j = 1; j <= n; j++)
46                  if (fx[j])
47                      lx[j] -= t;
48              for (int j = 1; j <= m; j++)
49                  if (fy[j])
50                      ly[j] += t;
51                  else
52                      slack[j] -= t;
53          }
54      }
55      for (int i = 1; i <= m; i++)
56          if (p[i])
57              ans += a[p[i]][i];
58      printf("%d\n", ans);
59      return 0;
60  }
```

2.12 Dinic

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 1001, M = 10001;
4   int n, m, S, T, u, v, r, tot, ans;
5   int Head[N], cur[N], Next[M << 1], Link[M << 1], Rest[M << 1], d[N], From[N], Edge[N];
6   queue<int> q;
7   inline void AddEdge(int u, int v, int r) {
8       Next[++tot] = Head[u];
9       Link[tot] = v;
10      Rest[tot] = r;
11      Head[u] = tot;
12  }
13  bool BFS() {
14      for (int i = 1; i <= n; i++)
15          d[i] = INT_MAX;
16      d[S] = 0;
17      q.push(S);
18      while (!q.empty()) {
19          int now = q.front();
20          q.pop();
21          for (int i = Head[now], j; i; i = Next[i])
22              if (Rest[i] > 0 && d[now] + 1 < d[j = Link[i]]) {
23                  d[j] = d[now] + 1;
24                  q.push(j);
25              }
26      }
27      return d[T] < INT_MAX;
28  }
29  bool DFS(int x) {
30      if (x == T) {
31          int tmp = INT_MAX;
32          for (int i = T; i != S; i = From[i])
33              tmp = min(tmp, Rest[Edge[i]]);
34          for (int i = T; i != S; i = From[i]) {
35              Rest[Edge[i]] -= tmp;
36              Rest[Edge[i] ^ 1] += tmp;
37          }
38          ans += tmp;
39          return true;
40      }
```

```
41        for (int &i = cur[x], j; i; i = Next[i])
42            if (Rest[i] > 0 && d[x] + 1 == d[j = Link[i]]) {
43                From[j] = x;
44                Edge[j] = i;
45                if (DFS(j))
46                    return true;
47            }
48        return false;
49  }
50  int main() {
51        scanf("%d%d%d%d", &n, &m, &S, &T);
52        tot = 1;
53        for (int i = 1; i <= m; i++) {
54            scanf("%d%d%d", &u, &v, &r);
55            AddEdge(u, v, r);
56            AddEdge(v, u, 0);
57        }
58        while (BFS()) {
59            memcpy(cur, Head, sizeof(cur));
60            while (DFS(S));
61        }
62        printf("%d\n", ans);
63        return 0;
64  }
```

2.13   Edmonds-Karp（最小费用最大流）

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 1001, M = 10001;
4   int n, m, S, T, u, v, r, c, tmp, tot, sum, ans1, ans2;
5   int Head[N], Next[M << 1], Link[M << 1], Rest[M << 1], Cost[M << 1], d[N], From[N], Edge[N];
6   bool flag[N];
7   queue<int> q;
8   inline void AddEdge(int u, int v, int r, int c) {
9        Next[++tot] = Head[u];
10       Link[tot] = v;
11       Rest[tot] = r;
12       Cost[tot] = c;
13       Head[u] = tot;
14  }
15  bool BFS() {
16       for (int i = 1; i <= n; i++)
17           d[i] = INT_MAX;
18       d[S] = 0;
19       q.push(S);
20       flag[S] = true;
21       while (!q.empty()) {
22           int now = q.front();
23           q.pop();
24           flag[now] = false;
25           for (int i = Head[now], j; i; i = Next[i])
26               if (Rest[i] > 0 && d[now] + Cost[i] < d[j = Link[i]]) {
27                   d[j] = d[now] + Cost[i];
28                   From[j] = now;
29                   Edge[j] = i;
30                   if (!flag[j]) {
31                       q.push(j);
32                       flag[j] = true;
33                   }
34               }
35       }
36       return d[T] < INT_MAX;
37  }
38  int main() {
39       scanf("%d%d%d%d", &n, &m, &S, &T);
40       tot = 1;
41       for (int i = 1; i <= m; i++) {
42           scanf("%d%d%d%d", &u, &v, &r, &c);
43           AddEdge(u, v, r, c);
44           AddEdge(v, u, 0, −c);
```

```
45            }
46        while (BFS()) {
47            tmp = INT_MAX;
48            sum = 0;
49            for (int i = T; i != S; i = From[i]) {
50                tmp = min(tmp, Rest[Edge[i]]);
51                sum += Cost[Edge[i]];
52            }
53            for (int i = T; i != S; i = From[i]) {
54                Rest[Edge[i]] -= tmp;
55                Rest[Edge[i] ^ 1] += tmp;
56            }
57            ans1 += tmp;
58            ans2 += tmp * sum;
59        }
60        printf("%d␣%d\n", ans1, ans2);
61        return 0;
62    }
```

3 树算法

3.1 Tarjan（最近公共祖先）

```
1  #include <bits/stdc++.h>
2  #define fi first
3  #define se second
4  using namespace std;
5  const int N = 1000001, M = 1000001;
6  int n, m, u, v, tot, Head[N], Next[N << 1], Link[N << 1], a[N], ans[M];
7  bool flag[N];
8  vector<pair<int, int> > Q[N];
9  inline void AddEdge(int u, int v) {
10     Next[++tot] = Head[u];
11     Link[tot] = v;
12     Head[u] = tot;
13 }
14 int Get(int x) {
15     if (a[x] != x)
16         a[x] = Get(a[x]);
17     return a[x];
18 }
19 void DFS(int x) {
20     flag[x] = true;
21     a[x] = x;
22     for (int i = 0; i < Q[x].size(); i++)
23         ans[Q[x][i].se] = Get(a[Q[x][i].fi]);
24     for (int i = Head[x], j; i; i = Next[i])
25         if (!flag[j = Link[i]]) {
26             DFS(j);
27             a[j] = x;
28         }
29 }
30 int main() {
31     scanf("%d", &n);
32     for (int i = 1; i < n; i++) {
33         scanf("%d%d", &u, &v);
34         AddEdge(u, v);
35         AddEdge(v, u);
36     }
37     scanf("%d", &m);
38     for (int i = 1; i <= m; i++) {
39         scanf("%d%d", &u, &v);
40         Q[u].push_back({v, i});
41         Q[v].push_back({u, i});
42     }
43     DFS(1);
44     for (int i = 1; i <= m; i++)
45         printf("%d\n", ans[i]);
46     return 0;
47 }
```

3.2 树链剖分

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 100001;
int n, m, u, v, tot, num;
int d[N], f[N], s[N], son[N], top[N], idx[N], key[N], Head[N], Next[N << 1], Link[N << 1];
inline void AddEdge(int u, int v) {
    Next[++tot] = Head[u];
    Link[tot] = v;
    Head[u] = tot;
}
void DFS1(int x) {
    d[x] = d[f[x]] + 1;
    s[x] = 1;
    for (int i = Head[x], j; i; i = Next[i])
        if (!d[j = Link[i]]) {
            f[j] = x;
            DFS1(j);
            s[x] += s[j];
            if (s[j] > s[son[x]])
                son[x] = j;
        }
}
void DFS2(int x) {
    top[x] = x == son[f[x]] ? top[f[x]] : x;
    key[idx[x] = ++num] = x;
    if (son[x])
        DFS2(son[x]);
    for (int i = Head[x], j; i; i = Next[i]) {
        j = Link[i];
        if (f[j] == x && j != son[x])
            DFS2(j);
    }
}
int LCA(int x, int y) {
    int u, v;
    while ((u = top[x]) != (v = top[y]))
        if (d[u] > d[v])
            x = f[u];
        else
            y = f[v];
    if (d[x] > d[y])
        swap(x, y);
    return x;
}
int main() {
    scanf("%d", &n);
    for (int i = 1; i < n; i++) {
        scanf("%d%d", &u, &v);
        AddEdge(u, v);
        AddEdge(v, u);
    }
    DFS1(1);
    DFS2(1);
    scanf("%d", &m);
    for (int i = 1; i <= m; i++) {
        scanf("%d%d", &u, &v);
        printf("%d\n", LCA(u, v));
    }
    return 0;
}
```

4   数据结构

4.1   并查集

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1000001;
```

```
4   int n, a[N], b[N];
5   int Find(int x) {
6       if (a[x] != x)
7           a[x] = Find(a[x]);
8       return a[x];
9   }
10  void Merge(int x, int y) {
11      if ((x = Find(x)) == (y = Find(y)))
12          return;
13      b[x] < b[y] ? a[x] = y : a[y] = x;
14      if (b[x] == b[y])
15          b[x]++;
16  }
17  int main() {
18      for (int i = 1; i <= n; i++)
19          a[i] = i;
20      return 0;
21  }
```

4.2 字母树

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 1000001;
4   int pos, son[N][26], num[N];
5   void Insert(char s[]) {
6       int p = 1, t;
7       for (int i = 0; s[i]; i++) {
8           t = s[i] − 97;
9           if (!son[p][t])
10              son[p][t] = ++pos;
11          p = son[p][t];
12      }
13      num[p]++;
14  }
15  int Find(char s[]) {
16      int p = 1, t;
17      for (int i = 0; s[i]; i++) {
18          t = s[i] − 97;
19          if (!son[p][t])
20              return 0;
21          p = son[p][t];
22      }
23      return num[p];
24  }
25  int main() {
26      pos = 1;
27      return 0;
28  }
```

4.3 左偏树

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001;
4   int num, l[N], r[N], d[N], key[N];
5   int Merge(int p, int q) {
6       if (!p)
7           return q;
8       if (!q)
9           return p;
10      if (key[p] > key[q])
11          swap(p, q);
12      r[p] = Merge(r[p], q);
13      if (d[l[p]] < d[r[p]])
14          swap(l[p], r[p]);
15      d[p] = d[r[p]] + 1;
16      return p;
17  }
```

```
18  void Push(int &p, int x) {
19      key[++num] = x;
20      p = Merge(p, num);
21  }
22  void Pop(int &p) {
23      p = Merge(l[p], r[p]);
24  }
25  int Top(int p) {
26      return key[p];
27  }
28  int main() {
29      d[0] = −1;
30      return 0;
31  }
```

4.4 树状数组

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001;
4   int n, sum[N];
5   void Add(int x, int y) {
6       for (; x <= n; x += x & −x)
7           sum[x] += y;
8   }
9   int Sum(int x) {
10      int ans = 0;
11      for (; x; x −= x & −x)
12          ans += sum[x];
13      return ans;
14  }
15  int main() {
16      return 0;
17  }
```

4.5 张昆玮线段树

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001;
4   int n, SIZE, a[N], sum[N << 2];
5   void Build() {
6       for (SIZE = 1; SIZE < n + 2; SIZE <<= 1);
7       for (int i = 1; i <= n; i++)
8           sum[SIZE + i] = a[i];
9       for (int i = SIZE − 1; i; i−−)
10          sum[i] = sum[i << 1] + sum[(i << 1) + 1];
11  }
12  void Add(int x, int y) {
13      for (x += SIZE; x; x >>= 1)
14          sum[x] += y;
15  }
16  int Sum(int x, int y) {
17      int ans = 0;
18      for (x += SIZE − 1, y += SIZE + 1; x ^ y ^ 1; x >>= 1, y >>= 1) {
19          if ((x & 1) == 0)
20              ans += sum[x ^ 1];
21          if ((y & 1) == 1)
22              ans += sum[y ^ 1];
23      }
24      return ans;
25  }
26  int main() {
27      return 0;
28  }
```

4.6 线段树

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 100001;
int num, a[N], l[N << 1], r[N << 1], ll[N << 1], rr[N << 1], sum[N << 1], lab[N << 1];
inline void Label(int p, int x) {
    sum[p] += (rr[p] - ll[p] + 1) * x;
    lab[p] += x;
}
inline void Down(int p) {
    if (ll[p] < rr[p]) {
        Label(l[p], lab[p]);
        Label(r[p], lab[p]);
    }
    lab[p] = 0;
}
inline void Up(int p) {
    sum[p] = sum[l[p]] + sum[r[p]];
}
void Build(int p, int x, int y) {
    ll[p] = x;
    rr[p] = y;
    if (x == y) {
        sum[p] = a[x];
        return;
    }
    int z = x + y >> 1;
    Build(l[p] = ++num, x, z);
    Build(r[p] = ++num, z + 1, y);
    Up(p);
}
void Add(int p, int x, int y, int z) {
    Down(p);
    if (ll[p] == x && rr[p] == y) {
        Label(p, z);
        return;
    }
    if (y < ll[r[p]])
        Add(l[p], x, y, z);
    else if (x > rr[l[p]])
        Add(r[p], x, y, z);
    else {
        Add(l[p], x, rr[l[p]], z);
        Add(r[p], ll[r[p]], y, z);
    }
    Up(p);
}
int Sum(int p, int x, int y) {
    Down(p);
    if (ll[p] == x && rr[p] == y)
        return sum[p];
    if (y < ll[r[p]])
        return Sum(l[p], x, y);
    else if (x > rr[l[p]])
        return Sum(r[p], x, y);
    else
        return Sum(l[p], x, rr[l[p]]) + Sum(r[p], ll[r[p]], y);
}
int main() {
    num = 1;
    return 0;
}
```

4.7 伸展树（区间）

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 100001;
int root, pos, l[N], r[N], f[N], s[N], key[N], lab[N], sum[N];
bool flag[N];
```

```cpp
inline void Down(int p) {
    if (l[p]) {
        key[l[p]] += lab[p];
        lab[l[p]] += lab[p];
        sum[l[p]] += s[l[p]] * lab[p];
        if (flag[p]) {
            flag[l[p]] = !flag[l[p]];
            swap(l[l[p]], r[l[p]]);
        }
    }
    if (r[p]) {
        key[r[p]] += lab[p];
        lab[r[p]] += lab[p];
        sum[r[p]] += s[r[p]] * lab[p];
        if (flag[p]) {
            flag[r[p]] = !flag[r[p]];
            swap(l[r[p]], r[r[p]]);
        }
    }
    lab[p] = 0;
    flag[p] = false;
}
inline void Up(int p) {
    s[p] = s[l[p]] + s[r[p]] + 1;
    sum[p] = sum[l[p]] + sum[r[p]] + key[p];
}
inline void L(int p) {
    int t = f[p];
    if (r[t] = l[p])
        f[l[p]] = t;
    if (f[p] = f[t])
        t == l[f[t]] ? l[f[t]] = p : r[f[t]] = p;
    f[t] = p;
    l[p] = t;
}
inline void R(int p) {
    int t = f[p];
    if (l[t] = r[p])
        f[r[p]] = t;
    if (f[p] = f[t])
        t == l[f[t]] ? l[f[t]] = p : r[f[t]] = p;
    f[t] = p;
    r[p] = t;
}
void Splay(int p, int T) {
    for (int q, t; (q = f[p]) != T; )
        if (f[q] == T) {
            p == l[q] ? R(p) : L(p);
            Up(q), Up(p);
        } else {
            t = f[q];
            if (p == l[q])
                q == l[t] ? (R(q), R(p)) : (R(p), L(p));
            else
                q == r[t] ? (L(q), L(p)) : (L(p), R(p));
            Up(t), Up(q), Up(p);
        }
    if (!T)
        root = p;
}
int Select(int x) {
    int p = root, t = s[l[root]];
    Down(p);
    while (x != t + 1) {
        if (x < t + 1)
            t -= s[r[p = l[p]]] + 1;
        else
            t += s[l[p = r[p]]] + 1;
        Down(p);
    }
    return p;
}
void Insert(int x, int y) {
```

```
79        int p = Select(x + 1);
80        Splay(p, 0);
81        Down(p);
82        for (p = r[p]; l[p]; p = l[p])
83            Down(p);
84        Down(p);
85        l[p] = ++pos;
86        f[pos] = p;
87        sum[pos] = key[pos] = y;
88        Splay(pos, 0);
89    }
90    void Delete(int x) {
91        int p = Select(x + 1);
92        Splay(p, 0);
93        Down(p);
94        for (p = l[p]; r[p]; p = r[p])
95            Down(p);
96        Down(p);
97        f[r[root]] = p;
98        r[p] = r[root];
99        f[l[root]] = 0;
100       Splay(p, 0);
101   }
102   void Add(int x, int y, int z) {
103       Splay(Select(x), 0);
104       Splay(Select(y + 2), root);
105       key[l[r[root]]] += z;
106       lab[l[r[root]]] += z;
107       sum[l[r[root]]] += s[l[r[root]]] * z;
108       Up(r[root]), Up(root);
109   }
110   void Reverse(int x, int y) {
111       Splay(Select(x), 0);
112       Splay(Select(y + 2), root);
113       flag[l[r[root]]] = !flag[l[r[root]]];
114       swap(l[l[r[root]]], r[l[r[root]]]);
115       Up(r[root]), Up(root);
116   }
117   int Sum(int x, int y) {
118       Splay(Select(x), 0);
119       Splay(Select(y + 2), root);
120       return sum[l[r[root]]];
121   }
122   int main() {
123       root = 1;
124       pos = 2;
125       r[1] = s[1] = 2;
126       f[2] = s[2] = 1;
127       return 0;
128   }
```

4.8 节点大小平衡树

```
1   #include <bits/stdc++.h>
2   using namespace std;
3   const int N = 100001;
4   int root, pos, l[N], r[N], s[N], key[N];
5   inline void L(int &p) {
6       int t = r[p];
7       r[p] = l[t];
8       l[t] = p;
9       s[t] = s[p];
10      s[p] = s[l[p]] + s[r[p]] + 1;
11      p = t;
12  }
13  inline void R(int &p) {
14      int t = l[p];
15      l[p] = r[t];
16      r[t] = p;
17      s[t] = s[p];
18      s[p] = s[l[p]] + s[r[p]] + 1;
```

```
19        p = t;
20  }
21  void Fix(int &p, bool flag) {
22      if (flag) {
23          if (s[l[r[p]]] > s[l[p]])
24              R(r[p]), L(p);
25          else if (s[r[r[p]]] > s[l[p]])
26              L(p);
27          else
28              return;
29      } else {
30          if (s[r[l[p]]] > s[r[p]])
31              L(l[p]), R(p);
32          else if (s[l[l[p]]] > s[r[p]])
33              R(p);
34          else
35              return;
36      }
37      Fix(l[p], false);
38      Fix(r[p], true);
39      Fix(p, false);
40      Fix(p, true);
41  }
42  void Insert(int &p, int x) {
43      if (p) {
44          s[p]++;
45          Insert(x < key[p] ? l[p] : r[p], x);
46          Fix(p, x >= key[p]);
47      } else {
48          p = ++pos;
49          key[p] = x;
50          s[p] = 1;
51      }
52  }
53  int Delete(int &p, int x) {
54      int ans;
55      s[p]--;
56      if (x == key[p] || x < key[p] && !l[p] || x > key[p] && !r[p]) {
57          ans = key[p];
58          l[p] ? key[p] = Delete(l[p], x + 1) : p = r[p];
59      } else
60          ans = Delete(x < key[p] ? l[p] : r[p], x);
61      Fix(p, false);
62      Fix(p, true);
63      return ans;
64  }
65  int Rank(int x) {
66      int p = root, t = s[l[root]], ans;
67      while (p)
68          if (x <= key[p]) {
69              ans = t;
70              p = l[p];
71              t -= s[r[p]] + 1;
72          } else {
73              p = r[p];
74              t += s[l[p]] + 1;
75          }
76      return ans + 1;
77  }
78  int Select(int x) {
79      int p = root, t = s[l[root]];
80      while (x != t + 1)
81          if (x < t + 1) {
82              p = l[p];
83              t -= s[r[p]] + 1;
84          } else {
85              p = r[p];
86              t += s[l[p]] + 1;
87          }
88      return key[p];
89  }
90  int Pred(int x) {
91      int p = root, t;
```

```
 92     while (p)
 93         if (x > key[p]) {
 94             t = p;
 95             p = r[p];
 96         } else
 97             p = l[p];
 98     return key[t];
 99 }
100 int Succ(int x) {
101     int p = root, t;
102     while (p)
103         if (x < key[p]) {
104             t = p;
105             p = l[p];
106         } else
107             p = r[p];
108     return key[t];
109 }
110 int main() {
111     return 0;
112 }
```

5 数学

5.1 快速幂

```
 1 #include <bits/stdc++.h>
 2 using namespace std;
 3 int a, b, ans;
 4 int main() {
 5     scanf("%d%d", &a, &b);
 6     ans = 1;
 7     while (b) {
 8         if (b & 1)
 9             ans = ans * a;
10         a = a * a;
11         b >>= 1;
12     }
13     printf("%d\n", ans);
14     return 0;
15 }
```

5.2 Euclid

```
 1 #include <bits/stdc++.h>
 2 using namespace std;
 3 int a, b;
 4 int gcd(int a, int b) {
 5     return b ? gcd(b, a % b) : a;
 6 }
 7 int main() {
 8     scanf("%d%d", &a, &b);
 9     printf("%d\n", gcd(a, b));
10     return 0;
11 }
```

5.3 扩展 Euclid

```
 1 #include <bits/stdc++.h>
 2 using namespace std;
 3 int a, b, x, y, t;
 4 int gcd(int a, int b, int &x, int &y) {
 5     if (b) {
 6         int t, xt, yt;
 7         t = gcd(b, a % b, xt, yt);
```

```
8        x = yt;
9        y = xt − a / b * yt;
10       return t;
11    } else {
12        x = 1;
13        y = 0;
14        return a;
15    }
16 }
17 int main() {
18    scanf("%d%d", &a, &b);
19    t = gcd(a, b, x, y);
20    printf("%d␣%d␣%d\n", x, y, t);
21    return 0;
22 }
```

5.4 Miller-Rabin 测试

```
1  #include <bits/stdc++.h>
2  using namespace std;
3  typedef long long ll;
4  ll n;
5  ll Mul(ll a, ll b, ll MOD) {
6      ll ans = 0;
7      while (b) {
8          if (b & 1)
9              ans = (ans + a) % MOD;
10         a = (a << 1) % MOD;
11         b >>= 1;
12     }
13     return ans;
14 }
15 ll Pow(ll a, ll b, ll MOD) {
16     ll ans = 1;
17     while (b) {
18         if (b & 1)
19             ans = Mul(ans, a, MOD);
20         a = Mul(a, a, MOD);
21         b >>= 1;
22     }
23     return ans;
24 }
25 bool Judge(ll p) {
26     if (p < 2)
27         return false;
28     int num = 0;
29     ll t = p − 1, t1, t2;
30     for (; !(t & 1); t >>= 1)
31         num++;
32     for (int i = 0; i < 5; i++) {
33         t1 = Pow(rand() % (p − 1) + 1, t, p);
34         for (int j = 0; t1 != 1 && j < num; j++) {
35             t2 = Mul(t1, t1, p);
36             if (t1 != 1 && t1 != p − 1 && t2 == 1)
37                 return false;
38             t1 = t2;
39         }
40         if (t1 != 1)
41             return false;
42     }
43     return true;
44 }
45 int main() {
46     srand(time(NULL));
47     scanf("%lld", &n);
48     puts(Judge(n) ? "YES" : "NO");
49     return 0;
50 }
```

5.5 Euler 筛

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 1000001;
int n, num, p[N], fai[N], miu[N];
bool flag[N];
int main() {
    scanf("%d", &n);
    fai[1] = miu[1] = 1;
    for (int i = 2; i <= n; i++) {
        if (!flag[i]) {
            p[++num] = i;
            fai[i] = i - 1;
            miu[i] = -1;
        }
        for (int j = 1; j <= num; j++) {
            if (i * p[j] > n)
                break;
            flag[i * p[j]] = true;
            if (i % p[j] == 0) {
                fai[i * p[j]] = fai[i] * p[j];
                miu[i * p[j]] = 0;
                break;
            } else {
                fai[i * p[j]] = fai[i] * (p[j] - 1);
                miu[i * p[j]] = -miu[i];
            }
        }
    }
    printf("%d\n", num);
    for (int i = 1; i < num; i++)
        printf("%d ", p[i]);
    printf("%d\n", p[num]);
    for (int i = 1; i < n; i++)
        printf("%d ", fai[i]);
    printf("%d\n", fai[n]);
    for (int i = 1; i < n; i++)
        printf("%d ", miu[i]);
    printf("%d\n", miu[n]);
    return 0;
}
```

5.6 Gauss 消元

```cpp
#include <bits/stdc++.h>
using namespace std;
const int N = 101, M = 101;
const double EPS = 1e-5;
int n, m, tmp;
double a[M][N + 1], t[M][N + 1], temp[N + 1];
bool flag;
int main() {
    scanf("%d%d", &n, &m);
    for (int i = 1; i <= m; i++)
        for (int j = 1; j <= n + 1; j++)
            scanf("%lf", &t[i][j]);
    for (int i = 1; i <= n; i++) {
        tmp = 0;
        for (int j = 1; j <= m; j++) {
            flag = false;
            for (int k = 1; !flag && k <= n; k++)
                if (fabs(t[j][k]) > EPS)
                    flag = true;
            if (flag)
                memcpy(a[++tmp], t[j], sizeof(t[j]));
            else if (fabs(t[j][n + 1]) > EPS) {
                puts("No Solution");
                return 0;
            }
        }
    }
```

```
27          if ((m = tmp) < n) {
28              puts("Infinite␣Solutions");
29              return 0;
30          }
31          flag = false;
32          for (int j = i; !flag && j <= m; j++)
33              if (fabs(a[j][i]) > EPS) {
34                  memcpy(temp, a[i], sizeof(temp));
35                  memcpy(a[i], a[j], sizeof(temp));
36                  memcpy(a[j], temp, sizeof(temp));
37                  flag = true;
38              }
39          if (!flag) {
40              puts("Infinite␣Solutions");
41              return 0;
42          }
43          for (int j = i + 1; j <= n + 1; j++)
44              a[i][j] /= a[i][i];
45          a[i][i] = 1;
46          for (int j = i + 1; j <= m; j++) {
47              for (int k = i + 1; k <= n + 1; k++)
48                  a[j][k] -= a[i][k] * a[j][i];
49              a[j][i] = 0;
50          }
51          memcpy(t, a, sizeof(a));
52      }
53      for (int i = n - 1; i; i--)
54          for (int j = i + 1; j <= n; j++)
55              a[i][n + 1] -= a[i][j] * a[j][n + 1];
56      for (int i = 1; i < n; i++)
57          printf("%f␣", a[i][n + 1]);
58      printf("%f\n", a[n][n + 1]);
59      return 0;
60 }
```

5.7 快速 Fourier 变换

```
1  #include <bits/stdc++.h>
2  using namespace std;
3  const int N = 100001;
4  const double PI = acos(-1);
5  int n, m, LENG, SIZE;
6  double t;
7  complex<double> a[N << 2], b[N << 2], c[N << 2];
8  complex<double> ya[N << 2], yb[N << 2], yc[N << 2], yt[N << 2];
9  void DFT(complex<double> a[], complex<double> y[], bool flag) {
10     for (int i = 0; i < SIZE; i++) {
11         int t = 0;
12         for (int j = 0; j < LENG; j++)
13             t += (i >> j & 1) << LENG - j - 1;
14         y[i] = a[t];
15     }
16     for (int t = 1; t < SIZE; t <<= 1) {
17         double tmp = (flag ? -1 : 1) * PI / t;
18         for (int i = 0; i < SIZE; i += t << 1)
19             for (int j = 0; j < t; j++) {
20                 yt[i + j] = y[i + j] + polar(1.0, tmp * j) * y[i + t + j];
21                 yt[i + t + j] = y[i + j] + polar(1.0, tmp * (t + j)) * y[i + t + j];
22             }
23         memcpy(y, yt, sizeof(yt));
24     }
25     if (flag)
26         for (int i = 0; i < SIZE; i++)
27             y[i] /= SIZE;
28 }
29 int main() {
30     scanf("%d%d", &n, &m);
31     for (int i = 0; i < n; i++) {
32         scanf("%lf", &t);
33         a[i] = {t, 0};
34     }
```

```
35      for (int i = 0; i < m; i++) {
36          scanf("%lf", &t);
37          b[i] = {t, 0};
38      }
39      for (LENG = 0, SIZE = 1; SIZE < n + m − 1; LENG++, SIZE <<= 1);
40      DFT(a, ya, false);
41      DFT(b, yb, false);
42      for (int i = 0; i < SIZE; i++)
43          yc[i] = ya[i] * yb[i];
44      DFT(yc, c, true);
45      for (int i = 0; i < n + m − 2; i++)
46          printf("%f␣", c[i].real());
47      printf("%f\n", c[n + m − 2].real());
48      return 0;
49  }
```

6 计算几何

6.1 线段相交

```
1   #include <bits/stdc++.h>
2   #define x first
3   #define y second
4   #define x1 first.first
5   #define y1 first.second
6   #define x2 second.first
7   #define y2 second.second
8   using namespace std;
9   typedef pair<double, double> Point;
10  typedef pair<Point, Point> Segment;
11  Segment a, b;
12  inline double Cross(Point a, Point b, Point c) {
13      return (b.x − a.x) * (c.y − a.y) − (c.x − a.x) * (b.y − a.y);
14  }
15  inline bool Judge(Segment a, Segment b) {
16      if (max(a.x1, a.x2) < min(b.x1, b.x2) || max(b.x1, b.x2) < min(a.x1, a.x2))
17          return false;
18      if (max(a.y1, a.y2) < min(b.y1, b.y2) || max(b.y1, b.y2) < min(a.y1, a.y2))
19          return false;
20      return Cross(a.x, a.y, b.x) * Cross(a.x, a.y, b.y) <= 0 &&
21              Cross(b.x, b.y, a.x) * Cross(b.x, b.y, a.y) <= 0;
22  }
23  int main() {
24      scanf("%lf%lf%lf%lf%lf%lf%lf%lf", &a.x1, &a.y1, &a.x2, &a.y2, &b.x1, &b.y1, &b.x2, &b.y2);
25      puts(Judge(a, b) ? "Yes" : "No");
26      return 0;
27  }
```

6.2 多边形面积

```
1   #include <bits/stdc++.h>
2   #define x first
3   #define y second
4   using namespace std;
5   typedef pair<double, double> Point;
6   const int N = 1000001;
7   int n;
8   double ans;
9   Point p[N];
10  inline double Cross(Point a, Point b, Point c) {
11      return (b.x − a.x) * (c.y − a.y) − (c.x − a.x) * (b.y − a.y);
12  }
13  int main() {
14      scanf("%d", &n);
15      for (int i = 1; i <= n; i++)
16          scanf("%lf%lf", &p[i].x, &p[i].y);
17      for (int i = 3; i <= n; i++)
18          ans += Cross(p[1], p[i − 1], p[i]);
```

```
19      printf("%f\n", ans / 2);
20      return 0;
21  }
```

6.3 Graham 扫描

```
1   #include <bits/stdc++.h>
2   #define x first
3   #define y second
4   using namespace std;
5   typedef pair<double, double> Point;
6   const int N = 100001;
7   int n, top;
8   Point p[N], s[N];
9   inline double Sqr(double x) {
10      return x * x;
11  }
12  inline double Dist(Point a, Point b) {
13      return sqrt(Sqr(a.x − b.x) + Sqr(a.y − b.y));
14  }
15  inline double Cross(Point a, Point b, Point c) {
16      return (b.x − a.x) * (c.y − a.y) − (c.x − a.x) * (b.y − a.y);
17  }
18  inline bool cmp(Point a, Point b) {
19      return Cross(p[0], a, b) > 0 || Cross(p[0], a, b) == 0 && Dist(p[0], a) < Dist(p[0], b);
20  }
21  int main() {
22      scanf("%d", &n);
23      for (int i = 0; i < n; i++) {
24          scanf("%lf%lf", &p[i].x, &p[i].y);
25          if (p[i].y < p[0].y || p[i].y == p[0].y && p[i].x < p[0].x)
26              swap(p[0], p[i]);
27      }
28      sort(p + 1, p + n, cmp);
29      s[top = 1] = p[0];
30      for (int i = 1; i < n; i++) {
31          for (; top > 1 && Cross(s[top − 1], s[top], p[i]) < 0; top−−);
32          s[++top] = p[i];
33      }
34      for (; top > 2 && Cross(s[top − 1], s[top], s[1]) < 0; top−−);
35      printf("%d\n", top);
36      for (int i = 1; i <= top; i++)
37          printf("%f␣%f\n", s[i].x, s[i].y);
38      return 0;
39  }
```

6.4 最小圆覆盖

```
1   #include <bits/stdc++.h>
2   #define x first
3   #define y second
4   using namespace std;
5   typedef pair<double, double> Point;
6   const int N = 1000001;
7   const double EPS = 1e−5;
8   int n;
9   double r;
10  Point O, p[N];
11  inline double Sqr(double x) {
12      return x * x;
13  }
14  inline double Dist(Point a, Point b) {
15      return sqrt(Sqr(a.x − b.x) + Sqr(a.y − b.y));
16  }
17  inline Point Calc(Point a, Point b, Point c) {
18      if (fabs((b.x − a.x) * (c.y − a.y) − (c.x − a.x) * (b.y − a.y)) < EPS)
19          if (Dist(a, c) > Dist(b, c))
20              return {(a.x + c.x) / 2, (a.y + c.y) / 2};
21          else
```

```
22            return {(b.x + c.x) / 2, (b.y + c.y) / 2};
23        double k1, k2, b1, b2;
24        k1 = (a.x − c.x) / (c.y − a.y);
25        b1 = (a.y + c.y) / 2 − k1 * (a.x + c.x) / 2;
26        k2 = (b.x − c.x) / (c.y − b.y);
27        b2 = (b.y + c.y) / 2 − k2 * (b.x + c.x) / 2;
28        return {(b2 − b1) / (k1 − k2), (k1 * b2 − k2 * b1) / (k1 − k2)};
29    }
30    int main() {
31        scanf("%d", &n);
32        for (int i = 1; i <= n; i++)
33            scanf("%lf%lf", &p[i].x, &p[i].y);
34        random_shuffle(p + 1, p + n + 1);
35        O = p[1];
36        r = 0;
37        for (int i = 2; i <= n; i++)
38            if (Dist(O, p[i]) > r) {
39                O = p[i];
40                r = 0;
41                for (int j = 1; j < i; j++)
42                    if (Dist(O, p[j]) > r) {
43                        O = {(p[i].x + p[j].x) / 2, (p[i].y + p[j].y) / 2};
44                        r = Dist(O, p[j]);
45                        for (int k = 1; k < j; k++)
46                            if (Dist(O, p[k]) > r) {
47                                O = Calc(p[i], p[j], p[k]);
48                                r = Dist(O, p[k]);
49                            }
50                    }
51            }
52        printf("%f␣%f\n%f\n", O.x, O.y, r);
53        return 0;
54    }
```