

1 Basic

1.1 Basic codeblock setting

```
1 Settings -> Editor -> Keyboard shortcuts ->
  Plugins -> Source code formatter (AStyle
  )
2 Settings -> Source Formatter -> Padding
3 Delete empty lines within a function or
  method
4 Insert space padding around operators
5 Insert space padding around parentheses on
  outside
6 Remove extra space padding around
  parentheses
```

1.2 Basic vim setting

```
1 /*at home directory*/
2 /* vi ~/.vimrc */
3 syntax enable
4 set smartindent
5 set tabstop=4
6 set shiftwidth=4
7 set expandtab
8 set relativenumber
```

1.3 Code Template

```
1 #include <bits/stdc++.h>
2 using namespace std;
3 typedef long long ll;
4 typedef unsigned long long ull;
5 typedef pair<int, int> pii;
6 #define x first
7 #define y second
8 #define pb push_back
9 #define len length()
10 #define all(p) p.begin(), p.end()
11 #define endl '\n'
12 #define bug(x) cout << "value of " << #x <<
  " is " << x << endl;
13 #define bugarr(x) \
14   for (auto i : x) \
15     cout << i << ' '; \
16   cout << endl;
17
18 int main()
19 {
20   ios::sync_with_stdio(0);
21   cin.tie(0);
22   return 0;
23 }
```

1.4 Python

```
1 //輸入
2 import sys
3 line = sys.stdin.readline() // 會讀到換行
4 input().strip()
5
6 array = [0] * (N) //N個0
7 range(0, N) // 0 ~ N-1
8 D, R, N = map(int, line[:-1].split()) // 分
  三個 int 變數
9
10 pow(a, b, c) // a ^ b % c
11
12 print(*objects, sep = ' ', end = '\n')
13 // objects -- 可以一次輸出多個對象
14 // sep -- 分開多個objects
15 // end -- 默認值是\n
16
17 // EOF break
18 try:
19     while True:
20         //input something
21 except EOFError:
22     pass
```

1.5 Range data

```
1 int (-2147483648 to 2147483647)
2 unsigned int(0 to 4294967295)
3 long(-2147483648 to 2147483647)
4 unsigned long(0 to 4294967295)
5 long long(-9223372036854775808 to
  9223372036854775807)
6 unsigned long long (0 to
  18446744073709551615)
```

1.6 Some Function

```
1 round(double f); // 四捨五入
2 ceil(double f); // 進入
3 floor(double f); // 捨去
4 __builtin_popcount(int n); // 32bit有多少 1
5 to_string(int s); // int to string
6
7 /** 全排列要先 sort !!! */
8 next_permutation(num.begin(), num.end());
9 prev_permutation(num.begin(), num.end());
10 //用binary search找大於或等於val的最小值的位
  置
11 vector<int>::iterator it = lower_bound(v.
  begin(), v.end(), val);
12 //用binary search找大於val的最小值的位置
13 vector<int>::iterator it = upper_bound(v.
  begin(), v.end(), val);
14 /*queue*/
15
```

```
16 queue<datatype> q;
17 front(); /*取出最前面的值(沒有移除掉)*/
18 back(); /*取出最後面的值(沒有移除掉)*/
19 pop(); /*移掉最前面的值*/
20 push(); /*新增值到最後面*/
21 empty(); /*回傳bool,檢查是不是空的queue*/
22 size(); /*queue 的大小*/
23
24 /*stack*/
25 stack<datatype> s;
26 top(); /*取出最上面的值(沒有移除掉)*/
27 pop(); /*移掉最上面的值*/
28 push(); /*新增值到最上面*/
29 empty(); /*bool 檢查是不是空*/
30 size(); /*stack 的大小*/
31
32 /*unordered_set*/
33 unordered_set<datatype> s;
34 unordered_set<datatype> s(arr, arr + n);
35 /*initial with array*/
36 insert(); /*插入值*/
37 erase(); /*刪除值*/
38 empty(); /*bool 檢查是不是空*/
39 count(); /*判斷元素存在回傳1 無則回傳0*/
```

1.7 Time

```
1 cout << 1.0 * clock() / CLOCKS_PER_SEC <<
  endl;
```

2 DP

2.1 3 維 DP 思路

```
1 解題思路: dp[i][j][k]
2 i 跟 j 代表 range i ~ j 的 value
3 k 在我的理解裡是視題目的要求而定的
4 像是 Remove Boxes 當中 k 代表的是在 i 之前還
  有多少個連續的箱子
5 所以每次區間消去的值就是(k+1) * (k+1)
6 換言之, 我認為可以理解成 k 的意義就是題目今
  天所關注的重點, 就是老師說的題目所規定的
  運算
```

2.2 Knapsack Bounded

```
1 const int N = 100, W = 100000;
2 int cost[N], weight[N], number[N];
3 int c[W + 1];
4 void knapsack(int n, int w)
5 {
```

```
6   for (int i = 0; i < n; ++i)
7   {
8       int num = min(number[i], w / weight[
9       i]);
10      for (int k = 1; num > 0; k *= 2)
11      {
12          if (k > num)
13              k = num;
14          num -= k;
15          for (int j = w; j >= weight[i] *
16              k; --j)
17              c[j] = max(c[j], c[j -
18              weight[i] * k] + cost[i]
19              * k);
20      }
21  }
22  cout << "Max Prince" << c[w];
23 }
```

2.3 Knapsack sample

```
1 int Knapsack(vector<int> weight, vector<int>
  value, int bag_Weight)
2 {
3     // vector<int> weight = {1, 3, 4};
4     // vector<int> value = {15, 20, 30};
5     // int bagWeight = 4;
6     vector<vector<int>> dp(weight.size(),
7     vector<int>(bagWeight + 1, 0));
8     for (int j = weight[0]; j <= bagWeight;
9     j++)
10         dp[0][j] = value[0];
11     // weight數組的大小就是物品個數
12     for (int i = 1; i < weight.size(); i++)
13     { // 遍歷物品
14         for (int j = 0; j <= bagWeight; j++)
15         { // 遍歷背包容量
16             if (j < weight[i]) dp[i][j] = dp
17             [i - 1][j];
18             else dp[i][j] = max(dp[i - 1][j],
19             dp[i - 1][j - weight[i]]
20             + value[i]);
21         }
22     }
23     cout << dp[weight.size() - 1][bagWeight]
24     << endl;
25 }
```

2.4 Knapsack Unbounded

```
1 const int N = 100, W = 100000;
2 int cost[N], weight[N];
3 int c[W + 1];
4 void knapsack(int n, int w)
5 {
6     memset(c, 0, sizeof(c));
7     for (int i = 0; i < n; ++i)
8         for (int j = weight[i]; j <= w; ++j)
```

```

9         c[j] = max(c[j], c[j - weight[i
10             ]] + cost[i]);
11     }
    cout << "最高的價值為" << c[w];
}

```

2.5 LCIS

```

1 int LCIS_len(vector<int> arr1, vector<int>
    arr2)
2 {
3     int n = arr1.size(), m = arr2.size();
4     vector<int> table(m, 0);
5     for (int j = 0; j < m; j++)
6         table[j] = 0;
7     for (int i = 0; i < n; i++)
8     {
9         int current = 0;
10        for (int j = 0; j < m; j++)
11        {
12            if (arr1[i] == arr2[j])
13                if (current + 1 > table[j])
14                    table[j] = current + 1;
15
16            if (arr1[i] > arr2[j])
17                if (table[j] > current)
18                    current = table[j];
19        }
20    }
21    int result = 0;
22    for (int i = 0; i < m; i++)
23        if (table[i] > result)
24            result = table[i];
25    return result;
26 }

```

2.6 LCS

```

1 int LCS(vector<string> Ans, vector<string>
    num)
2 {
3     int N = Ans.size(), M = num.size();
4     vector<vector<int>> LCS(N + 1, vector<
        int>(M + 1, 0));
5     for (int i = 1; i <= N; ++i)
6     {
7         for (int j = 1; j <= M; ++j)
8         {
9             if (Ans[i - 1] == num[j - 1])
10                LCS[i][j] = LCS[i - 1][j -
                    1] + 1;
11            else
12                LCS[i][j] = max(LCS[i - 1][j],
                    LCS[i][j - 1]);
13        }
14    }
15    cout << LCS[N][M] << '\n';
16    //列印 LCS
17    int n = N, m = M;

```

```

18     vector<string> k;
19     while (n && m)
20     {
21         if (LCS[n][m] != max(LCS[n - 1][m],
                LCS[n][m - 1]))
22         {
23             k.push_back(Ans[n - 1]);
24             n--;
25             m--;
26         }
27         else if (LCS[n][m] == LCS[n - 1][m])
28             n--;
29         else if (LCS[n][m] == LCS[n][m - 1])
30             m--;
31     }
32     reverse(k.begin(), k.end());
33     for (auto i : k)
34         cout << i << " ";
35     cout << endl;
36     return LCS[N][M];
37 }

```

2.7 LIS

```

1 vector<int> ans;
2 void printLIS(vector<int> &arr, vector<int>
    &pos, int index)
3 {
4     if (pos[index] != -1)
5         printLIS(arr, pos, pos[index]);
6     // printf("%d", arr[index]);
7     ans.push_back(arr[index]);
8 }
9 void LIS(vector<int> &arr)
10 {
11     vector<int> dp(arr.size(), 1);
12     vector<int> pos(arr.size(), -1);
13     int res = INT_MIN, index = 0;
14     for (int i = 0; i < arr.size(); ++i)
15     {
16         for (int j = i + 1; j < arr.size();
                ++j)
17         {
18             if (arr[j] > arr[i])
19             {
20                 if (dp[i] + 1 > dp[j])
21                     dp[j] = dp[i] + 1;
22                 pos[j] = i;
23             }
24         }
25     }
26     if (dp[i] > res)
27     {
28         res = dp[i];
29         index = i;
30     }
31 }
32 cout << res << endl; // length
33 printLIS(arr, pos, index);
34 for (int i = 0; i < ans.size(); i++)
35 {
36     cout << ans[i];
37 }

```

```

38     if (i != ans.size() - 1)
39         cout << ' ';
40 }
41 cout << '\n';
42 }

```

2.8 LPS

```

1 void LPS(string s)
2 {
3     int maxlen = 0, l, r;
4     int n = s.size();
5     for (int i = 0; i < n; i++)
6     {
7         int x = 0;
8         while ((s[i - x] == s[i + x]) && (i
                - x >= 0) && (i + x < n)) //odd
9             length
10             x++;
11         x--;
12         if (2 * x + 1 > maxlen)
13         {
14             maxlen = 2 * x + 1;
15             l = i - x;
16             r = i + x;
17         }
18         x = 0;
19         while ((s[i - x] == s[i + 1 + x]) &&
                (i - x >= 0) && (i + 1 + x < n)) //even length
20             x++;
21         if (2 * x > maxlen)
22         {
23             maxlen = 2 * x;
24             l = i - x + 1;
25             r = i + x;
26         }
27     }
28     cout << maxlen << '\n'; // 最後長度
29     cout << l + 1 << ' ' << r + 1 << '\n';
30     //頭到尾
31 }

```

2.9 Max_subarray

```

1 /*Kadane's algorithm*/
2 int maxSubArray(vector<int> & nums) {
3     int local_max = nums[0], global_max =
        nums[0];
4     for (int i = 1; i < nums.size(); i++) {
5         local_max = max(nums[i], nums[i] +
                local_max);
6         global_max = max(local_max,
                global_max);
7     }
8     return global_max;
9 }

```

2.10 Money problem

```

1 //能否湊得某個價位
2 void change(vector<int> price, int limit)
3 {
4     vector<bool> c(limit + 1, 0);
5     c[0] = true;
6     for (int i = 0; i < price.size(); ++i)
7         // 依序加入各種面額
8         for (int j = price[i]; j <= limit;
                ++j) // 由低價位逐步到高價位
9             c[j] = c[j] | c[j - price[i]];
10        // 湊、湊、湊
11        if (c[limit]) cout << "YES\n";
12        else cout << "NO\n";
13 }
14 // 湊得某個價位的湊法總共幾種
15 void change(vector<int> price, int limit)
16 {
17     vector<int> c(limit + 1, 0);
18     c[0] = true;
19     for (int i = 0; i < price.size(); ++i)
20         for (int j = price[i]; j <= limit;
                ++j)
21             c[j] += c[j - price[i]];
22     cout << c[limit] << '\n';
23 }
24 // 湊得某個價位的最少錢幣用量
25 void change(vector<int> price, int limit)
26 {
27     vector<int> c(limit + 1, 0);
28     c[0] = true;
29     for (int i = 0; i < price.size(); ++i)
30         for (int j = price[i]; j <= limit;
                ++j)
31             c[j] = min(c[j], c[j - price[i]]
                    + 1);
32     cout << c[limit] << '\n';
33 }
34 //湊得某個價位的錢幣用量，有哪幾種可能性
35 void change(vector<int> price, int limit)
36 {
37     vector<int> c(limit + 1, 0);
38     c[0] = true;
39     for (int i = 0; i < price.size(); ++i)
40         for (int j = price[i]; j <= limit;
                ++j)
41             c[j] |= c[j - price[i]] << 1; //
42            錢幣數量加一，每一種可能性都
43            加一。
44 }
45 for (int i = 1; i <= 63; ++i)
46     if (c[i] & (1 << i))
47         cout << "用" << i << "個錢幣可湊
48             得價位" << m;

```

3 Flow & matching

3.1 Dinic

```

1 const long long INF = 1LL<<60;
2 struct Dinic { //O(VVE), with minimum cut
3     static const int MAXN = 5003;
4     struct Edge{
5         int u, v;
6         long long cap, rest;
7     };
8     int n, m, s, t, d[MAXN], cur[MAXN];
9     vector<Edge> edges;
10    vector<int> G[MAXN];
11    void init(){
12        edges.clear();
13        for ( int i = 0 ; i < n ; i++ ) G[i]
14            .clear();
15        n = 0;
16        // min cut start
17        bool side[MAXN];
18        void cut(int u) {
19            side[u] = 1;
20            for ( int i : G[u] ) {
21                if ( !side[ edges[i].v ] &&
22                    edges[i].rest )
23                    cut(edges[i].v);
24            }
25        }
26        // min cut end
27        int add_node(){
28            return n++;
29        }
30        void add_edge(int u, int v, long long
31            cap){
32            edges.push_back( {u, v, cap, cap} );
33            edges.push_back( {v, u, 0, 0LL} );
34            m = edges.size();
35            G[u].push_back(m-2);
36            G[v].push_back(m-1);
37        }
38        bool bfs(){
39            fill(d,d+n,-1);
40            queue<int> que;
41            que.push(s); d[s]=0;
42            while (!que.empty()){
43                int u = que.front(); que.pop();
44                for (int ei : G[u]){
45                    Edge &e = edges[ei];
46                    if (d[e.v] < 0 && e.rest >
47                        0){
48                        d[e.v] = d[u] + 1;
49                        que.push(e.v);
50                    }
51                }
52            }
53            return d[t] >= 0;
54        }
55        long long dfs(int u, long long a){
56            if ( u == t || a == 0 ) return a;
57            long long flow = 0, f;

```

```

55        for ( int &i=cur[u]; i < (int)G[u].
56            size(); i++) {
57            Edge &e = edges[ G[u][i] ];
58            if ( d[u] + 1 != d[e.v] )
59                continue;
60            f = dfs(e.v, min(a, e.rest) );
61            if ( f > 0 ) {
62                e.rest -= f;
63                edges[ G[u][i]^1 ].rest += f;
64                flow += f;
65                a -= f;
66                if ( a == 0 ) break;
67            }
68        }
69        return flow;
70    }
71    long long maxflow(int _s, int _t){
72        s = _s, t = _t;
73        long long flow = 0, mf;
74        while ( bfs() ){
75            fill(cur,cur+n,0);
76            while ( (mf = dfs(s, INF)) )
77                flow += mf;
78        }
79        return flow;
80    }
81 } dinic;

```

3.2 Edmonds_karp

```

1 /*Flow - Edmonds-karp*/
2 /*Based on UVa820*/
3 #define inf 1000000
4 int getMaxFlow(vector<vector<int>> &capacity
5     , int s, int t, int n){
6     int ans = 0;
7     vector<vector<int>> residual(n+1, vector<
8         int>(n+1, 0)); //residual network
9     while(true){
10        vector<int> bottleneck(n+1, 0);
11        bottleneck[s] = inf;
12        queue<int> q;
13        q.push(s);
14        vector<int> pre(n+1, 0);
15        while(!q.empty() && bottleneck[t] == 0){
16            int cur = q.front();
17            q.pop();
18            for(int i = 1; i <= n; i++){
19                if(bottleneck[i] == 0 && capacity[
20                    cur][i] > residual[cur][i]){
21                    q.push(i);
22                    pre[i] = cur;
23                    bottleneck[i] = min(bottleneck[cur]
24                        , capacity[cur][i] - residual
25                        [cur][i]);
26                }
27            }
28        }
29        if(bottleneck[t] == 0) break;
30        for(int cur = t; cur != s; cur = pre[cur]
31            ){
32                residual[pre[cur]][cur] +=
33                bottleneck[t];

```

```

27        residual[cur][pre[cur]] -=
28        bottleneck[t];
29    }
30    ans += bottleneck[t];
31    return ans;
32 }
33 int main(){
34     int testcase = 1;
35     int n;
36     while(cin>>n){
37         if(n == 0)
38             break;
39         vector<vector<int>> capacity(n+1, vector
40             <int>(n+1, 0));
41         int s, t, c;
42         cin >> s >> t >> c;
43         int a, b, bandwidth;
44         for(int i = 0 ; i < c ; ++i){
45             cin >> a >> b >> bandwidth;
46             capacity[a][b] += bandwidth;
47             capacity[b][a] += bandwidth;
48         }
49         cout << "Network " << testcase++ << endl
50             << endl;
51         cout << "The bandwidth is " <<
52             getMaxFlow(capacity, s, t, n) << "."
53             << endl;
54     }
55     return 0;
56 }

```

3.3 hungarian

```

1 /*bipartite - hungarian*/
2 struct Graph{
3     static const int MAXN = 5003;
4     vector<int> G[MAXN];
5     int n, match[MAXN], vis[MAXN];
6     void init(int _n){
7         n = _n;
8         for (int i=0; i<n; i++) G[i].clear()
9             ;
10    }
11    bool dfs(int u){
12        for (int v:G[u]){
13            if (vis[v]) continue;
14            vis[v]=true;
15            if (match[v]==-1 || dfs(match[v]
16                )){
17                match[v] = u;
18                match[u] = v;
19                return true;
20            }
21        }
22        return false;
23    }
24    int solve(){
25        int res = 0;
26        memset(match,-1,sizeof(match));
27        for (int i=0; i<n; i++){
28            if (match[i]==-1){

```

```

27        memset(vis,0,sizeof(vis));
28        if ( dfs(i) ) res++;
29    }
30    }
31    return res;
32 }
33 } graph;

```

3.4 Maximum_matching

```

1 /*bipartite - maximum matching*/
2 bool dfs(vector<vector<bool>> res,int node,
3     vector<int>& x, vector<int>& y, vector<
4     bool> pass){
5     for (int i = 0; i < res[0].size(); i++){
6         if(res[node][i] && !pass[i]){
7             pass[i] = true;
8             if(y[i] == -1 || dfs(res,y[i],x,
9                 y,pass)){
10                 x[node] = i;
11                 y[i] = node;
12                 return true;
13             }
14         }
15     }
16     return false;
17 }
18 int main(){
19     int n,m,l;
20     while(cin>>n>>m>>l){
21         vector<vector<bool>> res(n, vector<
22             bool>(m, false));
23         for (int i = 0; i < l; i++){
24             int a, b;
25             cin >> a >> b;
26             res[a][b] = true;
27         }
28         int ans = 0;
29         vector<int> x(n, -1);
30         vector<int> y(m, -1);
31         for (int i = 0; i < n; i++){
32             vector<bool> pass(m, false);
33             if(dfs(res,i,x,y,pass))
34                 ans += 1;
35         }
36         cout << ans << endl;
37     }
38     return 0;
39 }
40 /*
41 input:
42 4 3 5 //n matching m, l links
43 0 0
44 0 2
45 1 0
46 2 1
47 3 1
48 answer is 3
49 */

```

3.5 MFlow Model

```

1 typedef long long ll;
2 struct MF
3 {
4     static const int N = 5000 + 5;
5     static const int M = 60000 + 5;
6     static const ll oo = 1000000000000LL;
7
8     int n, m, s, t, tot, tim;
9     int first[N], next[M];
10    int u[M], v[M], cur[N], vi[N];
11    ll cap[M], flow[M], dis[N];
12    int que[N + N];
13
14    void Clear()
15    {
16        tot = 0;
17        tim = 0;
18        for (int i = 1; i <= n; ++i)
19            first[i] = -1;
20    }
21    void Add(int from, int to, ll cp, ll flw)
22    {
23        u[tot] = from;
24        v[tot] = to;
25        cap[tot] = cp;
26        flow[tot] = flw;
27        next[tot] = first[u[tot]];
28        first[u[tot]] = tot;
29        ++tot;
30    }
31    bool bfs()
32    {
33        ++tim;
34        dis[s] = 0;
35        vi[s] = tim;
36
37        int head, tail;
38        head = tail = 1;
39        que[head] = s;
40        while (head <= tail)
41        {
42            for (int i = first[que[head]]; i
43                != -1; i = next[i])
44            {
45                if (vi[v[i]] != tim && cap[i]
46                    > flow[i])
47                {
48                    vi[v[i]] = tim;
49                    dis[v[i]] = dis[que[head]]
50                        + 1;
51                    que[++tail] = v[i];
52                }
53            }
54            ++head;
55        }
56        return vi[t] == tim;
57    }
58    ll dfs(int x, ll a)
59    {
60        if (x == t || a == 0)
61            return a;
62        ll flw = 0;
63        for (int i = first[x]; i != -1; i = next[i])
64        {
65            if (dis[x] + 1 == dis[v[i]] && (
66                f = dfs(v[i], min(a, cap[i]
67                    - flow[i])) > 0)
68            {
69                flow[i] += f;
70                flow[i ^ 1] -= f;
71                a -= f;
72                flw += f;
73                if (a == 0)
74                    break;
75            }
76        }
77        return flw;
78    }
79    ll MaxFlow(int s, int t)
80    {
81        this->s = s;
82        this->t = t;
83        ll flw = 0;
84        while (bfs())
85        {
86            for (int i = 1; i <= n; ++i)
87                cur[i] = 0;
88            flw += dfs(s, oo);
89        }
90        return flw;
91    }
92    // MF Net;
93    // Net.n = n;
94    // Net.Clear();
95    // a 到 b (注意從1開始!!!!)
96    // Net.Add(a, b, w, 0);
97    // Net.MaxFlow(s, d)
98    // s 到 d 的 MF

```

4 Geometry

4.1 Closest Pair

```

1 //最近點對 (距離) //台大
2 vector<pair<double, double>> p;
3 double closest_pair(int l, int r)
4 {
5     // p 要對 x 軸做 sort
6     if (l == r)
7         return 1e9;
8     if (r - l == 1)
9         return dist(p[l], p[r]); // 兩點距離
10    int m = (l + r) >> 1;
11    double d = min(closest_pair(l, m),
12        closest_pair(m + 1, r));
13    vector<int> vec;
14    for (int i = m; i >= l && fabs(p[m].x -
15        p[i].x) < d; --i)
16        vec.push_back(i);

```

```

15    for (int i = m + 1; i <= r && fabs(p[m].
16        x - p[i].x) < d; ++i)
17        vec.push_back(i);
18    sort(vec.begin(), vec.end(), [&](int a,
19        int b)
20    { return p[a].y < p[b].y; });
21    for (int i = 0; i < vec.size(); ++i)
22        for (int j = i + 1; j < vec.size()
23            && fabs(p[vec[j]].y - p[vec[i]].
24                y) < d; ++j)
25            d = min(d, dist(p[vec[i]], p[vec
26                [j]]));
27    return d;
28 }

```

4.2 Line

```

1 template <typename T>
2 struct line
3 {
4     line() {}
5     point<T> p1, p2;
6     T a, b, c; //ax+by+c=0
7     line(const point<T> &x, const point<T> &
8         y) : p1(x), p2(y) {}
9     void pton()
10    { //轉成一般式
11        a = p1.y - p2.y;
12        b = p2.x - p1.x;
13        c = -a * p1.x - b * p1.y;
14    }
15    T ori(const point<T> &p) const
16    { //點和有向直線的關係 · >0左邊、=0在線上
17        <0右邊
18        return (p2 - p1).cross(p - p1);
19    }
20    T btw(const point<T> &p) const
21    { //點投影落在線段上<=0
22        return (p1 - p).dot(p2 - p);
23    }
24    bool point_on_segment(const point<T> &p)
25        const
26    { //點是否在線段上
27        return ori(p) == 0 && btw(p) <= 0;
28    }
29    T dis2(const point<T> &p, bool
30        is_segment = 0) const
31    { //點跟直線/線段的距離平方
32        point<T> v = p2 - p1, v1 = p - p1;
33        if (is_segment)
34        {
35            point<T> v2 = p - p2;
36            if (v.dot(v1) <= 0)
37                return v1.abs2();
38            if (v.dot(v2) >= 0)
39                return v2.abs2();
40        }
41        T tmp = v.cross(v1);
42        return tmp * tmp / v.abs2();
43    }
44    T seg_dis2(const line<T> &l) const
45    { //兩線段距離平方

```

```

1    return min({dis2(l.p1, 1), dis2(l.p2
2        , 1), l.dis2(p1, 1), l.dis2(p2,
3            1)});
4    }
5    point<T> projection(const point<T> &p)
6        const
7    { //點對直線的投影
8        point<T> n = (p2 - p1).normal();
9        return p - n * (p - p1).dot(n) / n.
10            abs2();
11    }
12    point<T> mirror(const point<T> &p) const
13    {
14        //點對直線的鏡射 · 要先呼叫pton轉成一般式
15        point<T> R;
16        T d = a * a + b * b;
17        R.x = (b * b * p.x - a * a * p.x - 2
18            * a * b * p.y - 2 * a * c) / d;
19        R.y = (a * a * p.y - b * b * p.y - 2
20            * a * b * p.x - 2 * b * c) / d;
21        return R;
22    }
23    bool equal(const line &l) const
24    { //直線相等
25        return ori(l.p1) == 0 && ori(l.p2)
26            == 0;
27    }
28    bool parallel(const line &l) const
29    {
30        return (p1 - p2).cross(l.p1 - l.p2)
31            == 0;
32    }
33    bool cross_seg(const line &l) const
34    {
35        return (p2 - p1).cross(l.p1 - p1) *
36            (p2 - p1).cross(l.p2 - p1) <= 0;
37        //直線是否交線段
38    }
39    int line_intersect(const line &l) const
40    { //直線相交情況 · -1無限多點、1交於一
41        點、0不相交
42        return parallel(l) ? (ori(l.p1) == 0
43            ? -1 : 0) : 1;
44    }
45    int seg_intersect(const line &l) const
46    {
47        T c1 = ori(l.p1), c2 = ori(l.p2);
48        T c3 = l.ori(p1), c4 = l.ori(p2);
49        if (c1 == 0 && c2 == 0)
50        { //共線
51            bool b1 = btw(l.p1) >= 0, b2 =
52                btw(l.p2) >= 0;
53            T a3 = l.btw(p1), a4 = l.btw(p2);
54            ;
55            if (b1 && b2 && a3 == 0 && a4 >=
56                0)
57                return 2;
58            if (b1 && b2 && a3 >= 0 && a4 ==
59                0)
60                return 3;
61            if (b1 && b2 && a3 >= 0 && a4 >=
62                0)
63                return 0;
64        }
65    }

```

```

88     return -1; //無限交點
89 }
90 else if (c1 * c2 <= 0 && c3 * c4 <=
91     0)
92     return 1;
93 return 0; //不相交
94 }
95 point<T> line_intersection(const line &l
96     ) const
97 { /*直線交點*/
98     point<T> a = p2 - p1, b = l.p2 - l.
99     p1, s = l.p1 - p1;
100     //if(a.cross(b)==0)return INF;
101     return p1 + a * (s.cross(b) / a.
102         cross(b));
103 }
104 point<T> seg_intersection(const line &l
105     ) const
106 { //線段交點
107     int res = seg_intersect(l);
108     if (res <= 0)
109         assert(0);
110     if (res == 2)
111         return p1;
112     if (res == 3)
113         return p2;
114     return line_intersection(l);
115 }
116 };

```

```

30     return x * b.x + y * b.y;
31 }
32 T cross(const point &b) const
33 {
34     return x * b.y - y * b.x;
35 }
36 point normal() const
37 { //求法向量
38     return point(-y, x);
39 }
40 T abs2() const
41 { //向量長度的平方
42     return dot(*this);
43 }
44 T rad(const point &b) const
45 { //兩向量的弧度
46     return fabs(atan2(fabs(cross(b)),
47         dot(b)));
48 }
49 T getA() const
50 { //對x軸的弧度
51     T A = atan2(y, x); //超過180度會變負
52     if (A <= -PI / 2)
53         A += PI * 2;
54     return A;
55 }
56 };

```

4.3 Point

```

1 const double PI = atan2(0.0, -1.0);
2 template <typename T>
3 struct point
4 {
5     T x, y;
6     point() {}
7     point(const T &x, const T &y) : x(x), y(
8         y) {}
9     point operator+(const point &b) const
10     {
11         return point(x + b.x, y + b.y);
12     }
13     point operator-(const point &b) const
14     {
15         return point(x - b.x, y - b.y);
16     }
17     point operator*(const T &b) const
18     {
19         return point(x * b, y * b);
20     }
21     point operator/(const T &b) const
22     {
23         return point(x / b, y / b);
24     }
25     bool operator==(const point &b) const
26     {
27         return x == b.x && y == b.y;
28     }
29     T dot(const point &b) const
30     {

```

4.4 Polygon

```

1 template <typename T>
2 struct polygon
3 {
4     polygon() {}
5     vector<point<T>> p; //逆時針順序
6     T area() const
7     { //面積
8         T ans = 0;
9         for (int i = p.size() - 1, j = 0; j
10             < (int)p.size(); i = j++)
11             ans += p[i].cross(p[j]);
12         return ans / 2;
13     }
14     point<T> center_of_mass() const
15     { //重心
16         T cx = 0, cy = 0, w = 0;
17         for (int i = p.size() - 1, j = 0; j
18             < (int)p.size(); i = j++)
19         {
20             T a = p[i].cross(p[j]);
21             cx += (p[i].x + p[j].x) * a;
22             cy += (p[i].y + p[j].y) * a;
23             w += a;
24         }
25         return point<T>(cx / 3 / w, cy / 3 /
26             w);
27     }
28     char ahas(const point<T> &t) const
29     { //點是否在簡單多邊形內，是的話回傳1、
30         在邊上回傳-1、否則回傳0

```

```

27 bool c = 0;
28 for (int i = 0, j = p.size() - 1; i
29     < p.size(); j = i++)
30     if (line<T>(p[i], p[j]).
31         point_on_segment(t))
32         return -1;
33     else if ((p[i].y > t.y) != (p[j
34         ].y > t.y) &&
35         t.x < (p[j].x - p[i].x)
36         * (t.y - p[i].y) /
37         (p[j].y - p[i].y)
38         + p[i].x)
39         c = !c;
40 return c;
41 }
42 char point_in_convex(const point<T> &x)
43     const
44 {
45     int l = 1, r = (int)p.size() - 2;
46     while (l <= r)
47     { //點是否在凸多邊形內，是的話回傳1
48         、在邊上回傳-1、否則回傳0
49         int mid = (l + r) / 2;
50         T a1 = (p[mid] - p[0]).cross(x -
51             p[0]);
52         T a2 = (p[mid + 1] - p[0]).cross
53             (x - p[0]);
54         if (a1 >= 0 && a2 <= 0)
55         {
56             T res = (p[mid + 1] - p[mid
57                 ]).cross(x - p[mid]);
58             return res > 0 ? 1 : (res >=
59                 0 ? -1 : 0);
60         }
61         else if (a1 < 0)
62             r = mid - 1;
63         else
64             l = mid + 1;
65     }
66     return 0;
67 }
68 vector<T> getA() const
69 { //凸包邊對x軸的夾角
70     vector<T> res; //一定是遞增的
71     for (size_t i = 0; i < p.size(); ++i
72         )
73         res.push_back((p[(i + 1) % p.
74             size()] - p[i]).getA());
75     return res;
76 }
77 bool line_intersect(const vector<T> &A,
78     const line<T> &l) const
79 { //O(logN)
80     int f1 = upper_bound(A.begin(), A.
81         end(), (l.p1 - l.p2).getA()) - A.
82         begin();
83     int f2 = upper_bound(A.begin(), A.
84         end(), (l.p2 - l.p1).getA()) - A.
85         begin();
86     return l.cross_seg(line<T>(p[f1], p[
87         f2]));
88 }
89 polygon cut(const line<T> &l) const
90 { //凸包對直線切割，得到直線l左側的凸包
91     polygon ans;

```

```

for (int n = p.size(), i = n - 1, j
    = 0; j < n; i = j++)
{
    if (l.ori(p[i]) >= 0)
    {
        ans.p.push_back(p[i]);
        if (l.ori(p[j]) < 0)
            ans.p.push_back(l.
                line_intersection(
                    line<T>(p[i], p[j])));
    }
    else if (l.ori(p[j]) > 0)
        ans.p.push_back(l.
            line_intersection(line<T>
                >(p[i], p[j])));
}
return ans;
}
static bool graham_cmp(const point<T> &a
    , const point<T> &b)
{ //凸包排序函數 // 起點點不同
// return (a.x < b.x) || (a.x == b.x
    && a.y < b.y); //最左下角開始
return (a.y < b.y) || (a.y == b.y &&
    a.x < b.x); //Y最小開始
}
void graham(vector<point<T>> &s)
{ //凸包 Convexhull 2D
    sort(s.begin(), s.end(), graham_cmp)
    ;
    p.resize(s.size() + 1);
    int m = 0;
    // cross >= 0 順時針 * cross <= 0 逆
    // 時針旋轉
    for (size_t i = 0; i < s.size(); ++i
        )
    {
        while (m >= 2 && (p[m - 1] - p[m
            - 2]).cross(s[i] - p[m -
            2]) <= 0)
            --m;
        p[m++] = s[i];
    }
    for (int i = s.size() - 2, t = m +
        1; i >= 0; --i)
    {
        while (m >= t && (p[m - 1] - p[m
            - 2]).cross(s[i] - p[m -
            2]) <= 0)
            --m;
        p[m++] = s[i];
    }
    if (s.size() > 1) // 重複頭一次需扣
        掉
        --m;
    p.resize(m);
}
T diam()
{ //直徑
    int n = p.size(), t = 1;
    T ans = 0;
    p.push_back(p[0]);
    for (int i = 0; i < n; i++)

```



```

118 {
119     point<T> now = p[i + 1] - p[i];
120     while (now.cross(p[t + 1] - p[i]) > now.cross(p[t] - p[i]))
121         t = (t + 1) % n;
122     ans = max(ans, (p[i] - p[t]).abs2());
123 }
124 return p.pop_back(), ans;
125 }
126 T min_cover_rectangle()
127 { //最小覆蓋矩形
128     int n = p.size(), t = 1, r = 1, l;
129     if (n < 3)
130         return 0; //也可以做最小周長矩形
131     T ans = 1e99;
132     p.push_back(p[0]);
133     for (int i = 0; i < n; i++)
134     {
135         point<T> now = p[i + 1] - p[i];
136         while (now.cross(p[t + 1] - p[i]) > now.cross(p[t] - p[i]))
137             t = (t + 1) % n;
138         while (now.dot(p[r + 1] - p[i]) > now.dot(p[r] - p[i]))
139             r = (r + 1) % n;
140         if (!i)
141             l = r;
142         while (now.dot(p[l + 1] - p[i]) <= now.dot(p[l] - p[i]))
143             l = (l + 1) % n;
144         T d = now.abs2();
145         T tmp = now.cross(p[t] - p[i]) * (now.dot(p[r] - p[i]) - now.dot(p[l] - p[i])) / d;
146         ans = min(ans, tmp);
147     }
148     return p.pop_back(), ans;
149 }
150 T dis2(polygon &p1)
151 { //凸包最近距離平方
152     vector<point<T>> &P = p, &Q = p1.p;
153     int n = P.size(), m = Q.size(), l = 0, r = 0;
154     for (int i = 0; i < n; ++i)
155         if (P[i].y < P[l].y)
156             l = i;
157     for (int i = 0; i < m; ++i)
158         if (Q[i].y < Q[r].y)
159             r = i;
160     P.push_back(P[0]), Q.push_back(Q[0]);
161     T ans = 1e99;
162     for (int i = 0; i < n; ++i)
163     {
164         while ((P[l] - P[l + 1]).cross(Q[r + 1] - Q[r]) < 0)
165             r = (r + 1) % m;
166         ans = min(ans, line<T>(P[l], P[l + 1]).seg_dis2(line<T>(Q[r], Q[r + 1])));
167         l = (l + 1) % n;
168     }
169     return P.pop_back(), Q.pop_back(), ans;
170 }
171 static char sign(const point<T> &t)
172 {
173     return (t.y == 0 ? t.x : t.y) < 0;
174 }
175 static bool angle_cmp(const line<T> &A, const line<T> &B)
176 {
177     point<T> a = A.p2 - A.p1, b = B.p2 - B.p1;
178     return sign(a) < sign(b) || (sign(a) == sign(b) && a.cross(b) > 0);
179 }
180 int halfplane_intersection(vector<line<T>> &s)
181 { //半平面交
182     sort(s.begin(), s.end(), angle_cmp);
183     //線段左側為該線段半平面
184     int L, R, n = s.size();
185     vector<point<T>> px(n);
186     vector<line<T>> q(n);
187     q[L = R = 0] = s[0];
188     for (int i = 1; i < n; ++i)
189     {
190         while (L < R && s[i].ori(px[R - 1]) <= 0)
191             --R;
192         while (L < R && s[i].ori(px[L]) <= 0)
193             ++L;
194         q[++R] = s[i];
195         if (q[R].parallel(q[R - 1]))
196         {
197             --R;
198             if (q[R].ori(s[i].p1) > 0)
199                 q[R] = s[i];
200         }
201         if (L < R)
202             px[R - 1] = q[R - 1].line_intersection(q[R]);
203     }
204     while (L < R && q[L].ori(px[R - 1]) <= 0)
205         --L;
206     p.clear();
207     if (R - L <= 1)
208         return 0;
209     px[R] = q[R].line_intersection(q[L]);
210     for (int i = L; i <= R; ++i)
211         p.push_back(px[i]);
212     return R - L + 1;
213 }
214 }
215 }
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4.5 Triangle

```

1 template <typename T>
2 struct triangle
3 {
4     point<T> a, b, c;
5     triangle() {}

```

```

15 triangle(const point<T> &a, const point<
16 T> &b, const point<T> &c) : a(a), b(b),
17 c(c) {}
18 T area() const
19 {
20     T t = (b - a).cross(c - a) / 2;
21     return t > 0 ? t : -t;
22 }
23 point<T> barycenter() const
24 { //重心
25     return (a + b + c) / 3;
26 }
27 point<T> circumcenter() const
28 { //外心
29     static line<T> u, v;
30     u.p1 = (a + b) / 2;
31     u.p2 = point<T>(u.p1.x - a.y + b.y,
32 u.p1.y + a.x - b.x);
33 v.p1 = (a + c) / 2;
34 v.p2 = point<T>(v.p1.x - a.y + c.y,
35 v.p1.y + a.x - c.x);
36 return u.line_intersection(v);
37 }
38 point<T> incenter() const
39 { //內心
40     T A = sqrt((b - c).abs2()), B = sqrt((a - c).abs2()), C = sqrt((a - b).abs2());
41     return point<T>(A * a.x + B * b.x + C * c.x, A * a.y + B * b.y + C * c.y) / (A + B + C);
42 }
43 point<T> perpcenter() const
44 { //垂心
45     return barycenter() * 3 - circumcenter() * 2;
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5 Graph

5.1 Bellman-Ford

```

1 /*SPA - Bellman-Ford*/
2 #define inf 99999 //define by you maximum
3 edges weight
4 vector<vector<int>> > edges;
5 vector<int> dist;
6 vector<int> ancestor;
7 void BellmanFord(int start, int node){
8     dist[start] = 0;
9     for(int i = 0; i < node-1; i++){
10         for(int j = 0; j < node; j++){
11             for(int k = 0; k < node; k++){
12                 if(edges[j][k] != -1){
13                     if(dist[j] + edges[j][k] < dist[k]){
14                         dist[k] = dist[j] + edges[j][k];
15                         ancestor[k] = j;
16                     }
17                 }
18             }
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```

20     else if (edges[i].second == q.
21         front() && pass[edges[i].
22         first] == 0)
23     {
24         p.push(edges[i].first);
25         result[edges[i].first] =
26             count;
27     }
28     else
29     {
30         newedges.push_back(edges[i])
31         ;
32     }
33     edges = newedges;
34     newedges.clear();
35     q.pop();
36     if (q.empty() == true)
37     {
38         q = p;
39         queue<int> tmp;
40         p = tmp;
41         count++;
42     }
43 }
44 int main()
45 {
46     int node;
47     cin >> node;
48     vector<pair<int, int>> edges;
49     int a, b;
50     while (cin >> a >> b)
51     {
52         /*a = b = -1 means input edges ended
53         */
54         if (a == -1 && b == -1)
55             break;
56         edges.push_back(pair<int, int>(a, b)
57         );
58     }
59     vector<int> result(node, -1);
60     BFS(result, edges, node, 0);
61     return 0;
62 }

```

5.3 DFS-rec

```

1  /*DFS - Recursive version*/
2  map<pair<int,int>,int> edges;
3  vector<int> pass;
4  vector<int> route;
5  void DFS(int start){
6      pass[start] = 1;
7      map<pair<int,int>,int>::iterator iter;
8      for(iter = edges.begin(); iter != edges.
9          end(); iter++){
10         if((*iter).first.first == start &&
11             (*iter).second == 0 && pass[(*)
12             iter).first.second] == 0){
13             route.push_back((*iter).first.
14                 second);
15             DFS((*iter).first.second);
16         }
17     }
18 }

```

```

13     else if((*iter).first.second ==
14         start && (*iter).second == 0 &&
15         pass[(*)iter).first.first] == 0){
16         route.push_back((*iter).first.
17             first);
18         DFS((*iter).first.first);
19     }
20 }
21 int main(){
22     int node;
23     cin>>node;
24     pass.resize(node,0);
25     int a,b;
26     while(cin>>a>>b){
27         if(a == -1 && b == -1)
28             break;
29         edges.insert(pair<pair<int,int>,int>
30             >(pair<int,int>(a,b),0));
31     }
32     int start;
33     cin>>start;
34     route.push_back(start);
35     DFS(start);
36     return 0;
37 }

```

5.4 Dijkstra

```

1  /*SPA - Dijkstra*/
2  const int MAXN = 1e5 + 3;
3  const int inf = INT_MAX;
4  typedef pair<int, int> pii;
5  vector<vector<pii>> weight;
6  vector<int> isDone(MAXN, false), dist,
7  ancestor;
8  void dijkstra(int s)
9  {
10     priority_queue<pii, vector<pii>, greater
11         <pii>> pq;
12     pq.push(pii(0, s));
13     ancestor[s] = -1;
14     while (!pq.empty())
15     {
16         int u = pq.top().second;
17         pq.pop();
18         isDone[u] = true;
19         for (auto &pr : weight[u])
20         {
21             int v = pr.first, w = pr.second;
22             if (!isDone[v] && dist[u] + w <
23                 dist[v])
24             {
25                 dist[v] = dist[u] + w;
26                 pq.push(pii(dist[v], v));
27                 ancestor[v] = u;
28             }
29         }
30     }
31 }

```

5.5 Euler circuit

```

1  /*Euler circuit*/
2  /*From NTU kiseki*/
3  /*G is graph, vis is visited, la is path*/
4  bool vis[N];
5  size_t la[K];
6  void dfs(int u, vector<int> &vec)
7  {
8      while (la[u] < G[u].size())
9      {
10         if (vis[G[u][la[u]].second])
11         {
12             ++la[u];
13             continue;
14         }
15         int v = G[u][la[u]].first;
16         vis[G[u][la[u]].second] = true;
17         ++la[u];
18         dfs(v, vec);
19         vec.push_back(v);
20     }
21 }

```

5.6 Floyd-warshall

```

1  /*SPA - Floyd-Warshall*/
2  // 有向圖・正邊 O(V³)
3  // 有向圖・無負環 O(V³)
4  // 有向圖・有負環 不適用
5
6  // 無向圖・正邊 O(V³)
7  // 無向圖・無負環 不適用
8  // 無向圖・有負環 不適用
9  /*Find min weight cycle*/
10 #define inf 99999
11 void floyd_warshall(vector<vector<int>> &
12     distance, vector<vector<int>> &ancestor,
13     int n)
14 {
15     for (int k = 0; k < n; k++)
16     {
17         for (int i = 0; i < n; i++)
18         {
19             for (int j = 0; j < n; j++)
20             {
21                 if (distance[i][k] +
22                     distance[k][j] <
23                     distance[i][j])
24                 {
25                     distance[i][j] =
26                         distance[i][k] +
27                         distance[k][j];
28                     ancestor[i][j] = k;
29                 }
30             }
31         }
32     }
33 }

```

```

21     distance[i][j] =
22         distance[i][k] +
23         distance[k][j];
24     ancestor[i][j] =
25         ancestor[k][j];
26 }
27 }
28 }
29 vector<vector<int>> distance(n, vector<int>(
30     n, inf));
31 vector<vector<int>> ancestor(n, vector<int>(
32     n, -1));
33 distance[a][b] = w;
34 ancestor[a][b] = w;
35 floyd_warshall(distance, ancestor, n);
36 /*Negative cycle detection*/
37 for (int i = 0; i < n; i++)
38 {
39     if (distance[i][i] < 0)
40     {
41         cout << "Negative cycle!" << endl;
42         break;
43     }
44 }

```

5.7 Hamilton_cycle

```

1  /*find hamilton cycle*/
2  void hamilton(vector<vector<int>> gp, int k,
3  int cur, vector<int>& solution, vector<
4  bool> pass, bool& flag){
5      if(k == gp.size()-1){
6          if(gp[cur][1] == 1){
7              cout << 1 << " ";
8              cur = solution[cur];
9          }
10         cout << cur << endl;
11         flag = true;
12         return;
13     }
14 }
15 for (int i = 0; i < gp[cur].size() && !
16     flag; i++){
17     if(gp[cur][i] == 1 && !pass[i]){
18         pass[i] = true;
19         solution[i] = cur;
20         hamilton(gp, k + 1, i, solution,
21             pass, flag);
22         pass[i] = false;
23     }
24 }
25 int main(){
26     int n;
27     while(cin>>n){
28         int a,b;
29         bool end = false;
30     }
31 }

```

```

29 vector<vector<int>> gp(n+1,vector<
    int>(n+1,0));
30 while(cin>>a>>b){
31     if(a == 0 && b == 0)
32         break;
33     gp[a][b] = 1;
34     gp[b][a] = 1;
35 }
36 vector<int> solution(n + 1, -1);
37 vector<bool> pass(n + 1, false);
38 solution[1] = 0;
39 pass[1] = true;
40 bool flag = false;
41 hamilton(gp, 1,1 ,solution,pass,flag
    );
42 if(!flag)
43     cout << "N" << endl;
44 }
45 return 0;
46 }
47 /*
48 4
49 1 2
50 2 3
51 2 4
52 3 4
53 3 1
54 0 0
55 output: 1 3 4 2 1
56 */

```

5.8 Kruskal

```

1 /*mst - Kruskal*/
2 struct edges{
3     int from;
4     int to;
5     int weight;
6     friend bool operator < (edges a, edges b
7     ){
8         return a.weight > b.weight;
9     }
10 };
11 int find(int x,vector<int>& union_set){
12     if(x != union_set[x])
13         union_set[x] = find(union_set[x],
14         union_set);
15     return union_set[x];
16 }
17 void merge(int a,int b,vector<int>&
18     union_set){
19     int pa = find(a, union_set);
20     int pb = find(b, union_set);
21     if(pa != pb)
22         union_set[pa] = pb;
23 }
24 void kruskal(priority_queue<edges> pq,int n)
25 {
26     vector<int> union_set(n, 0);
27     for (int i = 0; i < n; i++)
28         union_set[i] = i;
29     int edge = 0;
30     int cost = 0; //evaluate cost of mst

```

```

27 while(!pq.empty() && edge < n - 1){
28     edges cur = pq.top();
29     int from = find(cur.from, union_set)
30     ;
31     int to = find(cur.to, union_set);
32     if(from != to){
33         merge(from, to, union_set);
34         edge += 1;
35         cost += cur.weight;
36     }
37     pq.pop();
38 }
39 if(edge < n-1)
40     cout << "No mst" << endl;
41 else
42     cout << cost << endl;
43 }
44 int main(){
45     int n;
46     cin >> n;
47     int a, b, d;
48     priority_queue<edges> pq;
49     while(cin>>a>>b>>d){
50         if(a == -1 && b == -1 && d == -1)
51             break;
52         edges tmp;
53         tmp.from = a;
54         tmp.to = b;
55         tmp.weight = d;
56         pq.push(tmp);
57     }
58     kruskal(pq, n);
59     return 0;

```

5.9 Minimum Weight Cycle

```

1 // 最小環
2 // 圖上無負環 !!!!
3 #define INF 99999
4 vector<vector<int>> w, d, p;
5 vector<int> cycle;
6 int c = 0;
7 void trace(int i, int j)
8 {
9     cycle[c++] = i;
10    if (i != j)
11        trace(p[i][j], j);
12 }
13 void init(int n)
14 {
15     for (int i = 0; i < n; ++i)
16         d[i][i] = 0;
17 }
18 void minimum_cycle(int n)
19 {
20     int weight = 1e9;
21     for (int k = 0; k < n; ++k)
22     {
23         for (int i = 0; i < k; ++i)
24             for (int j = i + 1; j < k; ++j)
25                 if (i != j)

```

```

26     if (w[k][i] + d[i][j] +
27         w[j][k] < weight)
28     {
29         weight = w[k][i] + d
30         [i][j] + w[j][k]
31         ;
32         c = 0;
33         trace(i, j);
34         cycle[c++] = k;
35     }
36     for (int i = 0; i < n; ++i)
37     {
38         for (int j = 0; j < n; ++j)
39         {
40             if (d[i][k] + d[k][j] < d[i
41             ][j])
42             {
43                 d[i][j] = d[i][k] + d[k
44                 ][j];
45                 p[i][j] = p[i][k];
46             }
47         }
48     }
49     if (weight == 1e9)
50         cout << "No exist";
51     else
52     {
53         bug(weight);
54         bug(c);
55         bugarr(cycle);
56     }
57 }
58 w.resize(n, vector<int>(n, INF));
59 d.resize(n, vector<int>(n, INF));
60 p.resize(n, vector<int>(n));
61 cycle.resize(n);
62 //Edge input
63 w[a][b] = w;
64 d[a][b] = w;
65 p[a][b] = b;
66 init(n);
67 minimum_cycle(n);

```

5.10 Prim

```

1 /*mst - Prim*/
2 #define inf 99999
3 struct edges
4 {
5     int from;
6     int to;
7     int weight;
8     friend bool operator<(edges a, edges b)
9     {
10         return a.weight > b.weight;
11     }
12 };
13 void Prim(vector<vector<int>> gp, int n, int
14     start)
15 {
16     vector<bool> pass(n, false);

```

```

16 int edge = 0;
17 int cost = 0; //evaluate cost of mst
18 priority_queue<edges> pq;
19 for (int i = 0; i < n; i++)
20 {
21     if (gp[start][i] != inf)
22     {
23         edges tmp;
24         tmp.from = start;
25         tmp.to = i;
26         tmp.weight = gp[start][i];
27         pq.push(tmp);
28     }
29 }
30 pass[start] = true;
31 while (!pq.empty() && edge < n - 1)
32 {
33     edges cur = pq.top();
34     pq.pop();
35     if (!pass[cur.to])
36     {
37         for (int i = 0; i < n; i++)
38         {
39             if (gp[cur.to][i] != inf)
40             {
41                 edges tmp;
42                 tmp.from = cur.to;
43                 tmp.to = i;
44                 tmp.weight = gp[cur.to][
45                 i];
46                 pq.push(tmp);
47             }
48         }
49         pass[cur.to] = true;
50         edge += 1;
51         cost += cur.weight;
52     }
53 }
54 if (edge < n - 1)
55     cout << "No mst" << endl;
56 else
57     cout << cost << endl;
58 }
59 int main()
60 {
61     int n;
62     cin >> n;
63     int a, b, d;
64     vector<vector<int>> gp(n, vector<int>(n,
65     inf));
66     while (cin >> a >> b >> d)
67     {
68         if (a == -1 && b == -1 && d == -1)
69             break;
70         if (gp[a][b] > d)
71             gp[a][b] = d;
72     }
73     Prim(gp, n, 0);
74     return 0;

```

5.11 Union_find


```

1 // union_find from 台大
2 vector<int> father;
3 vector<int> people;
4 void init(int n)
5 {
6     for (int i = 0; i < n; i++)
7     {
8         father[i] = i;
9         people[i] = 1;
10    }
11 }
12 int Find(int x)
13 {
14     if (x != father[x])
15         father[x] = Find(father[x]);
16     return father[x];
17 }
18 void Union(int x, int y)
19 {
20     int m = Find(x);
21     int n = Find(y);
22     if (m != n)
23     {
24         father[n] = m;
25         people[m] += people[n];
26     }
27 }
28 }

```

6.3 Extended Euclidean

```

1 // ax + by = gcd(a,b)
2 pair<long long, long long> extgcd(long long
3     a, long long b)
4 {
5     if (b == 0)
6         return {1, 0};
7     long long k = a / b;
8     pair<long long, long long> p = extgcd(b,
9         a - k * b);
10    //cout << p.first << " " << p.second <<
11        endl;
12    //cout << "商數(k)= " << k << endl <<
13        endl;
14    return {p.second, p.first - k * p.second
15        };
16 }
17 int main()
18 {
19     int a, b;
20     cin >> a >> b;
21     pair<long long, long long> xy = extgcd(a,
22         b); //(x0,y0)
23     cout << xy.first << " " << xy.second <<
24         endl;
25     cout << xy.first << " * " << a << " + "
26         << xy.second << " * " << b << endl;
27     return 0;
28 }
29 // ax + by = gcd(a,b) * r
30 /*find |x|+|y| -> min*/
31 int main()
32 {
33     long long r, p, q; /*px+qy = r*/
34     int cases;
35     cin >> cases;
36     while (cases--)
37     {
38         cin >> r >> p >> q;
39         pair<long long, long long> xy =
40             extgcd(q, p); //(x0,y0)
41         long long ans = 0, tmp = 0;
42         double k, k1;
43         long long s, s1;
44         k = 1 - (double)(r * xy.first) / p;
45         s = round(k);
46         ans = llabs(r * xy.first + s * p) +
47             llabs(r * xy.second - s * q);
48         k1 = -(double)(r * xy.first) / p;
49         s1 = round(k1);
50         /*cout << k << endl << k1 << endl;
51             cout << s << endl << s1 << endl;
52             */
53         tmp = llabs(r * xy.first + s1 * p) +
54             llabs(r * xy.second - s1 * q);
55         ans = min(ans, tmp);
56         cout << ans << endl;
57     }
58     return 0;
59 }

```

6.4 Fermat

- $a^{(p-1)} \equiv 1 \pmod{p} \Leftrightarrow a * a^{(p-2)} \equiv 1$
 - $a^{(p-2)} \equiv 1/a$
- 同餘因數定理
 - $a \equiv b \pmod{p} \Leftrightarrow k|a - b$
- 同餘加法性質
 - $a \equiv b \pmod{p}$ and $c \equiv d \pmod{p}$
 $\Leftrightarrow a + c \equiv b + d \pmod{p}$
- 同餘相乘性質
 - $a \equiv b \pmod{p}$ and $c \equiv d \pmod{p}$
 $\Leftrightarrow ac \equiv bd \pmod{p}$
- 同餘次方性質
 - $a \equiv b \pmod{p} \Leftrightarrow a^n \equiv b^n \pmod{p}$
- 同餘倍方性質
 - $a \equiv b \pmod{p} \Leftrightarrow am \equiv bm \pmod{p}$

6.6 Log

```

1 double mylog(double a, double base)
2 {
3     //a 的對數底數 b = 自然對數 (a) / 自然對
4     數 (b)。
5     return log(a) / log(base);
6 }

```

6 Mathematics

6.1 Catalan

Catalan number

- 0~19項的catalan number
 - 1, 1, 2, 5, 14, 42, 132, 429, 1430, 4862, 16796, 58786, 208012, 742900, 2674440, 9694845, 35357670, 129644790, 477638700, 1767263190
- 公式: $C_n = \frac{1}{n+1} \binom{2n}{n} = \frac{(2n)!}{(n+1)!n!}$

6.2 Combination

```

1 /*input type string or vector*/
2 for (int i = 0; i < (1 << input.size()); ++i
3 )
4 {
5     string testCase = "";
6     for (int j = 0; j < input.size(); ++j)
7         if (i & (1 << j))
8             testCase += input[j];
9 }

```

6.5 Hex to Dec

```

1 int HextoDec(string num) //16 to 10
2 {
3     int base = 1;
4     int temp = 0;
5     for (int i = num.length() - 1; i >= 0; i
6         --)
7     {
8         if (num[i] >= '0' && num[i] <= '9')
9         {
10            temp += (num[i] - 48) * base;
11            base = base * 16;
12        }
13        else if (num[i] >= 'A' && num[i] <=
14            'F')
15        {
16            temp += (num[i] - 55) * base;
17            base = base * 16;
18        }
19    }
20    return temp;
21 }
22 void DecToHex(int p) //10 to 16
23 {
24     char *l = new (char);
25     sprintf(l, "%X", p);
26     //int l_intResult = stoi(l);
27     cout << l << "\n";
28     //return l_intResult;
29 }

```

6.7 Mod

```

1 int pow_mod(int a, int n, int m) // a ^ n
2     mod m;
3 // a, n, m
4 < 10 ^ 9
5 {
6     if (n == 0)
7         return 1;
8     int x = pow_mid(a, n / 2, m);
9     long long ans = (long long)x * x % m;
10    if (n % 2 == 1)
11        ans = ans * a % m;
12    return (int)ans;
13 }
14 int inv(int a, int n, int p) // n = p-2
15 {
16     long long res = 1;
17     for (; n; n >>= 1, (a *= a) %= p)
18         if (n & 1)
19             (res *= a) %= p;
20     return res;
21 }

```

6.8 Mod 性質

加法： $(a + b) \bmod p = (a \bmod p + b \bmod p) \bmod p$

減法： $(a - b) \bmod p = (a \bmod p - b \bmod p + p) \bmod p$

乘法： $(a * b) \bmod p = (a \bmod p * b \bmod p) \bmod p$

次方： $(a^b) \bmod p = ((a \bmod p)^b) \bmod p$

加法結合律： $((a + b) \bmod p + c) \bmod p = (a + (b + c)) \bmod p$

乘法結合律： $((a * b) \bmod p * c) \bmod p = (a * (b * c)) \bmod p$

加法交換律： $(a + b) \bmod p = (b + a) \bmod p$

乘法交換律： $(a * b) \bmod p = (b * a) \bmod p$

結合律： $((a + b) \bmod p * c) = ((a * c) \bmod p + (b * c) \bmod p) \bmod p$

如果 $a \equiv b \pmod{m}$ ，我們會說 a, b 在模 m 下同餘。

以下為性質：

- 整除性： $a \equiv b \pmod{m} \Rightarrow c * m = a - b, c \in \mathbb{Z}$
 $\Rightarrow a \equiv b \pmod{m} \Rightarrow m \mid a - b$

- 遞移性：若 $a \equiv b \pmod{c}, b \equiv d \pmod{c}$
 則 $a \equiv d \pmod{c}$

- 保持基本運算：

$$\begin{cases} a \equiv b \pmod{m} \\ c \equiv d \pmod{m} \end{cases} \Rightarrow \begin{cases} a \pm c \equiv b \pm d \pmod{m} \\ a * c \equiv b * d \pmod{m} \end{cases}$$

- 放大縮小模數：

$$k \in \mathbb{Z}^+, a \equiv b \pmod{m} \Leftrightarrow k * a \equiv k * b \pmod{k * m}$$

模逆元是取模下的反元素，即為找到 a^{-1} 使得 $aa^{-1} \equiv 1 \pmod{c}$ 。

整數 a 在模 c 下要有模反元素的充分必要條件為 a, c 互質。

模逆元如果存在會有無限個，任意兩相鄰模逆元相差 c 。

費馬小定理

給定一個質數 p 及一個整數 a ，那麼： $a^p \equiv a \pmod{p}$ 如果 $\gcd(a, p) = 1$ ，則： $a^{p-1} \equiv 1 \pmod{p}$

歐拉定理

歐拉定理是比較 general 版本的費馬小定理，給定兩個整數 n 和 a ，如果 $\gcd(a, n) = 1$ ， $a^{\Phi(n)} \equiv 1 \pmod{n}$ 如果 n 是質數， $\Phi(n) = n - 1$ ，也就是費馬小定理。

Wilson's theorem

給定一個質數 p ，則： $(p - 1)! \equiv -1 \pmod{p}$

6.9 PI

```
1 #define PI acos(-1)
2 #define PI M_PI
```

6.10 Prime table

```
1 const int maxn = sqrt(INT_MAX);
2 vector<int> p;
```

```
3 bitset<maxn> is_notp;
4 void PrimeTable()
5 {
6     is_notp.reset();
7     is_notp[0] = is_notp[1] = 1;
8     for (int i = 2; i <= maxn; ++i)
9     {
10         if (!is_notp[i])
11             p.push_back(i);
12         for (int j = 0; j < (int)p.size(); ++j)
13         {
14             if (i * p[j] > maxn)
15                 break;
16             is_notp[i * p[j]] = 1;
17             if (i % p[j] == 0)
18                 break;
19         }
20     }
21 }
```

6.11 Prime 判斷

```
1 typedef long long ll;
2 ll modmul(ll a, ll b, ll mod)
3 {
4     ll ret = 0;
5     for (; b >= 1, a = (a + a) % mod;
6         if (b & 1)
7             ret = (ret + a) % mod;
8         return ret;
9 }
10 ll qpow(ll x, ll u, ll mod)
11 {
12     ll ret = 1;
13     for (; u >= 1, x = modmul(x, x, mod);
14         if (u & 1)
15             ret = modmul(ret, x, mod);
16     return ret;
17 }
18 ll gcd(ll a, ll b)
19 {
20     return b ? gcd(b, a % b) : a;
21 }
22 ll Pollard_Rho(ll n, ll c)
23 {
24     ll i = 1, j = 2, x = rand() % (n - 1) + 1, y = x;
25     while (1)
26     {
27         i++;
28         x = (modmul(x, x, n) + c) % n;
29         ll p = gcd((y - x + n) % n, n);
30         if (p != 1 && p != n)
31             return p;
32         if (y == x)
33             return n;
34         if (i == j)
35         {
36             y = x;
37             j <<= 1;
38         }
39     }
```

```
39 }
40 }
41 bool Miller_Rabin(ll n)
42 {
43     ll x, pre, u = n - 1;
44     int i, j, k = 0;
45     if (n == 2 || n == 3 || n == 5 || n == 7 || n == 11)
46         return 1;
47     if (n == 1 || !(n % 2) || !(n % 3) || !(n % 5) || !(n % 7) || !(n % 11))
48         return 0;
49     while (!(u & 1))
50     {
51         k++;
52         u >>= 1;
53     }
54     srand((long long)12234336);
55     for (i = 1; i <= 50; i++)
56     {
57         x = rand() % (n - 2) + 2;
58         if (!(n % x))
59             return 0;
60         x = qpow(x, u, n);
61         pre = x;
62         for (j = 1; j <= k; j++)
63         {
64             x = modmul(x, x, n);
65             if (x == 1 && pre != 1 && pre != n - 1)
66                 return 0;
67             pre = x;
68         }
69         if (x != 1)
70             return 0;
71     }
72     return 1;
73 }
74 // if (Miller_Rabin(n)) puts("Prime");
```

6.12 Round(小數)

```
1 double myround(double number, unsigned int bits)
2 {
3     LL integerPart = number;
4     number -= integerPart;
5     for (unsigned int i = 0; i < bits; ++i)
6         number *= 10;
7     number = (LL)(number + 0.5);
8     for (unsigned int i = 0; i < bits; ++i)
9         number /= 10;
10    return integerPart + number;
11 }
12 //printf("%.1f\n", round(3.4515239, 1));
```

6.13 二分逼近法

```
1 #define eps 1e-14
2 void half_interval()
```

```
3 {
4     double L = 0, R = /*區間*/, M;
5     while (R - L >= eps)
6     {
7         M = (R + L) / 2;
8         if (/*函數*/ > /*方程式目標*/)
9             L = M;
10        else
11            R = M;
12    }
13    printf("%.31f\n", R);
14 }
```

6.14 公式

$$S_n = \frac{a(1-r^n)}{1-r} \quad a_n = \frac{a_1+a_n}{2} \quad \sum_{k=1}^n k = \frac{n(n+1)}{2}$$

$$\sum_{k=1}^n k^2 = \frac{n(n+1)(2n+1)}{6} \quad \sum_{k=1}^n k^3 = \left[\frac{n(n+1)}{2} \right]^2$$

6.15 四則運算

```
1 string s = ""; //開頭是負號要補0
2 long long int DFS(int le, int ri) // (0, string final index)
3 {
4     int c = 0;
5     for (int i = ri; i >= le; i--)
6     {
7         if (s[i] == '(')
8             c++;
9         if (s[i] == '(')
10            c--;
11        if (s[i] == '+' && c == 0)
12            return DFS(le, i - 1) + DFS(i + 1, ri);
13        if (s[i] == '-' && c == 0)
14            return DFS(le, i - 1) - DFS(i + 1, ri);
15    }
16    for (int i = ri; i >= le; i--)
17    {
18        if (s[i] == '(')
19            c++;
20        if (s[i] == '(')
21            c--;
22        if (s[i] == '*' && c == 0)
23            return DFS(le, i - 1) * DFS(i + 1, ri);
24        if (s[i] == '/' && c == 0)
25            return DFS(le, i - 1) / DFS(i + 1, ri);
26        if (s[i] == '%' && c == 0)
27            return DFS(le, i - 1) % DFS(i + 1, ri);
28    }
29    if ((s[le] == '(' && (s[ri] == ')'))
30        return DFS(le + 1, ri - 1); //去除刮號
```

```

31 if (s[le] == ' ' && s[ri] == ' ')
32     return DFS(le + 1, ri - 1); //去除左
        右兩邊空格
33 if (s[le] == ' ')
34     return DFS(le + 1, ri); //去除左邊空
        格
35 if (s[ri] == ' ')
36     return DFS(le, ri - 1); //去除右邊空
        格
37 long long int num = 0;
38 for (int i = le; i <= ri; i++)
39     num = num * 10 + s[i] - '0';
40 return num;
41 }

```

6.18 數字加法組合

```

1 void recur(int i, int n, int m, vector<int>
    &out, vector<vector<int>> &ans)
2 {
3     if (n == 0)
4     {
5         for (int i : out)
6             if (i > m)
7                 return;
8         ans.push_back(out);
9     }
10    for (int j = i; j <= n; j++)
11    {
12        out.push_back(j);
13        recur(j, n - j, m, out, ans);
14        out.pop_back();
15    }
16 }
17 vector<vector<int>> ans;
18 vector<int> zero;
19 recur(1, num, num, zero, ans);
20 // num 為 input 數字
21 for (int i = 0; i < ans.size(); i++)
22 {
23     for (int j = 0; j < ans[i].size() - 1; j
        ++
24         cout << ans[i][j] << " ";
25     cout << ans[i][ans[i].size() - 1] <<
        endl;
26 }

```

6.16 因數表

```

1 vector<vector<int>> arr(1000000);
2 const int limit = 10e7;
3 for (int i = 1; i <= limit; i++)
4 {
5     for (int j = i; j <= limit; j += i)
6         arr[j].pb(i); // i 為因數
7 }

```

6.17 數字乘法組合

```

1 void dfs(int j, int old, int num, vector<int>
    &com, vector<vector<int>> &ans)
2 {
3     for (int i = j; i <= sqrt(num); i++)
4     {
5         if (old == num)
6             com.clear();
7         if (num % i == 0)
8         {
9             vector<int> a;
10            a = com;
11            a.push_back(i);
12            finds(i, old, num / i, a, ans);
13            a.push_back(num / i);
14            ans.push_back(a);
15        }
16    }
17 }
18 vector<vector<int>> ans;
19 vector<int> zero;
20 dfs(2, num, num, zero, ans);
21 /*num 為 input 數字*/
22 for (int i = 0; i < ans.size(); i++)
23 {
24     for (int j = 0; j < ans[i].size() - 1; j
        ++
25         cout << ans[i][j] << " ";
26     cout << ans[i][ans[i].size() - 1] <<
        endl;
27 }

```

6.19 羅馬數字

```

1 int romanToInt(string s)
2 {
3     unordered_map<char, int> T;
4     T['I'] = 1;
5     T['V'] = 5;
6     T['X'] = 10;
7     T['L'] = 50;
8     T['C'] = 100;
9     T['D'] = 500;
10    T['M'] = 1000;
11
12    int sum = T[s.back()];
13    for (int i = s.length() - 2; i >= 0; --i)
14    {
15        if (T[s[i]] < T[s[i + 1]])
16            sum -= T[s[i]];
17        else
18            sum += T[s[i]];
19    }
20    return sum;
21 }

```

6.20 質因數分解

```

1 LL ans;
2 void find(LL n, LL c) // 配合質數判斷
3 {
4     if (n == 1)
5         return;
6     if (Miller_Rabin(n))
7     {
8         ans = min(ans, n);
9         // bug(ans); //質因數
10        return;
11    }
12    LL x = n, k = c;
13    while (x == n)
14        x = Pollard_Rho(x, c--);
15    find(n / x, k);
16    find(x, k);
17 }

```

6.21 質數數量

```

1 // 10 ^ 11 左右
2 #define LL long long
3 const int N = 5e6 + 2;
4 bool np[N];
5 int prime[N], pi[N];
6 int getprime()
7 {
8     int cnt = 0;
9     np[0] = np[1] = true;
10    pi[0] = pi[1] = 0;
11    for (int i = 2; i < N; ++i)
12    {
13        if (!np[i])
14            prime[++cnt] = i;
15        pi[i] = cnt;
16        for (int j = 1; j <= cnt && i *
            prime[j] < N; ++j)
17        {
18            np[i * prime[j]] = true;
19            if (i % prime[j] == 0)
20                break;
21        }
22    }
23    return cnt;
24 }
25 const int M = 7;
26 const int PM = 2 * 3 * 5 * 7 * 11 * 13 * 17;
27 int phi[PM + 1][M + 1], sz[M + 1];
28 void init()
29 {
30     getprime();
31     sz[0] = 1;
32     for (int i = 0; i <= PM; ++i)
33         phi[i][0] = i;
34     for (int i = 1; i <= M; ++i)
35     {
36         sz[i] = prime[i] * sz[i - 1];
37         for (int j = 1; j <= PM; ++j)
38             phi[j][i] = phi[j][i - 1] - phi[
                j / prime[i]][i - 1];
39     }
40 }

```

```

41 int sqrt2(LL x)
42 {
43     LL r = (LL)sqrt(x - 0.1);
44     while (r * r <= x)
45         ++r;
46     return int(r - 1);
47 }
48 int sqrt3(LL x)
49 {
50     LL r = (LL)cbrt(x - 0.1);
51     while (r * r * r <= x)
52         ++r;
53     return int(r - 1);
54 }
55 LL getphi(LL x, int s)
56 {
57     if (s == 0)
58         return x;
59     if (s <= M)
60         return phi[x % sz[s]][s] + (x / sz[s]
            ) * phi[sz[s]][s];
61     if (x <= prime[s] * prime[s])
62         return pi[x] - s + 1;
63     if (x <= prime[s] * prime[s] * prime[s]
        && x < N)
64     {
65         int s2x = pi[sqrt2(x)];
66         LL ans = pi[x] - (s2x + s - 2) * (
            s2x - s + 1) / 2;
67         for (int i = s + 1; i <= s2x; ++i)
68             ans += pi[x / prime[i]];
69         return ans;
70     }
71     return getphi(x, s - 1) - getphi(x /
        prime[s], s - 1);
72 }
73 LL getpi(LL x)
74 {
75     if (x < N)
76         return pi[x];
77     LL ans = getphi(x, pi[sqrt3(x)]) + pi[
        sqrt3(x)] - 1;
78     for (int i = pi[sqrt3(x)] + 1, ed = pi[
        sqrt2(x)]; i <= ed; ++i)
79         ans -= getpi(x / prime[i]) - i + 1;
80     return ans;
81 }
82 LL lehmer_pi(LL x)
83 {
84     if (x < N)
85         return pi[x];
86     int a = (int)lehmer_pi(sqrt2(sqrt2(x)));
87     int b = (int)lehmer_pi(sqrt2(x));
88     int c = (int)lehmer_pi(sqrt3(x));
89     LL sum = getphi(x, a) + (LL)(b + a - 2)
        * (b - a + 1) / 2;
90     for (int i = a + 1; i <= b; ++i)
91     {
92         LL w = x / prime[i];
93         sum -= lehmer_pi(w);
94         if (i > c)
95             continue;
96         LL lim = lehmer_pi(sqrt2(w));
97         for (int j = i; j <= lim; ++j)
98             sum -= lehmer_pi(w / prime[j]) -
                (j - 1);
99     }
100 }

```

```

99     }
100     return sum;
101 }
102 // lehmer_pi(n)

```

7 Other

7.1 binary search 三類變化

```

1 // 查找和目標值完全相等的數
2 int find(vector<int> &nums, int target)
3 {
4     int left = 0, right = nums.size();
5     while (left < right)
6     {
7         int mid = left + (right - left) / 2;
8         if (nums[mid] == target)
9             return mid;
10        else if (nums[mid] < target)
11            left = mid + 1;
12        else
13            right = mid;
14    }
15    return -1;
16 }
17 // 找第一個不小於目標值的數 == 找最後一個小
    於目標值的數
18 /*(lower_bound)*/
19 int find(vector<int> &nums, int target)
20 {
21     int left = 0, right = nums.size();
22     while (left < right)
23     {
24         int mid = left + (right - left) / 2;
25         if (nums[mid] < target)
26             left = mid + 1;
27        else
28            right = mid;
29    }
30    return right;
31 }
32 // 找第一個大於目標值的數 == 找最後一個不大
    於目標值的數
33 /*(upper_bound)*/
34 int find(vector<int> &nums, int target)
35 {
36     int left = 0, right = nums.size();
37     while (left < right)
38     {
39         int mid = left + (right - left) / 2;
40         if (nums[mid] <= target)
41             left = mid + 1;
42        else
43            right = mid;
44    }
45    return right;
46 }

```

7.2 heap sort

```

1 void MaxHeapify(vector<int> &array, int root
    , int length)
2 {
3     int left = 2 * root,
4         right = 2 * root + 1,
5         largest;
6     if (left <= length && array[left] >
7         array[root])
8         largest = left;
9     else
10        largest = root;
11    if (right <= length && array[right] >
12        array[largest])
13        largest = right;
14    if (largest != root)
15    {
16        swap(array[largest], array[root]);
17        MaxHeapify(array, largest, length);
18    }
19 }
20 void HeapSort(vector<int> &array)
21 {
22     array.insert(array.begin(), 0);
23     for (int i = (int)array.size() / 2; i >=
24         1; i--)
25         MaxHeapify(array, i, (int)array.size
26             () - 1);
27     int size = (int)array.size() - 1;
28     for (int i = (int)array.size() - 1; i >=
29         2; i--)
30     {
31         swap(array[1], array[i]);
32         size--;
33         MaxHeapify(array, 1, size);
34     }
35     array.erase(array.begin());
36 }

```

7.3 Merge sort

```

1 void Merge(vector<int> &arr, int front, int
    mid, int end)
2 {
3     vector<int> LeftSub(arr.begin() + front,
4         arr.begin() + mid + 1);
5     vector<int> RightSub(arr.begin() + mid +
6         1, arr.begin() + end + 1);
7     LeftSub.insert(LeftSub.end(), INT_MAX);
8     RightSub.insert(RightSub.end(), INT_MAX);
9     ;
10    int idxLeft = 0, idxRight = 0;
11
12    for (int i = front; i <= end; i++)
13    {
14        if (LeftSub[idxLeft] <= RightSub[
15            idxRight])
16        {
17            arr[i] = LeftSub[idxLeft];
18            idxLeft++;
19        }
20        else
21        {
22            arr[i] = RightSub[idxRight];
23            idxRight++;
24        }
25    }
26 }

```

```

16     }
17     else
18     {
19         arr[i] = RightSub[idxRight];
20         idxRight++;
21     }
22 }
23 void MergeSort(vector<int> &arr, int front,
    int end)
24 {
25     // front = 0 , end = arr.size() - 1
26     if (front < end)
27     {
28         int mid = (front + end) / 2;
29         MergeSort(arr, front, mid);
30         MergeSort(arr, mid + 1, end);
31         Merge(arr, front, mid, end);
32     }
33 }
34 }

```

7.4 Quick

```

1 int Partition(vector<int> &arr, int front,
    int end)
2 {
3     int pivot = arr[end];
4     int i = front - 1;
5     for (int j = front; j < end; j++)
6     {
7         if (arr[j] < pivot)
8         {
9             i++;
10            swap(arr[i], arr[j]);
11        }
12    }
13    i++;
14    swap(arr[i], arr[end]);
15    return i;
16 }
17 void QuickSort(vector<int> &arr, int front,
    int end)
18 {
19     // front = 0 , end = arr.size() - 1
20     if (front < end)
21     {
22         int pivot = Partition(arr, front,
23             end);
24         QuickSort(arr, front, pivot - 1);
25         QuickSort(arr, pivot + 1, end);
26    }
27 }

```

7.5 Weighted Job Scheduling

```

1 struct Job
2 {
3     int start, finish, profit;
4 };
5 bool jobComparataor(Job s1, Job s2)

```

```

6 {
7     return (s1.finish < s2.finish);
8 }
9 int latestNonConflict(Job arr[], int i)
10 {
11     for (int j = i - 1; j >= 0; j--)
12     {
13         if (arr[j].finish <= arr[i].start)
14             return j;
15     }
16     return -1;
17 }
18 int findMaxProfit(Job arr[], int n)
19 {
20     sort(arr, arr + n, jobComparataor);
21     int *table = new int[n];
22     table[0] = arr[0].profit;
23     for (int i = 1; i < n; i++)
24     {
25         int inclProf = arr[i].profit;
26         int l = latestNonConflict(arr, i);
27         if (l != -1)
28             inclProf += table[l];
29         table[i] = max(inclProf, table[i -
30             1]);
31     }
32     int result = table[n - 1];
33     delete[] table;
34     return result;
35 }

```

7.6 數獨解法

```

1 int getSquareIndex(int row, int column, int
    n)
2 {
3     return row / n * n + column / n;
4 }
5
6 bool backtracking(vector<vector<int>> &board
    , vector<vector<bool>> &rows, vector<
    vector<bool>> &cols,
7     vector<vector<bool>> &boxes
    , int index, int n)
8 {
9     int n2 = n * n;
10    int rowNum = index / n2, colNum = index
11        % n2;
12    if (index >= n2 * n2)
13        return true;
14
15    if (board[rowNum][colNum] != 0)
16        return backtracking(board, rows,
17            cols, boxes, index + 1, n);
18
19    for (int i = 1; i <= n2; i++)
20    {
21        if (!rows[rowNum][i] && !cols[colNum
22            ][i] && !boxes[getSquareIndex(
23                rowNum, colNum, n)][i])
24        {
25            rows[rowNum][i] = true;
26        }
27    }
28 }

```

```

22     cols[colNum][i] = true;
23     boxes[getSquareIndex(rowNum,
24         colNum, n)][i] = true;
25     board[rowNum][colNum] = i;
26     if (backtracking(board, rows,
27         cols, boxes, index + 1, n))
28         return true;
29     board[rowNum][colNum] = 0;
30     rows[rowNum][i] = false;
31     cols[colNum][i] = false;
32     boxes[getSquareIndex(rowNum,
33         colNum, n)][i] = false;
34 }
35 return false;
36 }
37 /*用法 main*/
38 int n = sqrt(數獨邊長大小) /*e.g. 9*9 n=3*/
39 vector<vector<int>> board(n * n + 1, vector<
40     int>(n * n + 1, 0));
41 vector<vector<bool>> isRow(n * n + 1, vector<
42     bool>(n * n + 1, false));
43 vector<vector<bool>> isColumn(n * n + 1,
44     vector<bool>(n * n + 1, false));
45 vector<vector<bool>> isSquare(n * n + 1,
46     vector<bool>(n * n + 1, false));
47 for (int i = 0; i < n * n; ++i)
48 {
49     for (int j = 0; j < n * n; ++j)
50     {
51         int number;
52         cin >> number;
53         board[i][j] = number;
54         if (number == 0)
55             continue;
56         isRow[i][number] = true;
57         isColumn[j][number] = true;
58         isSquare[getSquareIndex(i, j, n)][
59             number] = true;
60     }
61 }
62 if (backtracking(board, isRow, isColumn,
63     isSquare, 0, n))
64     /*有解答*/
65 else
66     /*解答*/

```

8 String

8.1 KMP

```

1 // 用在一個 s 內查找一個詞 w 的出現位置
2 void ComputePrefix(string s, int next[])
3 {
4     int n = s.length();
5     int q, k;
6     next[0] = 0;
7     for (k = 0, q = 1; q < n; q++)
8     {

```

```

9         while (k > 0 && s[k] != s[q])
10             k = next[k];
11         if (s[k] == s[q])
12             k++;
13         next[q] = k;
14     }
15 }
16 void KMPMatcher(string text, string pattern)
17 {
18     int n = text.length();
19     int m = pattern.length();
20     int next[pattern.length()];
21     ComputePrefix(pattern, next);
22     for (int i = 0, q = 0; i < n; i++)
23     {
24         while (q > 0 && pattern[q] != text[i]
25             ])
26             q = next[q];
27         if (pattern[q] == text[i])
28             q++;
29         if (q == m)
30         {
31             cout << "Pattern occurs with
32                 shift " << i - m + 1 << endl;
33             ;
34             q = 0;
35         }
36     }
37     // string s = "abcdabcdeabcd";
38     // string p = "bcd";
39     // KMPMatcher(s, p);
40     // cout << endl;

```

8.2 Min Edit Distance

```

1 int EditDistance(string a, string b)
2 {
3     vector<vector<int>> dp(a.size() + 1,
4         vector<int>(b.size() + 1, 0));
5     int m = a.length(), n = b.length();
6     for (int i = 0; i < m + 1; i++)
7     {
8         for (int j = 0; j < n + 1; j++)
9         {
10             if (i == 0)
11                 dp[i][j] = j;
12             else if (j == 0)
13                 dp[i][j] = i;
14             else if (a[i - 1] == b[j - 1])
15                 dp[i][j] = dp[i - 1][j - 1];
16             else
17                 dp[i][j] = 1 + min(min(dp[i]
18                     - 1][j], dp[i][j - 1]),
19                     dp[i - 1][j - 1]);
20         }
21     }
22     return dp[m][n];
23 }

```

8.3 Sliding window

```

1 string minWindow(string s, string t)
2 {
3     unordered_map<char, int> letterCnt;
4     for (int i = 0; i < t.length(); i++)
5         letterCnt[t[i]]++;
6     int minLength = INT_MAX, minStart = -1;
7     int left = 0, matchCnt = 0;
8     for (int i = 0; i < s.length(); i++)
9     {
10         if (--letterCnt[s[i]] >= 0)
11             matchCnt++;
12         while (matchCnt == t.length())
13         {
14             if (i - left + 1 < minLength)
15             {
16                 minLength = i - left + 1;
17                 minStart = left;
18             }
19             if (++letterCnt[s[left]] > 0)
20                 matchCnt--;
21             left++;
22         }
23     }
24     return minLength == INT_MAX ? "" : s.
25         substr(minStart, minLength);

```

8.4 Split

```

1 vector<string> mysplit(string s, string d)
2 {
3     int ps = 0, pe, dl = d.length();
4     string token;
5     vector<string> res;
6     while ((pe = s.find(d, ps)) != string::
7         npos)
8     {
9         token = s.substr(ps, pe - ps);
10        ps = pe + dl;
11        res.push_back(token);
12    }
13    res.push_back(s.substr(ps));
14    return res;

```

9 data structure

9.1 Bigint

```

1 //台大 //非必要請用python
2 struct Bigint
3 {
4     static const int LEN = 60; //
5     maxLEN

```

```

5     static const int BIGMOD = 10000; //10為
6     正常位數
7     int s;
8     int vl, v[LEN];
9     // vector<int> v;
10    Bigint() : s(1) { vl = 0; }
11    Bigint(long long a)
12    {
13        s = 1;
14        vl = 0;
15        if (a < 0)
16        {
17            s = -1;
18            a = -a;
19        }
20        while (a)
21        {
22            push_back(a % BIGMOD);
23            a /= BIGMOD;
24        }
25    }
26    Bigint(string str)
27    {
28        s = 1;
29        vl = 0;
30        int stPos = 0, num = 0;
31        if (!str.empty() && str[0] == '-')
32        {
33            stPos = 1;
34            s = -1;
35        }
36        for (int i = str.length() - 1, q =
37            1; i >= stPos; i--)
38        {
39            num += (str[i] - '0') * q;
40            if ((q *= 10) >= BIGMOD)
41            {
42                push_back(num);
43                num = 0;
44                q = 1;
45            }
46            if (num)
47                push_back(num);
48            n();
49        }
50        int len() const
51        {
52            return vl; //return SZ(v);
53        }
54        bool empty() const { return len() == 0; }
55        void push_back(int x)
56        {
57            v[vl++] = x; //v.PB(x);
58        }
59        void pop_back()
60        {
61            vl--; //v.pop_back();
62        }
63        int back() const
64        {
65            return v[vl - 1]; //return v.back();
66        }
67        void n()

```



```

67 {
68     while (!empty() && !back())
69         pop_back();
70 }
71 void resize(int nl)
72 {
73     v1 = nl;
74     fill(v, v + v1, 0); //fill(ALL(v),
75         0);
76 }
77 void print() const
78 {
79     if (empty())
80     {
81         putchar('0');
82         return;
83     }
84     if (s == -1)
85         putchar('-');
86     printf("%d", back());
87     for (int i = len() - 2; i >= 0; i--)
88         printf("%.4d", v[i]);
89 }
90 friend std::ostream &operator<<(std::
91     ostream &out, const Bigint &a)
92 {
93     if (a.empty())
94     {
95         out << "0";
96         return out;
97     }
98     if (a.s == -1)
99         out << "-";
100     out << a.back();
101     for (int i = a.len() - 2; i >= 0; i
102         --)
103     {
104         char str[10];
105         snprintf(str, 5, "%.4d", a.v[i])
106         ;
107         out << str;
108     }
109     return out;
110 }
111 int cp3(const Bigint &b) const
112 {
113     if (s != b.s)
114         return s - b.s;
115     if (s == -1)
116         return -(*this).cp3(-b);
117     if (len() != b.len())
118         return len() - b.len(); //int
119     for (int i = len() - 1; i >= 0; i--)
120         if (v[i] != b.v[i])
121             return v[i] - b.v[i];
122     return 0;
123 }
124 bool operator<(const Bigint &b) const
125 {
126     return cp3(b) < 0;
127 }
128 bool operator<=(const Bigint &b) const
129 {
130     return cp3(b) <= 0;
131 }
132 bool operator>(const Bigint &b) const
133 {
134     return cp3(b) > 0;
135 }
136 bool operator>=(const Bigint &b) const
137 {
138     return cp3(b) >= 0;
139 }
140 Bigint operator-() const
141 {
142     Bigint r = (*this);
143     r.s = -r.s;
144     return r;
145 }
146 Bigint operator+(const Bigint &b) const
147 {
148     if (s == -1)
149         return -(-(*this) + (-b));
150     if (b.s == -1)
151         return (*this) - (-b);
152     Bigint r;
153     int nl = max(len(), b.len());
154     r.resize(nl + 1);
155     for (int i = 0; i < nl; i++)
156     {
157         if (i < len())
158             r.v[i] += v[i];
159         if (i < b.len())
160             r.v[i] += b.v[i];
161         if (r.v[i] >= BIGMOD)
162         {
163             r.v[i + 1] += r.v[i] /
164                 BIGMOD;
165             r.v[i] %= BIGMOD;
166         }
167     }
168     r.n();
169     return r;
170 }
171 Bigint operator-(const Bigint &b) const
172 {
173     if (s == -1)
174         return -(-(*this) - (-b));
175     if (b.s == -1)
176         return (*this) + (-b);
177     if ((*this) < b)
178         return -(-b - (*this));
179     Bigint r;
180     r.resize(len());
181     for (int i = 0; i < len(); i++)
182     {
183         r.v[i] += v[i];
184         if (i < b.len())
185             r.v[i] -= b.v[i];
186         if (r.v[i] < 0)
187         {
188             r.v[i] += BIGMOD;
189             r.v[i + 1]--;
190         }
191     }
192     r.n();
193     return r;
194 }

```

```

194 }
195 r.n();
196 return r;
197 }
198 Bigint operator*(const Bigint &b)
199 {
200     Bigint r;
201     r.resize(len() + b.len() + 1);
202     r.s = s * b.s;
203     for (int i = 0; i < len(); i++)
204     {
205         for (int j = 0; j < b.len(); j
206             ++
207         {
208             r.v[i + j] += v[i] * b.v[j];
209             if (r.v[i + j] >= BIGMOD)
210             {
211                 r.v[i + j + 1] += r.v[i
212                     + j] / BIGMOD;
213                 r.v[i + j] %= BIGMOD;
214             }
215         }
216     }
217     r.n();
218     return r;
219 }
220 Bigint operator/(const Bigint &b)
221 {
222     Bigint r;
223     r.resize(max(1, len() - b.len() + 1)
224     );
225     int oriS = s;
226     Bigint b2 = b; // b2 = abs(b)
227     s = b2.s = r.s = 1;
228     for (int i = r.len() - 1; i >= 0; i
229         --)
230     {
231         int d = 0, u = BIGMOD - 1;
232         while (d < u)
233         {
234             int m = (d + u + 1) >> 1;
235             r.v[i] = m;
236             if ((r * b2) > (*this))
237                 u = m - 1;
238             else
239                 d = m;
240         }
241         r.v[i] = d;
242     }
243     s = oriS;
244     r.s = s * b.s;
245     r.n();
246     return r;
247 }
248 };

```

```

249 }
250 r.n();
251 return r;
252 }
253 Bigint operator*(const Bigint &b)
254 {
255     Bigint r;
256     r.resize(len() + b.len() + 1);
257     r.s = s * b.s;
258     for (int i = 0; i < len(); i++)
259     {
260         for (int j = 0; j < b.len(); j
261             ++
262         {
263             r.v[i + j] += v[i] * b.v[j];
264             if (r.v[i + j] >= BIGMOD)
265             {
266                 r.v[i + j + 1] += r.v[i
267                     + j] / BIGMOD;
268                 r.v[i + j] %= BIGMOD;
269             }
270         }
271     }
272     r.n();
273     return r;
274 }
275 Bigint operator/(const Bigint &b)
276 {
277     Bigint r;
278     r.resize(max(1, len() - b.len() + 1)
279     );
280     int oriS = s;
281     Bigint b2 = b; // b2 = abs(b)
282     s = b2.s = r.s = 1;
283     for (int i = r.len() - 1; i >= 0; i
284         --)
285     {
286         int d = 0, u = BIGMOD - 1;
287         while (d < u)
288         {
289             int m = (d + u + 1) >> 1;
290             r.v[i] = m;
291             if ((r * b2) > (*this))
292                 u = m - 1;
293             else
294                 d = m;
295         }
296         r.v[i] = d;
297     }
298     s = oriS;
299     r.s = s * b.s;
300     r.n();
301     return r;
302 }
303 Bigint operator%(const Bigint &b)
304 {
305     return (*this) - (*this) / b * b;
306 }
307 };

```

9.2 DisjointSet

```
1 struct DisjointSet {
```

```

2 int p[maxn], sz[maxn], n, cc;
3 vector<pair<int*, int>> his;
4 vector<int> sh;
5 void init(int _n) {
6     n = _n; cc = n;
7     for (int i = 0; i < n; ++i) sz[i] =
8         1, p[i] = i;
9     sh.clear(); his.clear();
10 }
11 void assign(int *k, int v) {
12     his.emplace_back(k, *k);
13     *k = v;
14 }
15 void save() {
16     sh.push_back((int)his.size());
17 }
18 void undo() {
19     int last = sh.back(); sh.pop_back();
20     while (his.size() != last) {
21         int *k, v;
22         tie(k, v) = his.back(); his.
23             pop_back();
24         *k = v;
25     }
26 }
27 int find(int x) {
28     if (x == p[x]) return x;
29     return find(p[x]);
30 }
31 void merge(int x, int y) {
32     x = find(x); y = find(y);
33     if (x == y) return;
34     if (sz[x] > sz[y]) swap(x, y);
35     assign(&sz[y], sz[x] + sz[y]);
36     assign(&p[x], y);
37     assign(&cc, cc - 1);
38 }
39 };

```

9.3 Matirx

```

1 template <typename T>
2 struct Matrix
3 {
4     using rt = std::vector<T>;
5     using mt = std::vector<rt>;
6     using matrix = Matrix<T>;
7     int r, c; // [r][c]
8     mt m;
9     Matrix(int r, int c) : r(r), c(c), m(r,
10         rt(c)) {}
11     Matrix(mt a) { m = a, r = a.size(), c =
12         a[0].size(); }
13     rt &operator[](int i) { return m[i]; }
14     matrix operator+(const matrix &a)
15     {
16         matrix rev(r, c);
17         for (int i = 0; i < r; ++i)
18             for (int j = 0; j < c; ++j)
19                 rev[i][j] = m[i][j] + a.m[i
20                     ][j];
21         return rev;
22     }
23 }

```

```

20 matrix operator-(const matrix &a)
21 {
22     matrix rev(r, c);
23     for (int i = 0; i < r; ++i)
24         for (int j = 0; j < c; ++j)
25             rev[i][j] = m[i][j] - a.m[i][j];
26     return rev;
27 }
28 matrix operator*(const matrix &a)
29 {
30     matrix rev(r, a.c);
31     matrix tmp(a.c, a.r);
32     for (int i = 0; i < a.r; ++i)
33         for (int j = 0; j < a.c; ++j)
34             tmp[j][i] = a.m[i][j];
35     for (int i = 0; i < r; ++i)
36         for (int j = 0; j < a.c; ++j)
37             for (int k = 0; k < c; ++k)
38                 rev.m[i][j] += m[i][k] *
39                     tmp[j][k];
40     return rev;
41 }
42 bool inverse() //逆矩陣判斷
43 {
44     Matrix t(r, r + c);
45     for (int y = 0; y < r; ++y)
46     {
47         t.m[y][c + y] = 1;
48         for (int x = 0; x < c; ++x)
49             t.m[y][x] = m[y][x];
50     }
51     if (!t.gas())
52         return false;
53     for (int y = 0; y < r; ++y)
54         for (int x = 0; x < c; ++x)
55             m[y][x] = t.m[y][c + x] / t.
56             m[y][y];
57     return true;
58 }
59 T gas() //行列式
60 {
61     vector<T> lazy(r, 1);
62     bool sign = false;
63     for (int i = 0; i < r; ++i)
64     {
65         if (m[i][i] == 0)
66         {
67             int j = i + 1;
68             while (j < r && !m[j][i])
69                 j++;
70             if (j == r)
71                 continue;
72             m[i].swap(m[j]);
73             sign = !sign;
74         }
75         for (int j = 0; j < r; ++j)
76         {
77             if (i == j)
78                 continue;
79             lazy[j] = lazy[j] * m[i][i];
80             T mx = m[j][i];
81             for (int k = 0; k < c; ++k)
82                 m[j][k] = m[j][k] * m[i][i] -
83                     mx * m[i][k];
84         }
85     }
86     return lazy[r-1];
87 }

```

9.4 Trie

```

1 // biginter字典數
2 struct BigInteger{
3     static const int BASE = 100000000;
4     static const int WIDTH = 8;
5     vector<int> s;
6     BigInteger(long long num = 0){
7         *this = num;
8     }
9     BigInteger operator = (long long num){
10         s.clear();
11         do{
12             s.push_back(num % BASE);
13             num /= BASE;
14         }while(num > 0);
15         return *this;
16     }
17     BigInteger operator = (const string& str)
18     {
19         s.clear();
20         int x, len = (str.length() - 1) /
21             WIDTH + 1;
22         for (int i = 0; i < len; ++i){
23             int end = str.length() - i*WIDTH;
24             int start = max(0, end-WIDTH);
25             sscanf(str.substr(start, end-
26                 start).c_str(), "%d", &x);
27             s.push_back(x);
28         }
29         return *this;
30     }
31     BigInteger operator + (const BigInteger&
32         b) const{
33         BigInteger c;
34         c.s.clear();
35         for (int i = 0, g = 0; i < s.size() || b.s.size() || g){
36             if(g == 0 && i < s.size() && i
37                 <= b.s.size()) break;
38             int x = g;
39             if(i < s.size()) x+=s[i];
40             if(i < b.s.size()) x+=b.s[i];
41             c.s.push_back(x % BASE);
42             g = x / BASE;
43         }
44         return c;
45     }
46 }

```

```

47 };
48 ostream& operator << (ostream &out, const
49     BigInteger& x){
50     out << x.s.back();
51     for(int i = x.s.size()-2; i >= 0; i--){
52         char buf[20];
53         sprintf(buf, "%08d", x.s[i]);
54         for(int j = 0; j < strlen(buf); j++){
55             out << buf[j];
56         }
57     }
58     return out;
59 }
60 istream& operator >> (istream &in,
61     BigInteger& x){
62     string s;
63     if(!(in >> s))
64         return in;
65     x = s;
66     return in;
67 }
68 struct Trie{
69     int c[5000005][10];
70     int val[5000005];
71     int sz;
72     int getIndex(char c){
73         return c - '0';
74     }
75     void init(){
76         memset(c[0], 0, sizeof(c[0]));
77         memset(val, -1, sizeof(val));
78         sz = 1;
79     }
80     void insert(BigInteger x, int v){
81         int u = 0;
82         int max_len_count = 0;
83         int firstNum = x.s.back();
84         char firstBuf[20];
85         sprintf(firstBuf, "%d", firstNum);
86         for(int j = 0; j < strlen(firstBuf);
87             j++){
88             int index = getIndex(firstBuf[j]);
89             if(!c[u][index]){
90                 memset(c[sz], 0, sizeof(c[
91                     sz]));
92                 val[sz] = v;
93                 c[u][index] = sz++;
94             }
95             u = c[u][index];
96             max_len_count++;
97         }
98         for(int i = x.s.size()-2; i >= 0; i
99             --){
100             char buf[20];
101             sprintf(buf, "%08d", x.s[i]);
102             for(int j = 0; j < strlen(buf)
103                 && max_len_count < 50; j++){
104                 int index = getIndex(buf[j]);
105                 if(!c[u][index]){
106                     memset(c[sz], 0, sizeof
107                         (c[sz]));
108                 }
109             }
110         }
111     }
112 }

```

```

99     val[sz] = v;
100     c[u][index] = sz++;
101 }
102 u = c[u][index];
103 max_len_count++;
104 }
105 if(max_len_count >= 50){
106     break;
107 }
108 }
109 }
110 int find(const char* s){
111     int u = 0;
112     int n = strlen(s);
113     for(int i = 0; i < n; ++i)
114     {
115         int index = getIndex(s[i]);
116         if(!c[u][index]){
117             return -1;
118         }
119         u = c[u][index];
120     }
121     return val[u];
122 }
123 }

```

9.5 分數

```

1 typedef long long ll;
2 struct fraction
3 {
4     ll n, d;
5     fraction(const ll &n = 0, const ll &d =
6         1) : n(n), d(d)
7     {
8         ll t = __gcd(n, d);
9         n /= t, d /= t;
10         if (d < 0)
11             n = -n, d = -d;
12     }
13     fraction operator-(const fraction &b)
14     {
15         return fraction(-n, d);
16     }
17     fraction operator+(const fraction &b)
18     {
19         return fraction(n * b.d + b.n * d, d * b
20             .d);
21     }
22     fraction operator-(const fraction &b)
23     {
24         return fraction(n * b.d - b.n * d, d * b
25             .d);
26     }
27     fraction operator*(const fraction &b)
28     {
29         return fraction(n * b.n, d * b.d);
30     }
31     fraction operator/(const fraction &b)
32     {
33         return fraction(n * b.d, d * b.n);
34     }
35 }

```

```
29 | {  
30 |     return fraction(n * b.d, d * b.n);  
31 | }  
32 | void print()  
33 | {  
34 |     cout << n;  
35 |     if (d != 1)  
36 |         cout << "/" << d;  
37 | }  
38 | };
```

TO DO WRITING NOT THINKING

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