

Problems Algorithms Lab 2013

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Checking Change

Bottom-up (iterative):

```
1  #include <iostream>
2  #include <vector>
3  #include <climits>
4  using namespace std;
5
6  void testcase() {
7      int C, M;
8      cin >> C >> M;
9      vector<int> change(10000, INT_MAX);
10     for(int c = 0; c < C; ++c) {
11         int coin; cin >> coin;
12         change[coin] = 1;
13     }
14
15     int rightmost = 1;
16     for(int m = 0; m < M; ++m) {
17         int input;
18         cin >> input;
19
20         if(rightmost < input) {
21             for(int i = rightmost+1; i <= input; ++i) {
22                 if(change[i] == 1) continue;
23                 int global_min = INT_MAX;
24                 for(int j = i-1; j > 0; --j) {
25                     if(change[j] != INT_MAX && change[i-j] != INT_MAX)
26                         global_min = min(global_min, change[j] + change[i-j]);
27                 }
28                 change[i] = global_min;
29             }
30             rightmost = input;
31         }
32
33         (change[input] == INT_MAX) ? cout << "not possible\n" : cout << change[input] << "\n";
34     }
35 }
36
37 int main() {
38     int TC; cin >> TC;
39     while (TC--) testcase();
40     return 0;
41 }
```

Top-down (recursive):

```
1  #include <vector>
2  #include <iostream>
3  #include <climits>
4  using namespace std;
5
6  int f(int val, vector<int>& counts) {
7      if(counts[val] != INT_MAX)
8          return counts[val];
9
10     int global_min = INT_MAX;
11     for(int j = val-1; j > 0; --j) {
12         int val1 = f(j, counts);
13         int val2 = f(val-j, counts);
14         if(val1 != INT_MAX && val2 != INT_MAX) {
15             global_min = min(global_min, val1+val2);
16         }
17     }
18
19     counts[val] = global_min;
20     return global_min;
21 }
22
23 void testcase() {
24     int C, M;
25     cin >> C >> M;
26     vector<int> counts(10000, INT_MAX);
27     for(int c = 0; c < C; ++c) {
28         int coin; cin >> coin;
```

```

29     counts[coin] = 1;
30 }
31
32 for(int m = 0; m < M; ++m) {
33     int input; cin >> input;
34     int sol = f(input, counts);
35     (sol == INT_MAX) ? cout << "not_possible\n" : cout << sol << "\n";
36 }
37 }
38
39 int main() {
40     int TC; cin >> TC;
41     while (TC--) testcase();
42     return 0;
43 }

```

Dominoes

```
1  #include <vector>
2  #include <iostream>
3  using namespace std;
4
5  void testcase() {
6      int N; cin >> N;
7      vector<int> tiles;
8      for(int i = 0; i < N; ++i) {
9          int h; cin >> h;
10         tiles.push_back(h);
11     }
12
13     int rightmost = 0;
14     int sum = N;
15     for(int i = 0; i < N; ++i) {
16         int j = tiles[i] + i - 1;
17         rightmost = max(rightmost, j);
18         if(rightmost >= N-1) break;
19         if(i >= rightmost) {
20             sum = rightmost+1;
21             break;
22         }
23     }
24     cout << sum << "\n";
25 }
26
27 int main() {
28     std::ios_base::sync_with_stdio(false);
29     int TC; cin >> TC;
30     while(TC--) testcase();
31 }
```

Shelves

```
1  #include <iostream>
2
3  using namespace std;
4
5  int main(void) {
6      // speeds up read and write
7      ios_base::sync_with_stdio(false);
8
9      // number of testcases we need to run
10     int nrCases;
11     cin >> nrCases;
12
13     for(int i = 0; i < nrCases; i++) {
14         // read the input for the test case
15         int l, m, n;
16         cin >> l >> m >> n;
17
18         // number of the two shelves and remaining length
19         int cm = 0;
20         int cn = 0;
21         int r = l;
22
23         for(int tmpCn = l/n; tmpCn >= 0 && r != 0; tmpCn--) {
24             // calculate the number of the small shelves
25             int tmpCm = (l - tmpCn * n) / m;
26             if(tmpCm >= n) {
27                 break;
28             }
29
30             // calculate the new remaining space and use it when smaller
31             int tmpR = l - tmpCn * n - tmpCm * m;
32             if(tmpR < r) {
33                 cn = tmpCn;
34                 cm = tmpCm;
35                 r = tmpR;
36             }
37         }
38
39         // output the result
40         cout << cm << " " << cn << " " << r << '\n';
41     }
42
43     return 0;
44 }
```

Even Pairs

```
1  #include<iostream>
2
3  using namespace std;
4
5  /*
6   * Dynamic programing. Running time O(n).
7   */
8
9  int main() {
10     int n, count, neven, nodd;
11
12     // Read the input
13     cin >> n;
14     int x[n];
15     for (int i = 0; i < n; i++) {
16         cin >> x[i];
17     }
18     // Calculate the values S_i
19     // S_i = sum of elements from x[1] to x[i]
20     int S[n];
21     S[0] = x[0];
22     for (int i = 1; i < n; i++) {
23         S[i] = x[i] + S[i-1];
24     }
25
26     // Calculate the result
27     // If S[i] is even and there is k < i with S[k] is even,
28     // then (k, i) is even pair. Similarly for odd S[i].
29     count = 0;
30     neven = 1;
31     nodd = 0;
32     for (int i = 0; i < n; i++) {
33         if (S[i] % 2 == 0) {
34             count += neven;
35             neven++;
36         } else {
37             count += nodd;
38             nodd++;
39         }
40     }
41     cout << count << endl;
42
43     return 0;
44 }
```


Aliens

```
1  #include <iostream>
2  #include <vector>
3  #include <algorithm>
4  #include <limits>
5  using namespace std;
6
7  typedef vector<pair<int, int> > vii;    // sorted by left, right.
8  bool sortDescAsc(const pair<int, int>& lhs, const pair<int, int>& rhs) {
9      if(lhs.first == rhs.first)
10         return (lhs.second > rhs.second);
11     else
12         return lhs.first < rhs.first;
13 }
14
15 void testcase() {
16     int n, m;
17     cin >> n >> m;
18     vii intervals;
19     int superior = n;
20     for(int i = 0; i < n; ++i) {
21         int pi, qi;
22         cin >> pi >> qi;
23         if(pi == 0 && qi == 0) {
24             --superior;
25             continue;
26         }
27         pair<int, int> entry = make_pair(pi, qi);
28         intervals.push_back(entry);
29     }
30
31     sort(intervals.begin(), intervals.end(), sortDescAsc);
32
33     int left = 0;
34     int right = 0;
35     for(int i = 0; i < intervals.size(); ++i) {
36         if(i+1 < intervals.size() && intervals[i+1].first == intervals[i].first && intervals[i+1].second ==
37             ↵ intervals[i].second)
38             --superior;
39         else if(left == intervals[i].first && right == intervals[i].second)
40             --superior;
41         else if(right >= intervals[i].second)
42             --superior;
43
44         if(right < intervals[i].second) {
45             left = intervals[i].first;
46             if(right != 0 && left-right > 1) {
47                 cout << "0\n";
48                 return;
49             }
50             right = intervals[i].second;
51         }
52     }
53
54     cout << superior << "\n";
55 }
56
57 int main() {
58     int TC;
59     cin >> TC;
60     while(TC--) testcase();
61 }
```

Boats

```
1  #include <vector>
2  #include <iostream>
3  #include <algorithm>
4  #include <climits>
5  using namespace std;
6
7  void testcase() {
8      int N; cin >> N;
9      vector<pair<int, int> > boats; // sorted by ring position.
10     for(int n = 0; n < N; ++n) {
11         int l, p; cin >> l >> p;
12         boats.push_back(make_pair(p, l));
13     }
14     sort(boats.begin(), boats.end());
15
16     int counter = 1;
17     int best_boat;
18     int best_right = INT_MAX;
19     int right = boats[0].first;
20     int b = 1;
21     while(b < N) {
22         if(boats[b].first < right) { ++b; continue; }
23         int temp = max(boats[b].first, boats[b].first + boats[b].second - (boats[b].first - right));
24
25         if(temp < best_right) {
26             best_boat = b;
27             best_right = temp;
28         }
29
30         if((boats[b].first >= best_right) || (b + 1 == N && boats[b].first >= right)) {
31             b = best_boat;
32             right = best_right;
33             best_right = INT_MAX;
34             ++counter;
35         }
36         ++b;
37     }
38     cout << counter << "\n";
39 }
40
41 int main() {
42     int TC; cin >> TC;
43     while (TC--) testcase();
44     return 0;
45 }
```

False Coin

```
1  #include <vector>
2  #include <iostream>
3  using namespace std;
4
5  typedef vector<int> vi;
6  typedef vector<pair<vi, char> > vii;
7
8  bool evaluate(vi ineq, int var, char sign) {
9      int left0 = 0;
10     int left1 = 0;
11     int right0 = 0;
12     int right1 = 0;
13     for(int l = 0, r = ineq.size()/2; l < ineq.size()/2; ++l, ++r) {
14         int var_l = ineq[l];
15         int var_r = ineq[r];
16         left0 += (var_l == var) ? 0 : 1;
17         left1 += (var_l == var) ? 1 : 0;
18         right0 += (var_r == var) ? 0 : 1;
19         right1 += (var_r == var) ? 1 : 0;
20     }
21     if(sign == '<') return (left0 < right0 || left1 < right1);
22     else return (left0 > right0 || left1 > right1);
23 }
24
25 void testcase() {
26     int N, K; cin >> N >> K;
27     vi coins(N, 0);
28     vii inequalities;
29
30     for(int k = 0; k < K; ++k) {
31         int C; cin >> C;
32         vi equation(2*C);
33         for(int i = 0; i < 2*C; ++i) {
34             int c; cin >> c;
35             equation[i] = c-1;
36         }
37         char sign; cin >> sign;
38         if(sign == '<' || sign == '>') inequalities.push_back(make_pair(equation, sign));
39         else for(int i = 0; i < 2*C; ++i) coins[equation[i]] = 1;
40     }
41
42     int knowns = 0;
43     int unknown = -1;
44     for(int i = 0; i < N; ++i) {
45         knowns += coins[i];
46         if(coins[i] == 1) continue;
47         for(int ineq = 0; ineq < inequalities.size(); ++ineq) {
48             vi inequality = inequalities[ineq].first;
49             bool result = evaluate(inequality, i, inequalities[ineq].second);
50             if(!result) {
51                 coins[i] = 1;
52                 ++knowns;
53                 break;
54             }
55         }
56         if(coins[i] == 0) unknown = i;
57     }
58     if(N - knowns == 1) cout << unknown+1 << "\n";
59     else cout << 0 << "\n";
60 }
61
62 int main() {
63     int TC; cin >> TC;
64     while (TC--) testcase();
65     return 0;
66 }
```

Formulas

```
1  #include <iostream>
2  #include <vector>
3  using namespace std;
4
5  void init_mergesort(vector<int> &racers, vector<int> &aux, int left, int right);
6  void sort(vector<int> &racers, vector<int> &aux, int left, int right);
7  void merge(vector<int> &racers, vector<int> &aux, int left, int pivot, int right);
8
9  vector<unsigned long> answers;
10
11 unsigned long overpasses;
12
13 int main(int argc, char const *argv[])
14 {
15
16     int testcases;
17     cin >> testcases;
18
19     for (int testcase = 0; testcase < testcases; testcase++)
20     {
21         int size;
22         cin >> size;
23
24         vector<int> racers;
25         vector<int> aux;
26
27         for (int racer = 0; racer < size; racer++)
28         {
29             int pos;
30             cin >> pos;
31             racers.push_back(pos);
32         }
33
34         aux = racers;
35
36         overpasses = 0;
37         init_mergesort(racers, aux, 0, size-1);
38         answers.push_back(overpasses % 10000);
39     }
40
41     for(vector<unsigned long>::iterator iter = answers.begin(); iter != answers.end(); iter++) {
42         cout << *iter << "\n";
43     }
44
45     return 0;
46 }
47
48 void init_mergesort(vector<int> &racers, vector<int> &aux, int left, int right) {
49     int pivot = (left + right) / 2;
50
51     sort(racers, aux, left, pivot);
52     sort(racers, aux, pivot + 1, right);
53     merge(racers, aux, left, pivot, right);
54 }
55
56 void sort(vector<int> &racers, vector<int> &aux, int left, int right) {
57     if (left < right)
58     {
59         int pivot = (left + right) / 2;
60         sort(racers, aux, left, pivot);
61         sort(racers, aux, pivot+1, right);
62         merge(racers, aux, left, pivot, right);
63     }
64 }
65
66 void merge(vector<int> &racers, vector<int> &aux, int left, int pivot, int right) {
67
68     unsigned long local_overpasses = 0;
69     int a = left;
70     int i = left;
71     int j = pivot + 1;
72
73     // TODO: if left - right smaller than threshold, then use insertion sort!
74     while( (i <= pivot) && (j <= right) )
```

```

75 {
76     if (racers[i] == racers[j]) {
77         aux[a++] = racers[i++];
78     }
79     if (racers[i] < racers[j]) {
80         aux[a++] = racers[i++];
81     }
82     if (racers[i] > racers[j]) {
83         aux[a++] = racers[j++];
84         local_overpasses += (pivot + 1 - left) - (i - left);
85     }
86 }
87
88 if (i <= pivot) for (int k = i; k <= pivot; k++) { aux[a++] = racers[k]; i++; }
89 if (j <= right) for (int k = j; k <= right; k++) { aux[a++] = racers[k]; j++; }
90
91 //TODO: make it faster!
92 for (int k = left; k <= right; k++) {
93     racers[k] = aux[k];
94 }
95
96 overpasses += local_overpasses;
97 }
98

```

Race Tracks

```
1  #include <vector>
2  #include <set>
3  #include <queue>
4  #include <sstream>
5  #include <string>
6  #include <iostream>
7  using namespace std;
8
9  vector<string> answers;
10
11 int main(int argc, char const *argv[])
12 {
13
14     int testsets;
15     cin >> testsets;
16
17     for (int testset = 0; testset < testsets; testset++) {
18
19         int m, n;
20         cin >> m >> n;
21
22         int s1, s2;
23         cin >> s1 >> s2;
24
25         int f1, f2;
26         cin >> f1 >> f2;
27
28         int numberObstacles;
29         cin >> numberObstacles;
30
31         vector< vector<bool> > obstacles (m, vector<bool>(n));
32         for (int o = 0; o < numberObstacles; o++)
33         {
34             int x1, y1, x2, y2;
35             cin >> x1 >> y1 >> x2 >> y2;
36
37             for (int x = x1; x <= x2; x++)
38             {
39                 for (int y = y1; y <= y2; y++) {
40                     obstacles[x][y] = true;
41                 }
42             }
43         }
44
45         if (obstacles[f1][f2] == true)
46         {
47             answers.push_back("No solution.");
48             continue;
49         }
50
51         // visited states
52         vector< vector< set<pair<int,int> > > > visited(m, vector<set<pair<int,int> > >(n) );
53
54         // fifo queue for BFS
55         queue<pair< pair< pair<int, int>, int>, pair<int, int> > > fifo;
56
57         // adding starting point to fifo queue
58         pair<pair< pair<int, int>,int>, pair<int, int> > start_point = make_pair( make_pair( make_pair(s1,s2) , 0), make_pair(0,0));
59         fifo.push(start_point);
60         visited[s1][s2].insert(make_pair(0,0));
61
62         bool success = false;
63
64         while (!fifo.empty()) {
65             pair<
66                 pair<
67                     pair<int, int>, int>,
68                     pair<int,int>
69                 > current_element = fifo.front();
70
71             // remove current element
72             fifo.pop();
73
```

```

74 // add to visited
75 int current_x = current_element.first.first.first;
76 int current_y = current_element.first.first.second;
77 int current_hops = current_element.first.second;
78 int current_xv = current_element.second.first;
79 int current_yv = current_element.second.second;
80
81 if ( (current_x == f1) && (current_y == f2) )
82 {
83     stringstream ss;
84     ss << "Optimal_solution_takes_" << current_hops << "_hops.";
85     answers.push_back(ss.str());
86     success = true;
87     break;
88 }
89
90 // get children, add to queue
91 for (int xv = -1; xv <= 1; xv++)
92 {
93     for (int yv = -1; yv <= 1; yv++) {
94
95         // updated velocity
96         int new_vx = current_xv + xv;
97         int new_vy = current_yv + yv;
98
99         // potential x and y coordinates
100        int new_x = current_x + new_vx;
101        int new_y = current_y + new_vy;
102
103        // check for velocity range (-3,3), grid range (m,n) and obstacles
104        if ((new_vx <= 3) && (new_vy <= 3)
105            && (new_vx >= -3) && (new_vy >= -3)
106            && (new_x < m) && (new_y < n)
107            && (new_y >= 0) && (new_x >= 0)
108            && obstacles[new_x][new_y] != true)
109        {
110            pair<int, int> child_velocity = make_pair(new_vx, new_vy);
111            if (visited[new_x][new_y].find(child_velocity) == visited[new_x][new_y].end())
112            {
113
114                if ( (new_x == f1) && (new_y == f2) )
115                {
116                    stringstream ss;
117                    ss << "Optimal_solution_takes_" << current_hops + 1 << "_hops.";
118                    answers.push_back(ss.str());
119                    success = true;
120                    goto loopend;
121                }
122
123                pair< pair<int, int>, int> child_position = make_pair(make_pair(new_x, new_y),
124                    current_hops + 1);
125                pair< pair< pair<int, int>, int>, pair<int,int> > fifo_element =
126                    make_pair(child_position, child_velocity);
127                fifo.push(fifo_element);
128
129                // add to visited nodes
130                visited[new_x][new_y].insert(child_velocity);
131            }
132        }
133    }
134
135    if(success == true) {
136        loopend:
137        break;
138    }
139 }
140
141 if (success == false) answers.push_back("No_solution.");
142 }
143
144 for (vector<string>::iterator iter = answers.begin(); iter != answers.end(); iter++)
145 {
146     cout << *iter << "\n";
147 }

```

```
148     }  
149  
150     return 0;  
151 }
```


Burning Coins

```
1  #include <vector>
2  #include <iostream>
3  using namespace std;
4
5  #define UNDEFINED -1
6  typedef vector<int> vi;
7  typedef vector<vi> vii;
8
9  int subsequence(int left, int right, vi& coins, vii& dp_table) {
10     if(dp_table[left][right] != UNDEFINED) return dp_table[left][right];
11
12     if(left > right) left = right;
13     if(left == right) return dp_table[left][right] = coins[left];
14     if(right - left == 1) return dp_table[left][right] = max(coins[left], coins[right]);
15
16     int min_left = min(subsequence(left+2, right, coins, dp_table), subsequence(left+1, right-1, coins,
17     ↵ dp_table));
18     int min_right = min(subsequence(left, right-2, coins, dp_table), subsequence(left+1, right-1, coins,
19     ↵ dp_table));
20     return dp_table[left][right] = max(coins[left]+min_left, coins[right]+min_right);
21 }
22
23 void testcase() {
24     int n; cin >> n;
25     vi coins(n);
26     for(int i = 0; i < n; ++i) {
27         int input; cin >> input;
28         coins[i] = input;
29     }
30
31     vii dp_table(n, vi(n, UNDEFINED));
32     subsequence(0, n-1, coins, dp_table);
33     cout << dp_table[0][n-1] << "\n";
34 }
35
36 int main() {
37     int TC; cin >> TC;
38     while(TC--) testcase();
39     return 0;
40 }
```

Jump

```
1 #include <vector>
2 #include <iostream>
3 #include <queue>
4 using namespace std;
5
6 typedef vector<unsigned long int> vi;
7
8 void testcase() {
9     int n, k; cin >> n >> k;
10    int input; cin >> input; // ignore first input.
11
12    priority_queue<pair<long unsigned int, int>, vector<pair<long unsigned int, int> >, greater<pair<long unsigned int, int> > > min_heap;
13
14    vi dp_table;
15    dp_table.push_back(0);
16
17    for(int i = 1; i < n; ++i) {
18        while((!min_heap.empty()) && (min_heap.top().second < max(0, i - k))) min_heap.pop();
19        min_heap.push(make_pair(dp_table[i-1], i-1));
20
21        int input; cin >> input;
22        long unsigned int new_min = input + min_heap.top().first;
23        dp_table.push_back(new_min);
24    }
25    cout << dp_table[n-1] << "\n";
26 }
27
28 int main() {
29     ios_base::sync_with_stdio(false);
30     int TC; cin >> TC;
31     while(TC--) testcase();
32     return 0;
33 }
```

Light Pattern

```
1  #include <vector>
2  #include <iostream>
3  #include <cmath>
4  using namespace std;
5
6  #define SWAP 1
7  #define NO_SWAP 0
8  typedef vector<int> vi;
9  typedef vector<vi> vii;
10
11 void testcase() {
12     int n, k, x; cin >> n >> k >> x;
13
14     vi pattern;
15     for(int i = k-1; i >= 0; i--) if(x - pow(2.0, i) >= 0) { x -= pow(2.0, i); pattern.push_back(1); } else {
16         pattern.push_back(0); }
17
18     vii changes(n/k, vi(2));
19     for(int i = 0, p = 0, b = 0; i < n; ++i, ++p) {
20         int input; cin >> input;
21         (pattern[p] == input) ? changes[b][SWAP] += 1 : changes[b][NO_SWAP] += 1;
22         if(p == k-1) { p = -1; ++b; }
23     }
24
25     vii dp_table(n/k, vi(2));
26     dp_table[0][SWAP] = changes[0][SWAP] + 1;
27     dp_table[0][NO_SWAP] = changes[0][NO_SWAP];
28     for(int b = 1; b < (n/k); ++b) {
29         dp_table[b][SWAP] = min(dp_table[b-1][SWAP] + changes[b][SWAP], dp_table[b-1][NO_SWAP] + 2 +
30             changes[b][SWAP]);
31         dp_table[b][NO_SWAP] = min(dp_table[b-1][NO_SWAP] + changes[b][NO_SWAP], dp_table[b-1][SWAP] +
32             changes[b][NO_SWAP]);
33     }
34
35     cout << min(dp_table[(n/k)-1][SWAP], dp_table[(n/k)-1][NO_SWAP]) << "\n";
36 }
37
38 int main() {
39     int TC; cin >> TC;
40     while(TC--) testcase();
41     return 0;
42 }
```

Longest Path

Based on DAG property of tree:

```
1  #include <vector>
2  #include <queue>
3  #include <iostream>
4  #include <algorithm>
5  using namespace std;
6
7  typedef vector<int> vi;
8  typedef vector<vi> AdjacencyList;
9
10 void drill(int target, int comingFrom, AdjacencyList& adj, vi& max, vector<priority_queue<int> >& incomingPaths, vi& longest, bool start) {
11     if(adj[target].size() == 1 && !start) {
12         max[target] = 0;
13         incomingPaths[comingFrom].push(1);
14         return;
15     }
16
17     for(unsigned int outgoing = 0; outgoing < adj[target].size(); ++outgoing) {
18         if(adj[target][outgoing] != comingFrom)
19             drill(adj[target][outgoing], target, adj, max, incomingPaths, longest, false);
20     }
21
22     int first = incomingPaths[target].top(); incomingPaths[target].pop();
23     int second = 0;
24     if(!incomingPaths[target].empty()) {
25         second = incomingPaths[target].top(); incomingPaths[target].pop();
26     }
27
28     max[target] = first;
29     longest[target] = first + second;
30     incomingPaths[comingFrom].push(first+1);
31 }
32
33 void testcase() {
34     int vertices; cin >> vertices;
35
36     if(vertices == 1) { int v1, v2; cin >> v1 >> v2; cerr << 1 << "\n"; return; }
37
38     AdjacencyList adj(vertices);
39     vi max(vertices, 0);
40     vi longest(vertices, 0);
41     vector<priority_queue<int> > incomingPaths(vertices);
42
43     for(int input = 0; input < vertices-1; ++input) {
44         int v1, v2; cin >> v1 >> v2;
45         adj[v1].push_back(v2);
46         adj[v2].push_back(v1);
47     }
48
49     drill(0, 0, adj, max, incomingPaths, longest, true);
50     cout << *max_element(longest.begin(), longest.end())+1 << "\n";
51 }
52
53 int main() {
54     ios_base::sync_with_stdio(false);
55     int TC; cin >> TC;
56     while(TC--) testcase();
57     return 0;
58 }
```

Graph traversal: 2xDFS

```
1  #include <vector>
2  #include <iostream>
3  #include <queue>
4  #include <algorithm>
5  using namespace std;
6
7  typedef vector<int> vi;
8  typedef vector<vi> vii;
9  int N;
10
```

```

11 pair<int, int> DFS(int start, vii& adj, vi& dist, vi& visited) {
12     queue<int> fifo;
13     fifo.push(start);
14     visited[start] = 1;
15
16     while(!fifo.empty()) {
17         int parent_id = fifo.front(); fifo.pop();
18         for(int child = 0; child < adj[parent_id].size(); ++child) {
19             int child_id = adj[parent_id][child];
20             if(visited[child_id] == 0) {
21                 fifo.push(child_id);
22                 visited[child_id] = 1;
23                 dist[child_id] = dist[parent_id] + 1;
24             }
25         }
26     }
27     vi::iterator it = max_element(dist.begin(), dist.end());
28     pair<int, int> val;
29     val.first = it - dist.begin();
30     val.second = *it;
31     return val;
32 }
33
34 void testcase() {
35     cin >> N;    // N vertices, by definition N-1 edges.
36     vii adj(N);
37     vi dist(N, 0);
38     vi visited(N, 0);
39
40     for(int n = 0; n < N-1; ++n) {
41         int v1, v2; cin >> v1 >> v2;
42         adj[v1].push_back(v2);
43         adj[v2].push_back(v1);
44     }
45     if(N == 1) { cout << 0 << "\n"; return; }
46
47     pair<int, int> pass1 = DFS(0, adj, dist, visited);
48     dist.assign(N, 0); visited.assign(N, 0);
49     pair<int, int> pass2 = DFS(pass1.first, adj, dist, visited);
50     cout << pass2.second+1 << "\n";
51 }
52
53 int main() {
54     cin.sync_with_stdio(false);
55     int TC; cin >> TC;
56     while(TC--) testcase();
57     return 0;
58 }

```

Ants

```
1  #include <vector>
2  #include <iostream>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/graph_traits.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/kruskal_min_spanning_tree.hpp>
7  #include <boost/graph/dijkstra_shortest_paths.hpp>
8  using namespace std;
9  using namespace boost;
10
11 typedef property<edge_weight_t, int, property<edge_index_t, int> > EdgeProperties;
12 typedef property<vertex_index_t, int> VertexProperties;
13 typedef adjacency_list<vecS, vecS, undirectedS, VertexProperties, EdgeProperties> Graph;
14 typedef graph_traits<Graph>::vertex_descriptor Vertex;
15 typedef graph_traits<Graph>::edge_descriptor Edge;
16 typedef property_map<Graph, edge_weight_t>::type WeightMap;
17 typedef property_map<Graph, edge_index_t>::type EIndexMap;
18 typedef property_map<Graph, vertex_index_t>::type VIndexMap;
19 typedef graph_traits<Graph>::edge_iterator EdgeIterator;
20 typedef vector<int> vi;
21 typedef vector<vi> vii;
22 typedef vector<Edge> ve;
23
24 void testcase() {
25     int N, M, S, a, b; cin >> N >> M >> S >> a >> b;
26
27     Graph g;
28     WeightMap weightMap = get(edge_weight, g);
29     EIndexMap eIndexMap = get(edge_index, g);
30     vii weights(M);
31
32     for(int e = 0; e < M; ++e) {
33         int t1, t2; cin >> t1 >> t2;
34         for(int s = 0; s < S; ++s) {
35             int s_weight; cin >> s_weight;
36             weights[e].push_back(s_weight);
37         }
38
39         Edge edge; bool success;
40         tie(edge, success) = add_edge(t1, t2, g);
41         eIndexMap[edge] = e;
42     }
43
44     Graph final;
45     WeightMap weightMapFinal = get(edge_weight, final);
46
47     for(int s = 0; s < S; ++s) {
48         int hive; cin >> hive;
49
50         EdgeIterator eit, eend;
51         for(tie(eit, eend) = edges(g); eit != eend; ++eit) weightMap[*eit] = weights[eIndexMap[*eit]][s];
52
53         ve mst(num_vertices(g)-1);
54         kruskal_minimum_spanning_tree(g, mst.begin());
55         for(ve::iterator edge = mst.begin(); edge != mst.end(); ++edge) {
56             Edge newEdge; bool success;
57             tie(newEdge, success) = add_edge(source(*edge, g), target(*edge, g), final);
58             weightMapFinal[newEdge] = weightMap[*edge];
59         }
60     }
61
62     vi d(num_vertices(final));
63     dijkstra_shortest_paths(final, vertex(a, final), distance_map(d[0]));
64     cout << d[b] << "\n";
65 }
66
67 int main() {
68     ios_base::sync_with_stdio(false);
69     int TC; cin >> TC;
70     while(TC--) testcase();
71     return 0;
72 }
```

Bridges

```
1  #include <vector>
2  #include <iostream>
3  #include <boost/tuple/tuple.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/graph/biconnected_components.hpp>
6  using namespace std;
7  using namespace boost;
8
9  typedef property<vertex_index_t, int> VertexProperties;
10 typedef adjacency_list< vecS, vecS, undirectedS, VertexProperties, no_property> Graph;
11 typedef property_map<Graph, vertex_index_t>::type VIndexMap;
12 typedef graph_traits<Graph>::vertex_descriptor Vertex;
13 typedef graph_traits<Graph>::edge_descriptor Edge;
14 typedef graph_traits<Graph>::adjacency_iterator Alter;
15 typedef vector<int> vi;
16 typedef vector<Vertex> vv;
17 typedef pair<int, int> pi;
18
19 void testcase() {
20     int N, M; cin >> N >> M;
21
22     if(N == 0 || M == 0) { cout << "0\n"; return; }
23
24     Graph g(N);
25     VIndexMap index = get(vertex_index, g);
26
27     for(int m = 0; m < M; ++m) {
28         int v1, v2; cin >> v1 >> v2;
29         add_edge(v1, v2, g);
30     }
31
32     vv art_points;
33     vi discover_time(num_vertices(g));
34     vi low_point(num_vertices(g));
35     vector<pi> bridges;
36     articulation_points(g,
37                         back_inserter(art_points),
38                         discover_time_map(&discover_time[0]).lowpoint_map(&low_point[0]));
39
40     // workaround for "root not chosen as articulation point if only one child".
41     if(out_degree(vertex(1, g), g) == 1) {
42         Vertex root = vertex(1, g);
43         art_points.insert(art_points.begin(), root);
44     }
45     for(int v = 0; v < art_points.size(); ++v) {
46         Vertex art_point = art_points[v];
47         Alter neighbour, neighbour_end;
48         for(tie(neighbour, neighbour_end) = adjacent_vertices(art_point, g); neighbour != neighbour_end; ↵
49             ↵ ++neighbour) {
50             if(low_point[*neighbour] > discover_time[art_point]) {
51                 //cout << "bridge found between: " << index[art_point] << "-" << index[*neighbour] << "\n";
52                 bridges.push_back(make_pair(min(index[art_point], index[*neighbour]), max(index[art_point], ↵
53                     ↵ index[*neighbour])));
54             }
55         }
56     }
57     sort(bridges.begin(), bridges.end());
58     cout << bridges.size() << "\n";
59     for(int b = 0; b < bridges.size(); ++b) {
60         cout << bridges[b].first << "┐" << bridges[b].second << "\n";
61     }
62 }
63
64 int main() {
65     int TC; cin >> TC;
66     while(TC--) testcase();
67     return 0;
68 }
```

```
1  #include <vector>
2  #include <iostream>
3  #include <algorithm>
```

```

4  #include <set>
5  using namespace std;
6
7  #define UNVISITED 0
8  #define VISITED 1
9  #define EXPLORED 2
10
11 typedef vector<int> vi;
12 typedef vector<vi> vii;
13 typedef pair<int, int> pi;
14
15 vi visited;
16 vi dfs_num;
17 vi dfs_low;
18
19 void dfs(int vertex, int parent, vii& adj, int counter) {
20     for(signed int child = 0; child < adj[vertex].size(); ++child) {
21         int child_vertex = adj[vertex][child];
22         if(child_vertex != parent) {
23             if(visited[child_vertex] == EXPLORED) {
24                 dfs_low[vertex] = min(dfs_num[child_vertex], dfs_low[vertex]);
25             }
26
27             if(visited[child_vertex] == UNVISITED) {
28                 visited[child_vertex] = EXPLORED;
29                 dfs_num[child_vertex] = ++counter;
30                 dfs_low[child_vertex] = dfs_num[child_vertex];
31                 dfs(child_vertex, vertex, adj, counter);
32             }
33         }
34     }
35
36     dfs_low[parent] = min(dfs_low[parent], dfs_low[vertex]);
37     visited[vertex] = VISITED;
38 }
39
40 void testcase() {
41     int N, M; cin >> N >> M;
42     visited.clear(); dfs_low.clear(); dfs_num.clear();
43     vii adj(N); visited.assign(N, UNVISITED); dfs_num.assign(N, 0); dfs_low.assign(N, 0);
44
45     if(N == 0 || M == 0) { cout << "0\n"; return; }
46
47     for(int m = 0; m < M; ++m) {
48         int v1, v2; cin >> v1 >> v2;
49         adj[(v1-1)].push_back(v2-1);
50         adj[(v2-1)].push_back(v1-1);
51     }
52
53     dfs_num[0] = 0; dfs_low[0] = 0; visited[0] = EXPLORED;
54     dfs(0, 0, adj, 0);
55
56     vector<pi> bridges;
57     set<int> art_points;
58     for(int u = 0; u < N; ++u) {
59         for(int v = 0; v < adj[u].size(); ++v) {
60             if(dfs_low[adj[u][v]] > dfs_num[u]) {
61                 bridges.push_back(make_pair(min(u, adj[u][v]), max(u, adj[u][v])));
62             }
63             if(dfs_low[adj[u][v]] >= dfs_num[u]) {
64                 // if it is not root, or it is root but has more than 1 child:
65                 art_points.insert(u);
66             }
67         }
68     }
69     sort(bridges.begin(), bridges.end());
70     cout << bridges.size() << "\n";
71     for(signed int b = 0; b < bridges.size(); ++b) {
72         cout << bridges[b].first+1 << " " << bridges[b].second+1 << "\n";
73     }
74 }
75
76 int main() {
77     int TC; cin >> TC;
78     while(TC--) testcase();
79     return 0;

```


Build The Graph

```
1  #include <iostream>
2  #include <boost/graph/adjacency_list.hpp>
3  #include <boost/tuple/tuple.hpp>
4  #include <boost/graph/kruskal_min_spanning_tree.hpp>
5  #include <boost/graph/dijkstra_shortest_paths.hpp>
6  using namespace std;
7  using namespace boost;
8
9  // create internal properties
10 typedef property<vertex_index_t, int> IndexProperty;
11 typedef property<edge_weight_t, int> WeightProperty;
12
13 // adjacency list with properties
14 typedef adjacency_list<vecS, vecS, undirectedS, no_property, WeightProperty, IndexProperty> Graph;
15
16 // Vertex and edge type
17 typedef graph_traits<Graph>::vertex_descriptor Vertex;
18 typedef graph_traits<Graph>::edge_descriptor Edge;
19 typedef graph_traits<Graph>::edge_iterator EdgeIterator;
20
21 // Property maps for accessing the properties
22 typedef property_map<Graph, edge_weight_t>::type WeightMap;
23 typedef property_map<Graph, vertex_index_t>::type IndexMap;
24
25 int main() {
26     ios_base::sync_with_stdio(false);
27     int t; cin >> t;
28
29     for(int i = 0; i < t; i++) {
30         int m, n; cin >> n >> m;
31
32         Graph G(n);
33         WeightMap weightMap = get(edge_weight, G);
34
35         for(int j = 0; j < m; j++) {
36             int v1, v2, w;
37             cin >> v1 >> v2 >> w;
38             Edge e;
39             tie(e, tuples::ignore) = add_edge(v1, v2, G);
40             weightMap[e] = w;
41         }
42
43         vector<Edge> spanningTree;
44         kruskal_minimum_spanning_tree(G, back_inserter(spanningTree));
45         int sumOfWeights = 0;
46
47         Graph mstGraph(n);
48         WeightMap mstWeightMap = get(edge_weight, mstGraph);
49         for (vector<Edge>::iterator ei = spanningTree.begin(); ei != spanningTree.end(); ++ei) {
50             sumOfWeights += weightMap[*ei];
51         }
52
53         vector<int> distances(n);
54         vector<Vertex> p_map(num_vertices(G));
55
56         Vertex startVertex = vertex(0, G);
57         dijkstra_shortest_paths(G, startVertex, predecessor_map(&p_map[0]).distance_map(&distances[0]));
58
59         int longestDistance = 0;
60         for(int k = 0; k < n; k++) {
61             int distance = distances[k];
62
63             if(distance > longestDistance) {
64                 longestDistance = distance;
65             }
66         }
67
68         cout << sumOfWeights << "\n" << longestDistance << endl;
69
70         /* Playing around with backtracking shortest path.
71         IndexMap index;
72         int target = 3;
73         while(target != p_map[index[vertex(target, G)]]) {
74             cout << target << "- " << p_map[index[vertex(target, G)]] << "\n";
```

```
75         target = p_map[index[vertex(target, G)]];
76     }
77     */
78 }
79 }
```

Deleted Entries

```
1  #include <vector>
2  #include <iostream>
3  #include <queue>
4  #include <algorithm>
5  using namespace std;
6
7  typedef vector<int> vi;
8  typedef vector<vi> vii;
9
10 int k;
11
12 void testcase() {
13     int n, m, k;
14     cin >> n >> m >> k;
15
16     vii adj(n);
17     vii groups(k);
18     vi col(n, -1);
19
20     for(int e = 0; e < m; ++e) {
21         int v1, v2; cin >> v1 >> v2;
22         adj[v1].push_back(v2);
23         adj[v2].push_back(v1);
24     }
25
26     queue<int> q; // lifo
27     int c = 0;
28     q.push(0);
29     col[0] = c;
30     groups[c].push_back(0);
31
32     while(!q.empty()) {
33         const int v = q.front(); q.pop();
34         for(int child = 0; child < adj[v].size(); ++child) {
35             const int u = adj[v][child];
36             if(col[u] != -1) continue;
37
38             c = (c == k-1) ? 0 : ++c;
39             if(col[v] == c) { c = (c == k-1) ? 0 : ++c; }
40             col[u] = c;
41             groups[c].push_back(u);
42             q.push(u);
43         }
44     }
45
46     if(n >= k && find(col.begin(), col.end(), -1) == col.end()) {
47         cout << "yes\n";
48         for(int g = 0; g < k; ++g) {
49             cout << groups[g].size();
50             for(int i = 0; i < groups[g].size(); ++i) {
51                 cout << " " << groups[g][i];
52             }
53             cout << "\n";
54         }
55     } else {
56         cout << "no\n";
57     }
58     col.clear();
59     adj.clear();
60     groups.clear();
61 }
62
63 int main() {
64     int TC; cin >> TC;
65     while(TC--) testcase();
66 }
```

Shy Programmers

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/boyer_myrvold_planar_test.hpp>
5  using namespace std;
6  using namespace boost;
7
8  typedef adjacency_list<vecS, vecS, undirectedS, no_property, no_property> Graph;
9
10 void testcase() {
11     int N, M; cin >> N >> M;
12     Graph g(N+1);
13     vector<int> processed(N, 0);
14     for(int m = 0; m < M; ++m) {
15         int a, b; cin >> a >> b;
16         add_edge(a, b, g);
17         if(!processed[a]) { add_edge(a, N+1, g); processed[a] = 1; }
18         if(!processed[b]) { add_edge(b, N+1, g); processed[b] = 1; }
19     }
20
21     if(boyer_myrvold_planarity_test(g))
22         cout << "yes\n";
23     else
24         cout << "no\n";
25 }
26
27 int main() {
28     int TC; cin >> TC;
29     while(TC--) testcase();
30     return 0;
31 }
```

Algocoon Group

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/tuple/tuple.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/graph/push_relabel_max_flow.hpp>
6  using namespace std;
7  using namespace boost;
8
9  typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
10 typedef adjacency_list<vecS, vecS, directedS, no_property,
11     property<edge_capacity_t, long,
12     property<edge_residual_capacity_t, long,
13     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
14 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
15 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
16 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
17 typedef graph_traits<Graph>::edge_descriptor Edge;
18 typedef graph_traits<Graph>::out_edge_iterator OutEdgeIterator;
19 Graph g;
20 EdgeCapacityMap capacity = get(edge_capacity, g);
21 ReverseEdgeMap reverseMap = get(edge_reverse, g);
22 ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
23
24 void add_edge(int from, int to, int cap, Graph& g) {
25     Edge there, back;
26     tie(there, tuples::ignore) = add_edge(from, to, g);
27     tie(back, tuples::ignore) = add_edge(to, from, g);
28     capacity[there] = cap;
29     capacity[back] = 0;
30     reverseMap[there] = back;
31     reverseMap[back] = there;
32 }
33
34 void testcase() {
35     int N, M; cin >> N >> M;
36     g = Graph(N);
37
38     for(int m = 0; m < M; ++m) {
39         int v1, v2, cost; cin >> v1 >> v2 >> cost;
40         add_edge(v1, v2, cost, g);
41     }
42
43     int max_flow = INT_MAX;
44     int source = -1;
45     int sink = -1;
46
47     for(int n = 1; n < N; ++n) {
48         int f1 = push_relabel_max_flow(g, 0, n);
49         if(f1 < max_flow) {
50             source = 0;
51             sink = n;
52             max_flow = f1;
53         }
54         int f2 = push_relabel_max_flow(g, n, 0);
55         if(f2 < max_flow) {
56             source = n;
57             sink = 0;
58             max_flow = f2;
59         }
60     }
61
62     int f = push_relabel_max_flow(g, source, sink);
63     vector<int> result;
64     vector<int> visited(N, 0);
65     visited[source] = 1;
66     queue<int> Q;
67     Q.push(source);
68     while(!Q.empty()) {
69         int v = Q.front(); Q.pop();
70         result.push_back(v);
71         OutEdgeIterator ebegin, eend;
72         for(tie(ebegin, eend) = out_edges(v, g); ebegin != eend; ++ebegin) {
73             if(res_capacity[*ebegin] != 0 && visited[target(*ebegin, g)] == 0) {
74                 Q.push(target(*ebegin, g));
```

```

75         visited[target(*ebegin, g)] = 1;
76     }
77 }
78 }
79
80 cout << f << "\n";
81 cout << result.size() << "\n";
82 for(int r = 0; r < result.size(); ++r)
83     cout << result[r] << "\n";
84 cout << "\n";
85 }
86
87 int main() {
88     int TC; cin >> TC;
89     while (TC--) testcase();
90 }

```

Buddies

```
1  #include <iostream>
2  #include <vector>
3  #include <map>
4  #include <set>
5  #include <string>
6  #include <boost/graph/adjacency_list.hpp>
7  #include <boost/graph/max_cardinality_matching.hpp>
8  using namespace std;
9  using namespace boost;
10
11 typedef adjacency_list<vecS, vecS, undirectedS, no_property, no_property> Graph;
12 typedef graph_traits<Graph>::vertex_descriptor Vertex;
13
14 void testcase() {
15     int N, C, F; cin >> N >> C >> F;
16     int counter = 0;
17     map<string, int> stringMap;
18     vector<set<int>> chars(N);
19     for(int i = 0; i < N; ++i) {
20         for(int c = 0; c < C; ++c) {
21             string input; cin >> input;
22             if(stringMap.count(input) == 0) stringMap[input] = counter++;
23             chars[i].insert(stringMap[input]);
24         }
25     }
26
27     Graph g(N);
28     for(int i = 0; i < N; ++i) {
29         for(int j = i+1; j < N; ++j) {
30             int matchings = 0;
31             for(set<int>::iterator it = chars[i].begin(); it != chars[i].end(); ++it) {
32                 if(chars[j].count(*it) == 1) {
33                     ++matchings;
34                     if(matchings > F) {
35                         add_edge(i, j, g);
36                         break; // could be the culprit.
37                     }
38                 }
39             }
40         }
41     }
42
43     vector<Vertex> mateMap(N, 0);
44     checked_edmonds_maximum_cardinality_matching(g, &mateMap[0]);
45     int matched = matching_size(g, &mateMap[0]);
46     if(matched*2 == N) cout << "not_optimal\n";
47     else cout << "optimal\n";
48 }
49
50 int main() {
51     int TC; cin >> TC;
52     while(TC--) testcase();
53     return 0;
54 }
```


Satellites

```
1 #include <iostream>
2 #include <vector>
3 #include <stack>
4 #include <boost/graph/adjacency_list.hpp>
5 #include <boost/graph/max_cardinality_matching.hpp>
6 using namespace std;
7 using namespace boost;
8
9 typedef adjacency_list<vecS, vecS, undirectedS, no_property, no_property> Graph;
10 typedef graph_traits<Graph>::vertex_descriptor Vertex;
11 typedef graph_traits<Graph>::out_edge_iterator OEI;
12
13 void testcase() {
14     int G, S, L; cin >> G >> S >> L;
15
16     Graph g(G+S);
17     for(int l = 0; l < L; ++l) {
18         int u, v; cin >> u >> v;
19         add_edge(u, G+v, g);
20     }
21
22     vector<Vertex> mateMap(G+S, 0);
23     checked_edmonds_maximum_cardinality_matching(g, &mateMap[0]);
24     matching_size(g, &mateMap[0]);
25
26     stack<int> fifo;
27     vector<int> visited(G+S, 0);
28     for(int v = 0; v < G; ++v) {
29         if(mateMap[v] == graph_traits<Graph>::null_vertex()) {
30             visited[v] = 1;
31             fifo.push(v);
32         }
33     }
34
35     while(!fifo.empty()) {
36         int u = fifo.top(); fifo.pop();
37         OEI ebegin, eend;
38         for(tie(ebegin, eend) = out_edges(u, g); ebegin != eend; ++ebegin) {
39             int v = boost::target(*ebegin, g);
40             if(visited[v] == 1) continue;
41             if(u < G) {
42                 if(mateMap[u] != v) {
43                     visited[v] = 1;
44                     fifo.push(v);
45                 }
46             } else {
47                 if(mateMap[u] == v) {
48                     visited[v] = 1;
49                     fifo.push(v);
50                 }
51             }
52         }
53     }
54
55     vector<int> sat;
56     vector<int> ground;
57     for(int v = 0; v < G; ++v)
58         if(visited[v] == 0) ground.push_back(v);
59     for(int v = G; v < G+S; ++v)
60         if(visited[v] == 1) sat.push_back(v);
61
62     cout << ground.size() << "\n" << sat.size() << "\n";
63     for(int i = 0; i < ground.size(); ++i) cout << ground[i] << "\n";
64     for(int i = 0; i < sat.size(); ++i) cout << sat[i]-G << "\n";
65     cout << "\n";
66 }
67
68 int main() {
69     int TC; cin >> TC;
70     while (TC--> 0) testcase();
71     return 0;
72 }
```

Kingdom Defense

```
1 #include <iostream>
2 #include <vector>
3 #include <boost/tuple/tuple.hpp>
4 #include <boost/graph/adjacency_list.hpp>
5 #include <boost/graph/push_relabel_max_flow.hpp>
6 using namespace std;
7 using namespace boost;
8
9 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
10 typedef adjacency_list<vecS, vecS, directedS, no_property,
11     property<edge_capacity_t, long,
12     property<edge_residual_capacity_t, long,
13     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
14 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
15 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
16 typedef graph_traits<Graph>::edge_descriptor Edge;
17
18 void add_edge(int f, int t, int cap, Graph& g) {
19     EdgeCapacityMap capacity = get(edge_capacity, g);
20     ReverseEdgeMap rev_edge = get(edge_reverse, g);
21
22     Edge edge;
23     tie(edge, tuples::ignore) = add_edge(f, t, g);
24     Edge reverse_edge;
25     tie(reverse_edge, tuples::ignore) = add_edge(t, f, g);
26     capacity[edge] = cap;
27     rev_edge[edge] = reverse_edge;
28     capacity[reverse_edge] = 0;
29     rev_edge[reverse_edge] = edge;
30 }
31
32 void testcase() {
33     int V, E; cin >> V >> E;
34     Graph g(V+2);
35     int source = V;
36     int sink = V+1;
37
38     vector<int> vertices;
39     for(int v = 0; v < V; ++v) {
40         int g, d; cin >> g >> d;
41         vertices.push_back(d - g);
42     }
43
44     for(int e = 0; e < E; ++e) {
45         int f, t, lb, ub; cin >> f >> t >> lb >> ub;
46         add_edge(f, t, ub-lb, g);
47         vertices[f] += lb;
48         vertices[t] -= lb;
49     }
50
51     int flow_out = 0;
52     bool all_pos = true;
53     for(int v = 0; v < V; ++v) {
54         if(vertices[v] < 0) {
55             add_edge(source, v, abs(vertices[v]), g);
56         } else if(vertices[v] > 0) {
57             all_pos = false;
58             add_edge(v, sink, vertices[v], g);
59             flow_out += abs(vertices[v]);
60         }
61     }
62
63     int max_flow = push_relabel_max_flow(g, source, sink);
64     (max_flow == flow_out || all_pos) ? cout << "yes\n" : cout << "no\n";
65 }
66
67 int main() {
68     int TC; cin >> TC;
69     while(TC--) testcase();
70 }
```

Coin Tossing

```
1 #include <iostream>
2 #include <boost/graph/adjacency_list.hpp>
3 #include <boost/graph/push_relabel_max_flow.hpp>
4 #include <boost/tuple/tuple.hpp>
5 using namespace std;
6 using namespace boost;
7
8 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
9 typedef adjacency_list<vecS, vecS, directedS, no_property,
10     property<edge_capacity_t, long,
11     property<edge_residual_capacity_t, long,
12     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
13 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
14 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
15 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
16 typedef graph_traits<Graph>::edge_descriptor Edge;
17
18 void add_edge(int from, int to, int c, Graph& g) {
19     EdgeCapacityMap capacity = get(edge_capacity, g);
20     ReverseEdgeMap reverse = get(edge_reverse, g);
21     ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
22
23     Edge there, back;
24     tie(there, tuples::ignore) = add_edge(from, to, g);
25     tie(back, tuples::ignore) = add_edge(to, from, g);
26     capacity[there] = c;
27     capacity[back] = 0;
28     reverse[there] = back;
29     reverse[back] = there;
30 }
31
32 void testcase() {
33     int N, M; cin >> N >> M;
34     Graph g(N+M+2);
35     int source = N+M+1;
36     int sink = source + 1;
37
38     for(int m = N; m < N+M; ++m) {
39         int p1, p2, outcome;
40         cin >> p1 >> p2 >> outcome;
41         add_edge(source, m, 1, g);
42
43         if(outcome == 1) {
44             add_edge(m, p1, 1, g);
45         }
46         if(outcome == 2) {
47             add_edge(m, p2, 1, g);
48         }
49         if(outcome == 0) {
50             add_edge(m, p1, 1, g);
51             add_edge(m, p2, 1, g);
52         }
53     }
54
55     int sum = 0;
56     for(int p = 0; p < N; ++p) {
57         int score; cin >> score;
58         sum += score;
59         add_edge(p, sink, score, g);
60     }
61
62     int f_max = push_relabel_max_flow(g, source, sink);
63     if(M == sum && f_max == sum) cout << "yes\n";
64     else cout << "no\n";
65 }
66
67 int main() {
68     int TC; cin >> TC;
69     while(TC--) testcase();
70 }
```

Antenna

```
1 #include <iostream>
2 #include <vector>
3 #include <cmath>
4 #include <CGAL/Exact_predicates_exact_constructions_kernel_with_sqrt.h>
5 #include <CGAL/Min_circle_2.h>
6 #include <CGAL/Min_circle_2_traits_2.h>
7 using namespace std;
8
9 typedef CGAL::Exact_predicates_exact_constructions_kernel_with_sqrt K;
10 typedef CGAL::Min_circle_2_traits_2<K> Traits;
11 typedef CGAL::Min_circle_2<Traits> Min_circle;
12
13 double ceil_to_double(const K::FT& x)
14 {
15     double a = ceil(CGAL::to_double(x));
16     while (a < x) a += 1;
17     while (a-1 >= x) a -= 1;
18     return a;
19 }
20
21 void testcase(int n) {
22     vector<K::Point_2> citizens;
23     for(int coord = 0; coord < n; ++coord) {
24         double x, y; cin >> x >> y;
25         K::Point_2 citizen(x, y);
26         citizens.push_back(citizen);
27     }
28
29     Min_circle mc(citizens.begin(), citizens.end(), true); // true important for speed.
30     Traits::Circle c = mc.circle();
31     K::FT radius = sqrt(c.squared_radius());
32
33     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0); // scientific notation will be used ↯
34         ↵ otherwise!
35     cout << ceil_to_double(radius) << "\n";
36 }
37
38 int main() {
39     while(true) {
40         int n; cin >> n;
41         if(n == 0) return 0;
42         testcase(n);
43     }
44     return 0;
45 }
```

Almost Antenna

```
1 #include <iostream>
2 #include <vector>
3 #include <CGAL/Exact_predicates_exact_constructions_kernel_with_sqrt.h>
4 #include <CGAL/Min_circle_2.h>
5 #include <CGAL/Min_circle_2_traits_2.h>
6 using namespace std;
7
8 typedef CGAL::Exact_predicates_exact_constructions_kernel_with_sqrt K;
9 typedef CGAL::Min_circle_2_traits_2<K> Traits;
10 typedef CGAL::Min_circle_2<Traits> Min_circle;
11
12 double ceil_to_double(const K::FT& x) {
13     double a = ceil(CGAL::to_double(x));
14     while (a < x) a += 1;
15     while (a-1 >= x) a -= 1;
16     return a;
17 }
18
19 void testcase(int N) {
20     vector<K::Point_2> points;
21     for(int n = 0; n < N; ++n) {
22         double x, y; cin >> x >> y;
23         points.push_back(K::Point_2(x, y));
24     }
25     Min_circle mc(points.begin(), points.end(), true);
26
27     K::FT min_rad; bool min_set = false;
28     for(Min_circle::Support_point_iterator it = mc.support_points_begin(); it != mc.support_points_end(); ++it) {
29         vector<K::Point_2>::iterator sp = find(points.begin(), points.end(), *it);
30         iter_swap(sp, points.begin());
31         Min_circle mc2(points.begin()+1, points.end(), true);
32         Traits::Circle c = mc2.circle();
33         K::FT radius = c.squared_radius();
34         if(radius < min_rad || !min_set) {
35             min_rad = radius;
36             min_set = true;
37         }
38     }
39
40     cout << ceil_to_double(CGAL::sqrt(min_rad)) << "\n";
41 }
42
43 int main() {
44     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
45     while(true) {
46         int N; cin >> N;
47         if(N == 0) return 0;
48         testcase(N);
49     }
50 }
```

Hit

```
1 #include <iostream>
2 #include <vector>
3 #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
4 using namespace std;
5
6 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
7
8 void testcase(int n) {
9     double x1, y1, x2, y2;
10    cin >> x1 >> y1 >> x2 >> y2;
11    K::Point_2 p1(x1, y1);
12    K::Point_2 p2(x2, y2);
13    K::Ray_2 ray(p1, p2);
14
15    vector<K::Segment_2> obstacles;
16    for(int o = 0; o < n; ++o) {
17        double r, s, t, u;
18        cin >> r >> s >> t >> u;
19        K::Point_2 p1(r, s);
20        K::Point_2 p2(t, u);
21        K::Segment_2 obstacle(p1, p2);
22        obstacles.push_back(obstacle);
23    }
24
25    bool intersect = false;
26    for(int obstacle = 0; obstacle < obstacles.size(); ++obstacle) {
27        if(CGAL::do_intersect(obstacles[obstacle], ray)) {
28            intersect = true;
29            break;
30        }
31    }
32
33    (intersect) ? cout << "yes\n" : cout << "no\n";
34 }
35
36 int main() {
37     while(true) {
38         int n; cin >> n;
39         if(n == 0) return 0;
40         testcase(n);
41     }
42 }
```

First Hit

```
1 #include <iostream>
2 #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
3 #include <CGAL/enum.h>
4 #include <climits>
5 using namespace std;
6
7 typedef CGAL::Exact_predicates_exact_constructions_kernel K;
8
9 double floor_to_double(const K::FT& x) {
10     double a = std::floor(CGAL::to_double(x));
11     while (a > x) a -= 1;
12     while (a+1 <= x) a += 1;
13     return a;
14 }
15
16 void testcase(int n) {
17     K::Ray_2 ray;
18     double x1, y1, x2, y2; cin >> ray;
19
20     bool min_exists = false;
21     K::FT current_dist;
22     K::Point_2 current_point;
23
24     for(size_t o = 0; o < n; ++o) {
25         double r, s, t, u; cin >> r >> s >> t >> u;
26         K::Point_2 p1(r, s);
27         K::Point_2 p2(t, u);
28         K::Segment_2 obstacle (p1, p2);
29
30         if(CGAL::do_intersect(ray, obstacle)) {
31             K::Point_2 intersection_point;
32             CGAL::Object o = CGAL::intersection(ray, obstacle);
33             if(const K::Point_2* p = CGAL::object_cast<K::Point_2>(&o))
34                 intersection_point = *p;
35             else if (const K::Segment_2* s = CGAL::object_cast<K::Segment_2>(&o))
36                 intersection_point =
37                     CGAL::has_smaller_distance_to_point(ray.source(), s->source(), s->target()) ?
38                     s->source() : s->target();
39             else throw runtime_error("strange segment intersection");
40             K::FT intersection_dist = CGAL::squared_distance(intersection_point, ray.source());
41             if(!min_exists || current_dist > intersection_dist) {
42                 current_dist = intersection_dist;
43                 current_point = intersection_point;
44                 min_exists = true;
45             }
46         }
47     }
48
49     if(min_exists) cout << floor_to_double(current_point.x()) << " " << floor_to_double(current_point.y()) << "\n";
50     else cout << "no\n";
51 }
52
53 int main() {
54     cin.sync_with_stdio(false);
55     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
56     while(true) {
57         int n; cin >> n;
58         if(n == 0) return 0;
59         testcase(n);
60     }
61 }
```

Search Snippets

```
1  #include <iostream>
2  #include <vector>
3  #include <queue>
4  #include <climits>
5  using namespace std;
6
7  typedef vector<int> vi;
8  typedef vector<vi> vii;
9
10 void testcase() {
11     int N; cin >> N;
12     vi count;
13     for(int n = 0; n < N; ++n) {
14         int m; cin >> m;
15         count.push_back(m);
16     }
17
18     vii lists(N);
19     for(int n = 0; n < N; ++n) {
20         for(int m = 0; m < count[n]; ++m) {
21             int p; cin >> p;
22             lists[n].push_back(p);
23         }
24     }
25
26     priority_queue<pair<int, pair<int, int> > > max_heap;
27     priority_queue<pair<int, pair<int, int> >, vector<pair<int, pair<int, int> > >, greater<pair<int, pair<int, int> > > min_heap;
28     for(int n = 0; n < N; ++n) {
29         max_heap.push(make_pair(lists[n][0], make_pair(n, 0)));
30         min_heap.push(make_pair(lists[n][0], make_pair(n, 0)));
31     }
32
33     int min_interval = INT_MAX;
34     while(true) {
35         pair<int, pair<int, int> > a = min_heap.top();
36         pair<int, pair<int, int> > b = max_heap.top();
37         int interval = b.first - a.first + 1;
38
39         min_interval = min(interval, min_interval);
40         int min_list = a.second.first;
41         int element = a.second.second;
42
43         if(element+1 < lists[min_list].size()) {
44             max_heap.push(make_pair(lists[min_list][element+1], make_pair(min_list, element+1)));
45             min_heap.pop();
46             min_heap.push(make_pair(lists[min_list][element+1], make_pair(min_list, element+1)));
47         } else {
48             break;
49         }
50     }
51
52     cout << min_interval << "\n";
53 }
54
55 int main() {
56     int TC; cin >> TC;
57     while (TC--> testcase());
58     return 0;
59 }
```


Bistro

```
1  #include <vector>
2  #include <iostream>
3  #include <cmath>
4  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
5  #include <CGAL/Delaunay_triangulation_2.h>
6  using namespace std;
7
8  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
9  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
10 typedef Triangulation::Finite_faces_iterator faces_iterator;
11
12 double floor_to_double(const K::FT& x)
13 {
14     double a = std::floor(CGAL::to_double(x));
15     while (a > x) a -= 1;
16     while (a+1 <= x) a += 1;
17     return a;
18 }
19
20 void testcase(int n) {
21     vector<K::Point_2> delaunay_vertices;
22     for(int i = 0; i < n; ++i) {
23         K::Point_2 p; cin >> p;
24         delaunay_vertices.push_back(p);
25     }
26
27     Triangulation t;
28     t.insert(delaunay_vertices.begin(), delaunay_vertices.end());
29
30     int points; cin >> points;
31     for(int i = 0; i < points; ++i) {
32         K::Point_2 p; cin >> p;
33         Triangulation::Vertex_handle v = t.nearest_vertex(p);
34         K::Point_2 vp = v->point();
35         K::FT distance = CGAL::squared_distance(p, vp);
36         cout << floor_to_double(distance) << "\n";
37     }
38 }
39
40 int main() {
41     cin.sync_with_stdio(false);
42     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
43     while(true) {
44         int n; cin >> n;
45         if(n == 0) return 0;
46         testcase(n);
47     }
48     return 0;
49 }
```

Germes

```
1  #include <iostream>
2  #include <vector>
3  #include <set>
4  #include <cmath>
5  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
6  #include <CGAL/Delaunay_triangulation_2.h>
7  using namespace std;
8
9  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
10 typedef CGAL::Delaunay_triangulation_2<K> Delaunay;
11 typedef Delaunay::Finite_edges_iterator FEI;
12 typedef Delaunay::Finite_vertices_iterator FVI;
13
14 void testcase(int N) {
15     vector<K::Segment_2> rect;
16     int x1, y1, x2, y2;
17     cin >> x1 >> y1 >> x2 >> y2;
18     rect.push_back(K::Segment_2(K::Point_2(x1, y1), K::Point_2(x1, y2)));
19     rect.push_back(K::Segment_2(K::Point_2(x1, y2), K::Point_2(x2, y2)));
20     rect.push_back(K::Segment_2(K::Point_2(x2, y2), K::Point_2(x2, y1)));
21     rect.push_back(K::Segment_2(K::Point_2(x2, y1), K::Point_2(x1, y1)));
22
23     vector<K::Point_2> points;
24     for(int n = 0; n < N; ++n) {
25         int x, y; cin >> x >> y;
26         points.push_back(K::Point_2(x, y));
27     }
28
29     vector<pair<K::FT, pair<Delaunay::Vertex_handle, Delaunay::Vertex_handle> > > lines;
30     Delaunay t;
31     t.insert(points.begin(), points.end());
32     for(FEI edge = t.finite_edges_begin(); edge != t.finite_edges_end(); ++edge) {
33         Delaunay::Vertex_handle v1 = edge->first->vertex((edge->second + 1) % 3);
34         Delaunay::Vertex_handle v2 = edge->first->vertex((edge->second + 2) % 3);
35         K::Segment_2 seg = t.segment(edge);
36         K::FT length = CGAL::sqrt(seg.squared_length());
37         lines.push_back(make_pair(length, make_pair(v1, v2)));
38     }
39
40     for(FVI v = t.finite_vertices_begin(); v != t.finite_vertices_end(); ++v) {
41         Delaunay::Vertex_handle vertex = v;
42         K::FT min_dist; bool min_set = false;
43         for(int i = 0; i < 4; ++i) {
44             K::FT dist = CGAL::squared_distance(rect[i], v->point());
45             if(dist < min_dist || !min_set) { min_dist = dist; min_set = true; }
46         }
47         lines.push_back(make_pair(CGAL::sqrt(min_dist)*2, make_pair(vertex, vertex)));
48     }
49     sort(lines.begin(), lines.end());
50
51     int dead = 0;
52     int time = 0;
53     int pointer = 0;
54     bool not_printed = true;
55     set<Delaunay::Vertex_handle> bact;
56     while(dead < N) {
57         K::FT length_t = 2 * (pow(time, 2.0) + 0.5);
58         while(lines[pointer].first <= length_t) {
59             if(dead == 0) cout << time << "┐";
60
61             pair<Delaunay::Vertex_handle, Delaunay::Vertex_handle> p = lines[pointer].second;
62             if(p.first == p.second) bact.insert(p.first);
63             else { bact.insert(p.first); bact.insert(p.second); }
64             dead = bact.size();
65
66             if(dead / (double) N > 0.5 && not_printed) { cout << time << "┐"; not_printed = false; }
67             if(dead == N) { cout << time << "\n"; break; }
68
69             if(pointer+1 == lines.size()) break;
70             else ++pointer;
71         }
72         ++time;
73     }
74 }
```

```
75  
76 int main() {  
77     while(true){  
78         int N; cin >> N;  
79         if(N == 0) return 0;  
80         testcase(N);  
81     }  
82 }
```

Graypes

```
1 #include <vector>
2 #include <iostream>
3 #include <CGAL/Exact_predicates_inexact_constructions_kernel.h> // use inexact because Input points == output ↗
4     ↘ points.
5 #include <CGAL/Delaunay_triangulation_2.h>
6 using namespace std;
7
8 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
9 typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
10 typedef Triangulation::Finite_edges_iterator FEI;
11
12 double ceil_to_double(const K::FT& x)
13 {
14     double a = ceil(CGAL::to_double(x));
15     while (a < x) a += 1;
16     while (a-1 >= x) a -= 1;
17     return a;
18 }
19
20 void testcase(int n) {
21     vector<K::Point_2> points;
22     for(int i = 0; i < n; ++i) {
23         K::Point_2 p; cin >> p;
24         points.push_back(p);
25     }
26
27     Triangulation t;
28     t.insert(points.begin(), points.end());
29     K::FT min_length;
30     bool min_set = false;
31     for (FEI e = t.finite_edges_begin(); e != t.finite_edges_end(); e++) {
32         // REMEMBER bad idea: K::Segment_2 seg = t.segment(edge); seg.squared_length().
33         Triangulation::Vertex_handle v1 = e->first->vertex((e->second + 1) % 3);
34         Triangulation::Vertex_handle v2 = e->first->vertex((e->second + 2) % 3);
35
36         K::FT length = CGAL::squared_distance(v1->point(), v2->point());
37         if(!min_set || min_length > length) {
38             min_length = length;
39             min_set = true;
40         }
41     }
42
43     double seconds = ceil_to_double(CGAL::sqrt(min_length)*50);
44     cout << seconds << "\n";
45 }
46
47 int main() {
48     cin.sync_with_stdio(false);
49     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
50     while(true) {
51         int n; cin >> n;
52         if(n == 0) return 0;
53         testcase(n);
54     }
```

H1N1

```
1 #include <iostream>
2 #include <vector>
3 #include <queue>
4 #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
5 #include <CGAL/Delaunay_triangulation_2.h>
6 using namespace std;
7
8 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
9 typedef CGAL::Delaunay_triangulation_2<K> Delaunay;
10 typedef Delaunay::All_faces_iterator AFI;
11 typedef map<Delaunay::Face_handle, int> StateMap;
12
13 int testcase(int N) {
14     vector<K::Point_2> points;
15     for(int n = 0; n < N; ++n) {
16         double x, y; cin >> x >> y;
17         points.push_back(K::Point_2(x, y));
18     }
19
20     int M; cin >> M;
21     vector<pair<K::Point_2, double> > people;
22     for(int m = 0; m < M; ++m) {
23         double x, y, d; cin >> x >> y >> d;
24         people.push_back(make_pair(K::Point_2(x, y), d));
25     }
26
27     StateMap state;
28     Delaunay t;
29     t.insert(points.begin(), points.end());
30
31     for(int p = 0; p < M; ++p) {
32         K::Point_2 coord = people[p].first;
33         K::FT d = people[p].second;
34
35         if(CGAL::squared_distance(coord, t.nearest_vertex(coord)->point()) < d) {
36             cout << "n";
37             continue;
38         }
39
40         Delaunay::Face_handle start_face = t.locate(coord);
41         if(t.is_infinite(start_face)) {
42             cout << "y";
43             continue;
44         }
45
46         bool stop = false;
47         queue<Delaunay::Face_handle> fifo;
48         fifo.push(start_face);
49         int bfs_id = p+1;
50         state[start_face] = bfs_id;
51         while(!fifo.empty()) {
52             Delaunay::Face_handle f = fifo.front(); fifo.pop();
53             for(int e = 0; e < 3; ++e) {
54                 K::Segment_2 seg = t.segment(f, e);
55                 Delaunay::Face_handle neighbour = f->neighbor(e);
56
57                 if((seg.squared_length() >= 4*d) && state[neighbour] != bfs_id){
58                     if(t.is_infinite(neighbour)) {
59                         cout << "y";
60                         stop = true;
61                         break;
62                     }
63                     fifo.push(neighbour);
64                     state[neighbour] = bfs_id;
65                 }
66             }
67             if(stop) break;
68         }
69         if(!stop) cout << "n";
70     }
71     cout << "\n";
72 }
73
74
```

```
75 | int main() {  
76 |     while(true) {  
77 |         int N; cin >> N;  
78 |         if(N == 0) return 0;  
79 |         testcase(N);  
80 |     }  
81 | }
```

HikingMaps

```
1  #include <iostream>
2  #include <vector>
3  #include <queue>
4  #include <climits>
5  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
6  #include <CGAL/ch_jarvis.h>
7  using namespace std;
8
9  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;          // does not pass last TC with exact ↗
10     ↘ constructions.
11  typedef vector<int> vi;
12  typedef vector<vi> vii;
13
14  void testcase() {
15     int M, N; cin >> M >> N; // M-1 legs, N maps.
16
17     vector<pair<K::Point_2, K::Point_2> > legs;          // using a vector a segment, prevents from passing the 4th ↗
18     ↘ TC.
19     K::Point_2 prev;
20     cin >> prev;
21     for(int m = 1; m < M; ++m) {
22         int x, y; cin >> x >> y;
23         K::Point_2 now(x, y);
24         legs.push_back(make_pair(prev, now));
25         prev = now;
26     }
27
28     vii lists(M-1); // storing "leg contained by map" data.
29     for(int n = 0; n < N; ++n) {
30         vector<K::Point_2> points(6);
31         for(int i = 0; i < 6; ++i)
32             cin >> points[i];
33
34         vector<K::Point_2> ccw; // store the given vertices in counter-clockwise fashion.
35         CGAL::ch_jarvis_march(points.begin(), points.end(), points[0], points[0], back_inserter(ccw));
36         if(points[1] != ccw[1]) { // ugly... making sure two consecutive vertices span a triangle edge.
37             ccw.clear();
38             CGAL::ch_jarvis_march(points.begin(), points.end(), points[1], points[1], back_inserter(ccw));
39         }
40
41         for(int l = 0; l < legs.size(); ++l) { // iterate over each leg.
42             bool isOutside; // is set if to true, if origin or source is to the right to the edges.
43             for(int p = 0; p < ccw.size()-1; p = p+2) {
44                 isOutside = (CGAL::right_turn(ccw[p], ccw[p+1], legs[l].first) ||
45                             CGAL::right_turn(ccw[p], ccw[p+1], legs[l].second)) ? true : false; // if one of the leg ↗
46                 ↘ points outside, then set to yes.
47                 if(isOutside) break;
48             }
49             if(!isOutside) lists[l].push_back(n); // both end points of leg are inside.
50         }
51     }
52
53     vi pointers(M-1, 0);
54     priority_queue<int> max_heap;
55     priority_queue<pair<int, int>, std::vector<pair<int, int> >, greater<pair<int, int> > > min_heap;
56     for(int l = 0; l < lists.size(); ++l) {
57         max_heap.push(lists[l][0]);
58         min_heap.push(make_pair(lists[l][0], 1));
59     }
60
61     int min_interval = INT_MAX;
62     while(true) {
63         pair<int, int> min_pair = min_heap.top(); min_heap.pop();
64         int min_value = min_pair.first;
65         int min_list = min_pair.second;
66
67         int max_value = max_heap.top();
68         int min_new = abs(max_value - min_value);
69         min_interval = min(min_new, min_interval);
70         if(pointers[min_list] == lists[min_list].size()-1) break;
71
72         pointers[min_list]++;
73         int new_value = lists[min_list][pointers[min_list]];
74         max_heap.push(new_value);
75     }
```

```
72     min_heap.push(make_pair(new_value, min_list));
73 }
74
75     cout << min_interval+1 << "\n";
76 }
77
78 int main() {
79     ios_base::sync_with_stdio(false);
80     int TC; cin >> TC;
81     while(TC--) testcase();
82     return 0;
83 }
```


Maximize It!

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  #include <CGAL/Gmpz.h>
7  using namespace std;
8
9  #ifdef CGAL_USE_GMP
10 #include <CGAL/Gmpz.h>
11 typedef CGAL::Gmpz ET;
12 #else
13 #include <CGAL/MP_Float.h>
14 typedef CGAL::MP_Float ET;
15 #endif
16
17 // program and solution types
18 typedef CGAL::Quadratic_program<int> Program;
19 typedef CGAL::Quadratic_program_solution<ET> Solution;
20
21 void program_1(int a, int b) {
22     Program qp (CGAL::SMALLER, true, 0, false, 0);    // use bounds instead of extra constraints.
23     const int X = 0;
24     const int Y = 1;
25
26     // minimize -b*y + a*x^2
27     qp.set_c(Y, -b);
28     qp.set_d(X, X, a*2);
29
30     // x + y <= 4
31     qp.set_a(X, 0, 1);
32     qp.set_a(Y, 0, 1);
33     qp.set_b(0, 4);
34
35     // 4x + 2y <= a*b
36     qp.set_a(X, 1, 4);
37     qp.set_a(Y, 1, 2);
38     qp.set_b(1, a*b);
39
40     // -x + y <= 1
41     qp.set_a(X, 2, -1);
42     qp.set_a(Y, 2, 1);
43     qp.set_b(2, 1);
44
45     Solution s = CGAL::solve_quadratic_program(qp, ET());
46     assert(s.solves_quadratic_program(qp));
47
48     if(s.is_optimal()) {
49         int sign;
50         (s.objective_value() <= 0) ? sign = -1 : sign = 1;
51         cout << floor(to_double(sign*s.objective_value())) << "\n";    // std::ceil?, ceil_to_double fct?
52     } else if(s.is_unbounded())
53         cout << "unbounded\n";
54     else if(s.is_infeasible())
55         cout << "no\n";
56
57 }
58
59 void program_2(int a, int b) {
60     Program qp (CGAL::SMALLER, false, 0, true, 0);
61     const int X = 0;
62     const int Y = 1;
63     const int Z = 2;
64
65     qp.set_l(Z, 0);
66     qp.set_u(Z, false);
67
68     // minimize a*x^2 + b*y + z^4
69     qp.set_d(X, X, 2*a);
70     qp.set_d(Z, Z, 2*1);    // by convention: we multiply value by 2.
71
72     qp.set_c(Y, b);
73
74     qp.set_a(X, 0, 1);
```

```

75     qp.set_a(Y, 0, 1);
76     qp.set_b(0, -4);
77     qp.set_r(0, CGAL::LARGER);
78
79     qp.set_a(X, 1, 4);
80     qp.set_a(Y, 1, 2);
81     qp.set_a(Z, 1, 1);
82     qp.set_b(1, -1*a*b);
83     qp.set_r(1, CGAL::LARGER);
84
85     qp.set_a(X, 2, -1);
86     qp.set_a(Y, 2, 1);
87     qp.set_b(2, -1);
88     qp.set_r(2, CGAL::LARGER);
89
90     qp.set_a(Z, 3, 1);
91     qp.set_b(3, 0);
92     qp.set_r(3, CGAL::LARGER);
93
94     Solution s = CGAL::solve_quadratic_program(qp, ET());
95     assert(s.solves_quadratic_program(qp));
96
97     if(s.is_optimal()) {
98         double result = ceil(CGAL::to_double(s.objective_value()));
99         cout << result << "\n";
100    }
101    else if(s.is_unbounded())
102        cout << "unbounded\n";
103    else if(s.is_infeasible())
104        cout << "no\n";
105 }
106
107 int main() {
108     ios_base::sync_with_stdio(false);
109     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
110     int p, a, b;
111     while(true) {
112         cin >> p;
113         if(p == 0) return 0;
114         cin >> a >> b;
115         if(p == 1) program_1(a, b);
116         if(p == 2) program_2(a, b);
117     }
118 }

```

Collisions

```
1 #include <iostream>
2 #include <vector>
3 #include <set>
4 #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
5 #include <CGAL/Delaunay_triangulation_2.h>
6 #include <CGAL/Triangulation_vertex_base_with_info_2.h>
7 using namespace std;
8
9 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
10 typedef CGAL::Delaunay_triangulation_2<K> D_Triangulation;
11 typedef D_Triangulation::Finite_edges_iterator FEI;
12 typedef set<D_Triangulation::Vertex_handle> vertex_set;
13
14 void testcase() {
15     int n, d; cin >> n >> d;
16
17     vector<K::Point_2> points;
18     for(int i = 0; i < n; ++i) {
19         int x, y; cin >> x >> y;
20         points.push_back(K::Point_2(x, y));
21     }
22
23     D_Triangulation t;
24     t.insert(points.begin(), points.end());
25     vertex_set in_danger;
26     for(FEI e = t.finite_edges_begin(); e != t.finite_edges_end(); ++e) {
27         D_Triangulation::Vertex_handle v1 = e->first->vertex((e->second + 1) % 3);
28         D_Triangulation::Vertex_handle v2 = e->first->vertex((e->second + 2) % 3);
29         K::FT squared_d = CGAL::squared_distance(v1->point(), v2->point());
30         double distance = CGAL::sqrt(squared_d);
31
32         if(distance < d) {
33             in_danger.insert(v1); in_danger.insert(v2);
34         }
35     }
36     cout << in_danger.size() << "\n";
37 }
38
39
40 int main() {
41     int TC; std::cin >> TC;
42     while(TC--) testcase();
43 }
```

Diet

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  using namespace std;
7
8  #ifdef CGAL_USE_GMP
9  #include <CGAL/Gmpz.h>
10 typedef CGAL::Gmpz ET;
11 #else
12 #include <CGAL/MP_Float.h>
13 typedef CGAL::MP_Float ET;
14 #endif
15
16 typedef CGAL::Quadratic_program<int> Program;
17 typedef CGAL::Quadratic_program_solution<ET> Solution;
18
19 // N: nutrients, M: foods
20 void testcase(int N, int M) {
21     Program lp(CGAL::SMALLER, true, 0, false, 0);
22
23     for(int n = 0; n < N; ++n) {
24         int min, max; cin >> min >> max;
25         lp.set_b(n, min);
26         lp.set_r(n, CGAL::LARGER);
27         lp.set_b(N+n, max);
28     }
29
30     for(int m = 0; m < M; ++m) {
31         int p; cin >> p;
32         lp.set_c(m, p);
33
34         for(int n = 0; n < N; ++n) {
35             int amount; cin >> amount;
36             lp.set_a(m, n, amount);
37             lp.set_a(m, N+n, amount);
38         }
39     }
40
41     Solution s = CGAL::solve_linear_program(lp, ET());
42     assert (s.solves_linear_program(lp));
43
44     if(s.is_infeasible())
45         cout << "No such diet.\n";
46     else
47         cout << floor(to_double(s.objective_value())) << "\n";
48 }
49
50 int main() {
51     while(true) {
52         int N, M; cin >> N >> M;
53         if(N == 0 && M == 0) return 0;
54         testcase(N, M);
55     }
56 }
```

Porfolios

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  using namespace std;
7
8  #ifdef CGAL_USE_GMP
9  #include <CGAL/Gmpz.h>
10 typedef CGAL::Gmpz ET;
11 #else
12 #include <CGAL/MP_Float.h>
13 typedef CGAL::MP_Float ET;
14 #endif
15
16 typedef CGAL::Quadratic_program<int> Program;
17 typedef CGAL::Quadratic_program_solution<ET> Solution;
18
19 // N: assets, M: portfolios
20 void testcase(int N, int M) {
21     Program qp(CGAL::SMALLER, true, 0, false, 0);
22
23     for(int n = 0; n < N; ++n) {
24         int c, r; cin >> c >> r;
25         qp.set_a(n, 0, c);
26         qp.set_a(n, 1, r);
27     }
28
29     for(int i = 0; i < N; ++i) {
30         for(int j = 0; j < N; ++j) {
31             int cij; cin >> cij;
32             qp.set_d(i, j, 2*cij);
33         }
34     }
35
36     for(int m = 0; m < M; ++m) {
37         int C, R, V; cin >> C >> R >> V;
38         qp.set_b(0, C);
39         qp.set_b(1, R);
40         qp.set_r(1, CGAL::LARGER);
41
42         Solution s = CGAL::solve_quadratic_program(qp, ET());
43         assert(s.solves_quadratic_program(qp));
44
45         //cout << s;
46
47         if(s.is_optimal() && (to_double(s.objective_value()) <= V)) {
48             cout << "Yes.\n";
49         } else {
50             cout << "No.\n";
51         }
52     }
53 }
54
55 int main() {
56     while(true) {
57         int N, M; cin >> N >> M;
58         if(N == 0 && M == 0) return 0;
59         testcase(N, M);
60     }
61 }
```

Inball

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  using namespace std;
7
8  #ifdef CGAL_USE_GMP
9  #include <CGAL/Gmpz.h>
10 typedef CGAL::Gmpz ET;
11 #else
12 #include <CGAL/MP_Float.h>
13 typedef CGAL::MP_Float ET;
14 #endif
15
16 typedef CGAL::Quadratic_program<int> Program;
17 typedef CGAL::Quadratic_program_solution<ET> Solution;
18
19 int main() {
20     ios_base::sync_with_stdio(false);
21     int n; cin >> n;
22
23     while(n > 0) {
24         int d; cin >> d;
25         Program lp(CGAL::SMALLER, false, 0, false, 0);
26         lp.set_c(d, -1);
27         lp.set_l(d, true, 0);
28
29         for(int i = 0; i < n; ++i) {
30             int l2 = 0;
31             for(int j = 0; j < d; ++j) {
32                 int a; cin >> a;
33                 lp.set_a(j, i, a);
34                 l2 += a*a;
35             }
36             l2 = sqrt(l2);
37             lp.set_a(d, i, l2);
38
39             int b; cin >> b;
40             lp.set_b(i, b);
41         }
42
43         Solution s = CGAL::solve_linear_program(lp, ET());
44         if(s.is_infeasible()) {
45             cout << "none\n";
46         } else if(s.is_unbounded()) {
47             cout << "inf\n";
48         } else {
49             cout << floor(-CGAL::to_double(s.objective_value())) << "\n";
50         }
51
52         cin >> n;
53     }
54 }
```

Monkey Island

```
1  #include <vector>
2  #include <iostream>
3  #include <climits>
4  #include <boost/graph/strong_components.hpp>
5  #include <boost/graph/adjacency_list.hpp>
6  #include <boost/tuple/tuple.hpp>
7  using namespace std;
8  using namespace boost;
9
10 typedef vector<int> vi;
11 typedef adjacency_list<vecS, vecS, directedS, no_property, no_property> Graph;
12 typedef graph_traits<Graph>::edge_descriptor Edge;
13 typedef graph_traits<Graph>::edge_iterator EdgeIterator;
14
15 void testcase() {
16     int N, M; cin >> N >> M;
17
18     Graph g(N);
19     for(int e = 0; e < M; ++e) {
20         int v1, v2;
21         cin >> v1 >> v2;
22         add_edge(v1-1, v2-1, g);
23     }
24
25     vi costs(N);
26     for(int n = 0; n < N; ++n) {
27         int cost; cin >> cost;
28         costs[n] = cost;
29     }
30
31     vector<int> scc(N);
32     int nscc = strong_components(g, &scc[0]);
33
34     vi incoming_comp(nscc, 0);
35     EdgeIterator ebeg, eend;
36     for(tie(ebeg, eend) = edges(g); ebeg != eend; ++ebeg) {
37         int u = source(*ebeg, g);
38         int v = target(*ebeg, g);
39         if(scc[u] != scc[v]) incoming_comp[scc[v]] = 1;
40     }
41
42     int total = 0;
43     for(int comp = 0; comp < nscc; ++comp) {
44         if(incoming_comp[comp] == 1) continue;
45         int min_cost = INT_MAX;
46         for(int v = 0; v < N; ++v) {
47             if(scc[v] == comp) min_cost = min(min_cost, costs[v]);
48         }
49         total += min_cost;
50     }
51
52     cout << total << "\n";
53 }
54
55 int main() {
56     int TC; cin >> TC;
57     while(TC--) testcase();
58     return 0;
59 }
```

Placing Knights

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/tuple/tuple.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/graph/max_cardinality_matching.hpp>
6  using namespace std;
7  using namespace boost;
8
9  typedef vector<int> vi;
10 typedef vector<vi> vii;
11 typedef adjacency_list<vecS, vecS, undirectedS, no_property, no_property> Graph;
12 typedef graph_traits<Graph>::vertex_descriptor Vertex;
13
14 int N;
15
16 int co_to_index(int i, int j) {
17     return i*N + j;
18 }
19
20 void add_valid_edges(int i, int j, vii& holes, Graph& g) {
21     int y = 1;
22     for(int x = -2; x <= 2; x = x + 4) {
23         if(i+y >= 0 && i+y < N && j+x >= 0 && j+x <= N && holes[i+y][j+x] == 1) {
24             add_edge(co_to_index(i, j), co_to_index(i+y, j+x), g);
25         }
26     }
27     y = 2;
28     for(int x = -1; x <= 1; x = x + 2) {
29         if(i+y >= 0 && i+y < N && j+x >= 0 && j+x <= N && holes[i+y][j+x] == 1) {
30             add_edge(co_to_index(i, j), co_to_index(i+y, j+x), g);
31         }
32     }
33 }
34
35 void testcase() {
36     cin >> N;
37     Graph g(N*N);
38     vii holes(N, vi(N));
39     int sum_holes = 0;
40
41     for(int i = 0; i < N; ++i) {
42         for(int j = 0; j < N; ++j) {
43             int hole; cin >> hole;
44             holes[i][j] = hole;
45             if(holes[i][j] == 0) ++sum_holes;
46         }
47     }
48
49     for(int i = 0; i < N-1; ++i) {
50         for(int j = 0; j < N; ++j) {
51             if(holes[i][j] == 1) add_valid_edges(i, j, holes, g);
52         }
53     }
54
55     vector<Vertex> mateMap(num_vertices(g), 0);
56     checked_edmonds_maximum_cardinality_matching(g, &mateMap[0]);
57     // mistake: forgot to subtract the holes.
58     cout << num_vertices(g)- sum_holes - matching_size(g, &mateMap[0]) << "\n";
59 }
60
61 int main() {
62     int TC; cin >> TC;
63     while(TC--) testcase();
64     return 0;
65 }
```


Shopping Trip

```
1 #include <iostream>
2 #include <vector>
3 #include <boost/tuple/tuple.hpp>
4 #include <boost/graph/adjacency_list.hpp>
5 #include <boost/graph/push_relabel_max_flow.hpp>
6 using namespace std;
7 using namespace boost;
8
9 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
10 typedef adjacency_list<vecS, vecS, directedS, no_property,
11     property<edge_capacity_t, long,
12     property<edge_residual_capacity_t, long,
13     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
14 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
15 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
16 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
17 typedef graph_traits<Graph>::edge_descriptor Edge;
18
19 void testcase() {
20     int n, m, s; cin >> n >> m >> s;
21     Graph g(n);
22     EdgeCapacityMap capacity = get(edge_capacity, g);
23     ReverseEdgeMap rev_edge = get(edge_reverse, g);
24     ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
25
26     for(int store = 0; store < s; ++store){
27         int store_vertex; cin >> store_vertex;
28         Edge edge;
29         tie(edge, tuples::ignore) = add_edge(store_vertex, n, g);
30         Edge reverse_edge;
31         tie(reverse_edge, tuples::ignore) = add_edge(n, store_vertex, g);
32         capacity[edge] = 1;
33         rev_edge[edge] = reverse_edge;
34         capacity[reverse_edge] = 0;
35         rev_edge[reverse_edge] = edge;
36     }
37
38     for(int e = 0; e < m; ++e) {
39         int v1, v2; cin >> v1 >> v2;
40         Edge edge;
41         tie(edge, tuples::ignore) = add_edge(v1, v2, g);
42         Edge reverse_edge;
43         tie(reverse_edge, tuples::ignore) = add_edge(v2, v1, g);
44         capacity[edge] = 1;
45         rev_edge[edge] = reverse_edge;
46         capacity[reverse_edge] = 0;
47         rev_edge[reverse_edge] = edge;
48         Edge edge2;
49         tie(edge2, tuples::ignore) = add_edge(v2, v1, g);
50         Edge reverse_edge2;
51         tie(reverse_edge2, tuples::ignore) = add_edge(v1, v2, g);
52         capacity[edge2] = 1;
53         rev_edge[edge2] = reverse_edge2;
54         capacity[reverse_edge2] = 0;
55         rev_edge[reverse_edge2] = edge2;
56     }
57
58     long max_flow = push_relabel_max_flow(g, 0, n);
59     if(max_flow == s) cout << "yes\n"; else cout << "no\n";
60 }
61
62 int main() {
63     int TC; cin >> TC;
64     while(TC--) testcase();
65     return 0;
66 }
```

TheeV

```
1 #include <iostream>
2 #include <vector>
3 #include <climits>
4 #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
5 #include <CGAL/Min_circle_2.h>
6 #include <CGAL/Min_circle_2_traits_2.h>
7 using namespace std;
8
9 typedef CGAL::Exact_predicates_exact_constructions_kernel K;
10 typedef CGAL::Min_circle_2_traits_2<K> Traits;
11 typedef CGAL::Min_circle_2<Traits> Min_circle;
12
13 double ceil_to_double(const K::FT& x) {
14     double a = ceil(CGAL::to_double(x));
15     while (a < x) a += 1;
16     while (a-1 >= x) a -= 1;
17     return a;
18 }
19
20 void testcase() {
21     int N; cin >> N;
22
23     vector<pair<K::FT, K::Point_2> > points;
24     int x1, y1; cin >> x1 >> y1;
25     K::Point_2 t1 = K::Point_2(x1, y1);
26     points.push_back(make_pair(0, t1));
27
28     for(int n = 1; n < N; ++n) {
29         int x, y; cin >> x >> y;
30         K::Point_2 p = K::Point_2(x, y);
31         points.push_back(make_pair(CGAL::squared_distance(t1, p), p));
32     }
33     sort(points.begin(), points.end());
34
35     K::FT r1 = points[N-1].first;
36     K::FT r2 = 0;
37     K::FT s = r1;
38     int i = N-2;
39     Min_circle mc;
40     while(r1 > r2 && i > 0) {
41         r1 = points[i].first;
42         mc.insert(points[i+1].second);
43         Traits::Circle c = mc.circle();
44         r2 = c.squared_radius();
45         --i;
46     }
47
48     if(r1 == r2)
49         s = r1;
50     if(r2 > r1)
51         s = min(points[i+2].first, r2);
52
53     cout << ceil_to_double(s) << "\n";
54 }
55
56 int main() {
57     cin.sync_with_stdio(false);
58     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
59     int TC; cin >> TC;
60     while (TC--) testcase();
61     return 0;
62 }
```

Poker Chips

```
1  #include <iostream>
2  #include <vector>
3  #include <map>
4  #include <cmath>
5  using namespace std;
6
7  typedef vector<int> vi;
8  typedef vector<vi> vii;
9  typedef map<vector<int>, int> vector_int;
10
11 vi M;
12 int N;
13 vector_int dp_table;
14 vii chips;
15
16 int find_max(vi& state) {
17     if(dp_table.count(state) == 1)
18         return dp_table[state];
19
20     for(int n = 1; n < pow(2.0, N); ++n) {
21         vi new_state = state;
22         int T = 0;
23         int prev = -1;
24
25         for(int k = 0; k < N; ++k) {
26             if((n & (1 << k)) && (state[k] != 0)) {
27                 int color = chips[k][state[k]-1];
28                 if(prev == color || prev == -1) {
29                     --new_state[k];
30                     prev = color;
31                     ++T;
32                 } else {
33                     T = 0; // !important to avoids wasted loops and computing invalid states.
34                     break;
35                 }
36             }
37         }
38
39         if(T != 0) { // if T=0, then invalid subset.
40             int K = (T <= 1) ? 0 : pow(2.0, T-2);
41             dp_table[state] = max(find_max(new_state) + K, dp_table[state]);
42         }
43     }
44
45     return dp_table[state];
46 }
47
48 void testcase() {
49     cin >> N;
50     M = vi(N);
51     for(int n = 0; n < N; ++n)
52         cin >> M[n];
53
54     chips = vii(N);
55     for(int n = 0; n < N; ++n) {
56         for(int m = 0; m < M[n]; ++m) {
57             int col; cin >> col;
58             chips[n].push_back(col);
59         }
60     }
61
62     dp_table = vector_int();
63     cout << find_max(M) << "\n";
64 }
65
66 int main() {
67     ios_base::sync_with_stdio(false);
68     int TC; cin >> TC;
69     while(TC--) testcase();
70     return 0;
71 }
```

Portfolio Revisited

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  using namespace std;
7
8  #ifdef CGAL_USE_GMP
9  #include <CGAL/Gmpz.h>
10 typedef CGAL::Gmpz ET;
11 #else
12 #include <CGAL/MP_Float.h>
13 typedef CGAL::MP_Float ET;
14 #endif
15
16 typedef CGAL::Quadratic_program<int> Program;
17 typedef CGAL::Quadratic_program_solution<ET> Solution;
18
19 void testcase(int N, int M) {
20     Program qp (CGAL::SMALLER, true, 0, false, 0);
21
22     for(int n = 0; n < N; ++n) {
23         int c, r; cin >> c >> r;
24         qp.set_a(n, 0, c);
25         qp.set_a(n, 1, r);
26     }
27     qp.set_r(1, CGAL::LARGER);
28
29     for(int i = 0; i < N; ++i) {
30         for(int j = 0; j < N; ++j) {
31             int vij; cin >> vij;
32             qp.set_d(i, j, 2*vij);
33         }
34     }
35
36     for(int m = 0; m < M; ++m) {
37         int C, V; cin >> C >> V;
38         int R = 0;
39         qp.set_b(0, C);
40         qp.set_b(1, R);
41
42         int lo = 0;
43         int hi = 100;
44         bool fixed = false;
45         while(lo <= hi) {
46             int mid = (fixed) ? (lo + (hi-lo+1)/2) : hi;
47
48             qp.set_b(1, mid);
49             Solution s = CGAL::solve_quadratic_program(qp, ET());
50             assert(s.solves_quadratic_program(qp));
51
52             if(s.is_optimal() && s.objective_value() <= V) {
53                 R = mid;
54                 if(!fixed) {
55                     lo = hi+1;
56                     hi = 2*hi;
57                 } else {
58                     lo = mid+1;
59                 }
60             } else {
61                 fixed = true;
62                 hi = mid-1;
63             }
64         }
65         cout << R << "\n";
66     }
67 }
68
69 int main() {
70     while(true) {
71         int N, M; cin >> N >> M;
72         if(N == 0 && M == 0) return 0;
73         testcase(N, M);
74     }
```


Stamp Exhibition

```
1  #include <iostream>
2  #include <cassert>
3  #include <cmath>
4  #include <CGAL/basic.h>
5  #include <CGAL/QP_models.h>
6  #include <CGAL/QP_functions.h>
7  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
8  using namespace std;
9
10 #ifdef CGAL_USE_GMP
11 #include <CGAL/Gmpq.h>
12 typedef CGAL::Gmpq ET;
13 #else
14 #include <CGAL/MP_Float.h>
15 typedef CGAL::MP_Float ET;
16 #endif
17
18 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
19 typedef CGAL::Quadratic_program<double> Program;
20 typedef CGAL::Quadratic_program_solution<ET> Solution;
21
22 void testcase() {
23     int L, S, W; cin >> L >> S >> W;
24
25     vector<K::Point_2> lamps;
26     for(int l = 0; l < L; ++l) {
27         int x, y; cin >> x >> y;
28         lamps.push_back(K::Point_2(x, y));
29     }
30
31     vector<pair<K::Point_2, double> > stamps;
32     for(int s = 0; s < S; ++s) {
33         int x, y; double m; cin >> x >> y >> m;
34         stamps.push_back(make_pair(K::Point_2(x, y), m));
35     }
36
37     vector<K::Segment_2> walls;
38     for(int w = 0; w < W; ++w) {
39         int x1, y1, x2, y2; cin >> x1 >> y1 >> x2 >> y2;
40         walls.push_back(K::Segment_2(K::Point_2(x1, y1), K::Point_2(x2, y2)));
41     }
42
43     if(S == 0) { cout << "yes\n"; return; }
44     if(L == 0) { cout << "no\n"; return; }
45
46     Program lp (CGAL::SMALLER, true, 1, true, pow(2.0, 12));
47     for(int l = 0; l < L; ++l) {
48         for(int s = 0; s < S; ++s) {
49             bool intersect = false;
50             for(int w = 0; w < W; ++w) {
51                 K::Segment_2 stamp_lamp(stamps[s].first, lamps[l]);
52                 if(CGAL::do_intersect(stamp_lamp, walls[w])) {
53                     intersect = true;
54                     break;
55                 }
56             }
57
58             double param = 0;
59             if(!intersect)
60                 param = 1.0/CGAL::squared_distance(stamps[s].first, lamps[l]);
61             lp.set_a(l, s, param);
62             lp.set_a(l, S+s, param);
63             lp.set_b(s, stamps[s].second);
64             lp.set_b(S+s, 1.0);
65             lp.set_r(S+s, CGAL::LARGER);
66         }
67     }
68
69     Solution s = CGAL::solve_linear_program(lp, ET());
70     assert (s.solves_linear_program(lp));
71     (!s.is_infeasible()) ? cout << "yes\n" : cout << "no\n";
72 }
73
74 int main() {
```

```
75     int TC; cin >> TC;
76     while(TC--) testcase();
77     return 0;
78 }
```

Tetris

```
1 #include <iostream>
2 #include <boost/graph/adjacency_list.hpp>
3 #include <boost/graph/push_relabel_max_flow.hpp>
4 #include <boost/tuple/tuple.hpp>
5 using namespace std;
6 using namespace boost;
7
8 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
9 typedef adjacency_list<vecS, vecS, directedS, no_property,
10     property<edge_capacity_t, long,
11     property<edge_residual_capacity_t, long,
12     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
13 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
14 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
15 typedef graph_traits<Graph>::edge_descriptor Edge;
16
17 void add_edge(int from, int to, int cap, Graph& g) {
18     //cout << "adding edge: " << from << " " << to << " " << cap << "\n";
19     EdgeCapacityMap capacity = get(edge_capacity, g);
20     ReverseEdgeMap reverse = get(edge_reverse, g);
21
22     Edge there, back;
23     tie(there, tuples::ignore) = add_edge(from, to, g);
24     tie(back, tuples::ignore) = add_edge(to, from, g);
25     capacity[there] = cap;
26     capacity[back] = 0;
27     reverse[there] = back;
28     reverse[back] = there;
29 }
30
31 void testcase() {
32     int W, N; cin >> W >> N;
33
34     int source = 0;
35     int sink = W;
36     Graph g(2*W);
37
38     for(int v = 1; v < W; ++v) {
39         add_edge(v, W+v, 1, g);
40     }
41
42     for(int n = 0; n < N; ++n) {
43         int v1, v2; cin >> v1 >> v2;
44         int from = (min(v1, v2) == 0) ? 0 : min(v1, v2) + W;
45         int to = max(v1, v2);
46         add_edge(from, to, 1, g);
47     }
48
49     int maxflow = push_relabel_max_flow(g, source, sink);
50     cout << maxflow << "\n";
51 }
52
53 int main() {
54     int TC; cin >> TC;
55     while(TC--) testcase();
56 }
```


Beach Bar

```
1  #include <vector>
2  #include <iostream>
3  #include <climits>
4  #include <algorithm>
5  using namespace std;
6
7  typedef vector<int> vi;
8  const int normalize = 1000000;
9
10 void testcase() {
11     int N; cin >> N;
12     vi points;
13     for(int n = 0; n < N; ++n) {
14         int x; cin >> x;
15         points.push_back(x + normalize);
16     }
17     sort(points.begin(), points.end());
18
19     int g_counter = INT_MIN;
20     int g_length = INT_MIN;
21     vi solution;
22     for(int n = 0; n < N; ++n) {
23         int start_interval = points[n];
24         int end_interval = start_interval + 200;
25         int k = n;
26         int counter = 0;
27         while(points[k] <= end_interval && k < N) {
28             ++counter;
29             ++k;
30         }
31         int length = (points[k-1] - start_interval);
32
33         if(counter > g_counter || (counter == g_counter && length < g_length)) {
34             g_counter = counter;
35             g_length = length;
36             solution.clear();
37         }
38
39         if(g_counter == counter && g_length == length) {
40             int output = start_interval + length/2 - normalize;
41             solution.push_back(output);
42             if(length % 2 != 0) {
43                 solution.push_back(output+1);
44             }
45         }
46     }
47
48     g_length = (g_length % 2 == 0) ? g_length/2 : g_length/2+1;
49     cout << g_counter << " " << g_length << "\n";
50     for(int s = 0; s < solution.size(); ++s) {
51         cout << solution[s];
52         if(s != solution.size() - 1) cout << " ";
53     }
54     cout << "\n";
55 }
56
57 int main() {
58     int TC; cin >> TC;
59     while(TC--) testcase();
60     return 0;
61 }
```

Cover

```
1 #include <iostream>
2 #include <vector>
3 #include <algorithm>
4 #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
5 #include <CGAL/Delaunay_triangulation_2.h>
6 using namespace std;
7
8 typedef CGAL::Exact_predicates_exact_constructions_kernel K;
9 typedef CGAL::Delaunay_triangulation_2<K> Delaunay;
10 typedef Delaunay::Finite_faces_iterator FFI;
11 typedef Delaunay::Finite_edges_iterator FEI;
12
13 double ceil_to_double(const K::FT& x) {
14     double a = ceil(CGAL::to_double(x));
15     while (a < x) a += 1;
16     while (a-1 >= x) a -= 1;
17     return a;
18 }
19
20 template<typename T>
21 K::FT check_intersection(const T* obj, const K::Point_2 p1, const vector<K::Segment_2>& rectangle) {
22     for (int i = 0; i < 4; ++i) {
23         if(!do_intersect(rectangle[i], *obj)) continue;
24         CGAL::Object o = intersection(rectangle[i], *obj);
25         const K::Point_2* p2 = CGAL::object_cast<K::Point_2>(&o);
26         K::FT sqrd = CGAL::squared_distance(p1, *p2);
27         return sqrd;
28     }
29     return 0;
30 }
31
32 void testcase(int N) {
33     vector<K::Point_2> points;
34     vector<K::Segment_2> rectangle;
35
36     double x1, y1, x2, y2;
37     cin >> x1 >> y1 >> x2 >> y2;
38     K::Point_2 sw(x1, y1);
39     K::Point_2 nw(x1, y2);
40     K::Point_2 se(x2, y1);
41     K::Point_2 ne(x2, y2);
42     rectangle.push_back(K::Segment_2(sw, nw));
43     rectangle.push_back(K::Segment_2(se, ne));
44     rectangle.push_back(K::Segment_2(sw, se));
45     rectangle.push_back(K::Segment_2(nw, ne));
46
47     for(int n = 0; n < N; ++n) {
48         double x, y; cin >> x >> y;
49         points.push_back(K::Point_2(x, y));
50     }
51
52     // O(n log n)
53     Delaunay t;
54     t.insert(points.begin(), points.end());
55     K::FT min_rad;
56
57     // check corners
58     min_rad = CGAL::squared_distance(sw, t.nearest_vertex(sw)->point());
59     min_rad = max(min_rad, CGAL::squared_distance(se, t.nearest_vertex(se)->point()));
60     min_rad = max(min_rad, CGAL::squared_distance(nw, t.nearest_vertex(nw)->point()));
61     min_rad = max(min_rad, CGAL::squared_distance(ne, t.nearest_vertex(ne)->point()));
62
63     // iterate over all faces to find largest circle - O(N)
64     for(FFI f = t.finite_faces_begin(); f != t.finite_faces_end(); ++f) {
65         K::Point_2 cc = t.circumcenter(f);
66         if(cc.x() >= x1 && cc.x() <= x2 && cc.y() >= y1 && cc.y() <= y2) {
67             K::Point_2 point = f->vertex(1)->point();
68             K::FT dist = CGAL::squared_distance(point, cc);
69             min_rad = max(min_rad, dist);
70         }
71     }
72
73     // check for intersection with rectangle boundary - O(n*4)
74     for(FEI e = t.finite_edges_begin(); e != t.finite_edges_end(); ++e) {
```

```

75     CGAL::Object o = t.dual(e);
76     if(const K::Ray_2* r = CGAL::object_cast<K::Ray_2>(&o))
77         min_rad = max(min_rad, check_intersection(r, t.segment(e).source(), rectangle));
78     else if(const K::Segment_2* s = CGAL::object_cast<K::Segment_2>(&o))
79         min_rad = max(min_rad, check_intersection(s, t.segment(e).source(), rectangle));
80 }
81
82 cout << ceil(CGAL::sqrt(to_double(min_rad))) << "\n";
83 }
84
85 int main() {
86     cin.sync_with_stdio(false);
87     cout << std::setiosflags(std::ios::fixed) << std::setprecision(0);
88     while(true) {
89         int N; cin >> N;
90         if(N == 0) return 0;
91         testcase(N);
92     }
93 }

```

Divisor Distance

```
1  #include <iostream>
2  #include <cmath>
3  using namespace std;
4
5  int ancestor(int v) {
6      for(int k = 2; k <= ceil(sqrt(v)); ++k) {
7          if(v % k == 0) return (v/k);
8      }
9      return 1;
10 }
11
12 void testcase() {
13     int N, C; cin >> N >> C;
14     for(int c = 0; c < C; ++c) {
15         int v1, v2; cin >> v1 >> v2;
16         int counter = 0;
17         while(v1 != v2) {
18             ++counter;
19             if(v1 < v2) {
20                 v2 = ancestor(v2);
21             } else {
22                 v1 = ancestor(v1);
23             }
24         }
25         cout << counter << "\n";
26     }
27 }
28
29 int main() {
30     ios_base::sync_with_stdio(false);
31     int TC; cin >> TC;
32     while(TC--) testcase();
33     return 0;
34 }
```

Tiles

```
1 #include <iostream>
2 #include <vector>
3 #include <boost/tuple/tuple.hpp>
4 #include <boost/graph/adjacency_list.hpp>
5 #include <boost/graph/max_cardinality_matching.hpp>
6 using namespace std;
7 using namespace boost;
8
9 typedef vector<int> vi;
10 typedef vector<vi> vii;
11 typedef adjacency_list<vecS, vecS, undirectedS, no_property, no_property> Graph;
12 typedef graph_traits<Graph>::vertex_descriptor Vertex;
13
14 void testcase() {
15     int W, H; cin >> W >> H;
16
17     vii matrix(H);
18     int blocked = 0;
19     int vcounter = 0;
20     for(int h = 0; h < H; ++h) {
21         for(int w = 0; w < W; ++w) {
22             char input; cin >> input;
23             blocked += (input == 'x');
24             matrix[h].push_back((input == '.' ? vcounter++ : -1));
25         }
26     }
27
28     int V = (W*H - blocked);
29     if(V % 2 == 1) {
30         cout << "no\n";
31         return;
32     }
33
34     Graph g(V);
35     for(int h = 0; h < H; ++h) {
36         for(int w = 0; w < W; ++w) {
37             if(matrix[h][w] == -1) continue;
38             if(w+1 < W && matrix[h][w+1] != -1) add_edge(matrix[h][w], matrix[h][w+1], g);
39             if(h+1 < H && matrix[h+1][w] != -1) add_edge(matrix[h][w], matrix[h+1][w], g);
40         }
41     }
42
43     vector<Vertex> mateMap(num_vertices(g), 0);
44     checked_edmonds_maximum_cardinality_matching(g, &mateMap[0]);
45     int matching = matching_size(g, &mateMap[0]);
46
47     if(matching * 2 == V) cout << "yes\n";
48     else cout << "no\n";
49 }
50
51 int main() {
52     int TC; cin >> TC;
53     while(TC--) testcase();
54     return 0;
55 }
```

Connecting Capitals

All the following algorithms run in linear time.

1 Maximum Matching in Tree

- Idea: recursive algorithm, the basecases are the leaves with Matching 0.
- At each vertex v the maximum matching of the subtree rooted at v .

```
1  #include <iostream>
2  #include <vector>
3  using namespace std;
4
5  typedef vector<int> vi;
6  typedef vector<vi> vii;
7
8  int matching(int vertex, int parent, vii& adj, vi& M) {
9      if(M[vertex] != -1) return M[vertex];
10
11     int total = 0;
12     for(int c = 0; c < adj[vertex].size(); ++c) {
13         if(adj[vertex][c] == parent) continue;
14         int child = adj[vertex][c];
15         total += matching(child, vertex, adj, M);
16     }
17     int Mprime = total; // crucial, otherwise I increment M[vertex] everytime I iterate over a.
18     M[vertex] = total;
19
20     for(int c = 0; c < adj[vertex].size(); ++c) {
21         if(adj[vertex][c] == parent) continue;
22         int a = adj[vertex][c];
23         total = 1 + Mprime - M[a];
24         for(int w = 0; w < adj[a].size(); ++w){
25             if(adj[a][w] == vertex) continue;
26             total += matching(adj[a][w], a, adj, M);
27         }
28         M[vertex] = max(total, M[vertex]);
29     }
30
31     return M[vertex];
32 }
33
34 void testcase() {
35     int N; cin >> N;
36     vii adj(N);
37     vi M(N, -1);
38
39     for(int n = 0; n < N-1; ++n) {
40         int v1, v2; cin >> v1 >> v2;
41         adj[v1].push_back(v2);
42         adj[v2].push_back(v1);
43     }
44
45     int match = matching(0, 0, adj, M);
46     cout << match << "\n";
47 }
48
49 int main() {
50     int TC; cin >> TC;
51     while(TC--) testcase();
52     return 0;
53 }
```

2 Outputting Maximum Matching

```
1  #include <iostream>
2  #include <vector>
3  using namespace std;
4
5  typedef vector<int> vi;
6  typedef vector<vi> vii;
```

```

7
8 int matching(int vertex, int parent, vii& adj, vi& M, vi& matchings) {
9     if(M[vertex] != -1) return M[vertex];
10
11     int total = 0;
12     for(int c = 0; c < adj[vertex].size(); ++c) {
13         if(adj[vertex][c] == parent) continue;
14         int child = adj[vertex][c];
15         total += matching(child, vertex, adj, M, matchings);
16     }
17     int Mprime = total;
18     M[vertex] = total;
19
20     for(int c = 0; c < adj[vertex].size(); ++c) {
21         if(adj[vertex][c] == parent) continue;
22         int a = adj[vertex][c];
23         total = 1 + Mprime - M[a];
24         for(int w = 0; w < adj[a].size(); ++w){
25             if(adj[a][w] == vertex) continue;
26             total += matching(adj[a][w], a, adj, M, matchings);
27         }
28         if(total > M[vertex]) {
29             matchings[vertex] = a;
30             M[vertex] = max(total, M[vertex]);
31         }
32     }
33
34     return M[vertex];
35 }
36
37 void testcase() {
38     int N; cin >> N;
39     vii adj(N);
40     vi M(N, -1);
41     vi matchings(N, -1);
42
43     for(int n = 0; n < N-1; ++n) {
44         int v1, v2; cin >> v1 >> v2;
45         adj[v1].push_back(v2);
46         adj[v2].push_back(v1);
47     }
48
49     int match = matching(0, 0, adj, M, matchings);
50     cout << match << "\n";
51
52     for(int m = 0; m < N; ++m) {
53         if(matchings[m] != -1) cout << m << " " << matchings[m] << "\n";
54     }
55 }
56
57 int main() {
58     int TC; cin >> TC;
59     while(TC--) testcase();
60     return 0;
61 }

```

3 MVC in Tree

Selection of the minimum set of vertices such that all edges are incident to one vertex.

```

1 #include <iostream>
2 #include <vector>
3 using namespace std;
4
5 typedef vector<int> vi;
6 typedef vector<vi> vii;
7
8 int N;
9 vii adj;
10 vii dp_table;
11
12 int MVC(int vertex, int parent, bool taken) {
13     if(dp_table[vertex][taken] != -1) return dp_table[vertex][taken];
14
15     int ans = 0;

```

```

16     if(adj[vertex].size() == 1 && vertex != 0) {
17         ans = taken;
18     }
19     else if(taken == 1) {
20         ans = 1;
21         for(int i = 0; i < (int)adj[vertex].size(); ++i) {
22             int child = adj[vertex][i];
23             if(child == parent) continue;
24             ans += min(MVC(child, vertex, false), MVC(child, vertex, true));
25         }
26     }
27     else if(taken == 0) {
28         ans = 0;
29         for(int i = 0; i < (int) adj[vertex].size(); ++i) {
30             int child = adj[vertex][i];
31             if(child == parent) continue;
32             ans += MVC(child, vertex, true);
33         }
34     }
35
36     dp_table[vertex][taken] = ans;
37     return ans;
38 }
39
40 void testcase() {
41     cin >> N;
42     adj.clear(); adj.assign(N, vi(0));
43     dp_table.clear(); dp_table.assign(N, vi(2, -1));
44
45     for(int n = 0; n < N-1; ++n) {
46         int v1, v2; cin >> v1 >> v2;
47         adj[v1].push_back(v2);
48         adj[v2].push_back(v1);
49     }
50
51     cout << min(MVC(0, 0, true), MVC(0, 0, false)) << "\n";
52
53     // print vertex cover. V - MVC = MIS, because tree = bipartite graph (Kőnigstheorem).
54     for(int i = 0; i < N; ++i) {
55         if(dp_table[i][1] <= dp_table[i][0]) cout << i << "␣";
56     }
57     cout << "\n";
58 }
59
60 int main() {
61     int TC; cin >> TC;
62     while(TC--) testcase();
63     return 0;
64 }

```

4 MIS in Tree

Selects a set of vertices, such that none of them are adjacent.

```

1  #include <iostream>
2  #include <vector>
3  using namespace std;
4
5  typedef vector<int> vi;
6  typedef vector<vi> vii;
7
8  vii adj;
9  vii dp_table;
10 vi values;
11
12 int MWIS(int v, bool taken) {
13     int ans;
14     if(adj[v].size() == 1 && v != 0) {
15         if(taken) return values[v];
16         else return 0;
17     }
18     else if(taken) {
19         ans = values[v];
20         for(int i = 0; i < (int) adj[v].size(); ++i) {
21             if(adj[v][i] == vertex) continue;

```



```

22         ans += values[adj[v][i]][false];
23     }
24 }
25 else if(!taken) {
26     for(int i = 0; i < (int) adj[v].size(); ++i) {
27         if(adj[v][i] == vertex) continue;
28         ans += max(values[adj[v][i]][true], values[adj[v][i]][false]);
29     }
30 }
31
32 dp_table[v][taken] = ans;
33 return ans;
34 }
35
36 void testcase() {
37     int N; cin >> N;
38     adj.clear(); adj.assign(N, vi(0));
39     dp_table.clear(); dp_table.assign(N, vi(2, -1));
40     values.clear(); values.assign(N, 0);
41
42     for(int n = 0; n < N-1; ++n) {
43         int v1, v2; cin >> v1 >> v2;
44         adj[v1].push_back(v2);
45         adj[v2].push_back(v1);ssssss
46     }
47
48     for(int n = 0; n < N; ++n) {
49         int val; cin >> val;
50         values[n] = val;
51     }
52
53     cout << max(MWIS(0, true), MWIS(0, false)) << "\n";
54 }
55
56 int main() {
57     int TC; cin >> TC;
58     while(TC--) testcase();
59     return 0;
60 }

```

Deleted Entries Stike Back

Missing.

Light The Stage

```
1  #include <vector>
2  #include <map>
3  #include <iostream>
4  #include <cmath>
5  #include <CGAL/Delaunay_triangulation_2.h>
6  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
7  using namespace std;
8
9  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
10 typedef CGAL::Delaunay_triangulation_2<K> Delaunay;
11 typedef vector<pair<K::Point_2, int> > vp;
12
13 int P, L, H;
14
15 vector<int> get_winners(int maxLamp, vp& participants, vector<K::Point_2>& lamps) {
16     Delaunay t;
17     t.insert(lamps.begin(), lamps.begin()+maxLamp);
18
19     vector<int> winners;
20     for(int p = 0; p < P; ++p) {
21         int radius = participants[p].second;
22         K::Point_2 loc = participants[p].first;
23         Delaunay::Vertex_handle lamp = t.nearest_vertex(loc);
24         K::FT dist = CGAL::squared_distance(loc, lamp->point());
25         K::FT dist_p = H+radius;
26         if(dist >= dist_p*dist_p) {
27             winners.push_back(p);
28         }
29     }
30     return winners;
31 }
32
33 void testcase() {
34     cin >> P >> L;
35     vp participants;
36     for(size_t p = 0; p < P; ++p) {
37         int x, y, r;
38         cin >> x >> y >> r;
39         participants.push_back(make_pair(K::Point_2(x, y), r));
40     }
41
42     cin >> H;
43
44     vector<K::Point_2> lamps;
45     for(size_t l = 0; l < L; ++l) {
46         int x, y;
47         cin >> x >> y;
48         lamps.push_back(K::Point_2(x, y));
49     }
50
51     vector<int> winners;
52     winners = get_winners(L, participants, lamps);
53     if(winners.size() != 0) {
54         for(int i = 0; i < winners.size(); ++i) cout << winners[i] << " ";
55         cout << "\n";
56         return;
57     }
58
59     int lo = 0;
60     int hi = L;
61     int D = -1;
62     map<int, int> results;
63     while(lo < hi) {
64         int mid = lo + (hi-lo+1)/2;
65         vector<int> survivors = get_winners(mid, participants, lamps);
66         int count = survivors.size();
67         results[mid] = (count == 0) ? -1 : count;
68
69         if(lo+1 == hi && results[lo] != 0 && results[hi] == -1) {
70             D = lo;
71             break;
72         }
73     }
74
75     if(count == 0) {
```

```

75         hi = mid;
76     } else {
77         lo = mid;
78     }
79 }
80 winners = get_winners(D, participants, lamps);
81 for(int i = 0; i < winners.size(); ++i) cout << winners[i] << " ";
82 cout << "\n";
83 }
84
85 int main() {
86     std::ios_base::sync_with_stdio(false);
87     int TC; cin >> TC;
88     while (TC--) testcase();
89     return 0;
90 }

```

Radiation

```
1  #include <iostream>
2  #include <vector>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6  using namespace std;
7
8  struct Point { int x; int y; int z; };
9
10 #ifdef CGAL_USE_GMP
11 #include <CGAL/Gmpz.h>
12 typedef CGAL::Gmpz ET, IT;
13 #else
14 #include <CGAL/MP_Float.h>
15 typedef CGAL::MP_Float ET;
16 #endif
17
18 typedef CGAL::Quadratic_program<IT> Program;
19 typedef CGAL::Quadratic_program_solution<ET> Solution;
20 map<pair<int, int>, IT> Powers;
21
22 IT pw(int b, int e) {
23     if(Powers[make_pair(b, e)] != 0)
24         return Powers[make_pair(b, e)];
25
26     IT sol = 1;
27     for(int i = 1; i <= e; ++i) {
28         sol *= b;
29     }
30     Powers[make_pair(b, e)] = sol;
31     return sol;
32 }
33
34 void testcase() {
35     int H, T; cin >> H >> T;
36
37     vector<Point> cells;
38     for(int c = 0; c < (H+T); ++c) {
39         Point p;
40         cin >> p.x >> p.y >> p.z;
41         cells.push_back(p);
42     }
43
44     int lo = 0;
45     int hi = 29;
46     int d = -1;
47     vector<int> results(30, -1);
48
49     while(lo <= hi) {
50         Program lp(CGAL::SMALLER, false, 0, false, 0);
51         lp.set_c(0, -1);
52         lp.set_u(0, true, 1); // MISTAKE!!! before set_u(0, 1);
53
54         int deg = lo + (hi-lo+1)/2;
55         for(int row = 0; row < cells.size(); ++row) {
56             lp.set_b(row, 0);
57             if(row >= H) { // tumor cell
58                 lp.set_a(0, row, -1);
59                 lp.set_r(row, CGAL::LARGER);
60             }
61
62             int col = 1;
63             for(int i = 0; i <= deg; ++i) {
64                 for(int j = 0; j <= deg-i; ++j) {
65                     for(int k = 0; k <= deg-i-j; ++k) {
66                         IT coeff = pw(cells[row].x, i) * pw(cells[row].y, j) * pw(cells[row].z, k);
67                         lp.set_a(col++, row, coeff);
68                     }
69                 }
70             }
71         }
72
73         CGAL::Quadratic_program_options options;
74         options.set_pricing_strategy(CGAL::QP_BLAND);
```

```

75     Solution s = CGAL::solve_linear_program(lp, ET(), options);
76     results[deg] = (CGAL::to_double(s.objective_value()) < 0 && s.is_optimal()) ? true : false;
77
78     if((lo < 29) && (results[lo] == 0) && (results[lo+1] == 1)) {
79         d = lo+1;
80         break;
81     } else if((hi > 0) && (results[hi] == 1 && results[hi-1] == 0)) {
82         d = hi;
83         break;
84     } else if(results[0] == 1) {
85         d = 0;
86         break;
87     } else {
88         if(results[deg]) hi = deg-1;
89         else lo = deg + 1;
90     }
91 }
92 (d == -1) ? cout << "Impossible!\n" : cout << d << "\n";
93 }
94
95 int main() {
96     ios_base::sync_with_stdio(false);
97     int TC; cin >> TC;
98     while(TC--) testcase();
99 }

```

Sweepers

```
1 #include <iostream>
2 #include <vector>
3 #include <boost/tuple/tuple.hpp>
4 #include <boost/graph/adjacency_list.hpp>
5 #include <boost/graph/push_relabel_max_flow.hpp>
6 #include <boost/graph/strong_components.hpp>
7 using namespace std;
8 using namespace boost;
9
10 typedef vector<int> vi;
11 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
12 typedef adjacency_list<vecS, vecS, directedS, no_property,
13     property<edge_capacity_t, long,
14     property<edge_residual_capacity_t, long,
15     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
16 typedef property_map<Graph, edge_capacity_t::type EdgeCapacityMap;
17 typedef property_map<Graph, edge_reverse_t::type ReverseEdgeMap;
18 typedef graph_traits<Graph>::edge_descriptor Edge;
19 typedef graph_traits<Graph>::vertex_descriptor Vertex;
20
21 int N, M, S;
22
23 void add_edge(int from, int to, int cap, Graph& g) {
24     EdgeCapacityMap capacity = get(edge_capacity, g);
25     ReverseEdgeMap reverse = get(edge_reverse, g);
26
27     Edge there, back;
28     tie(there, tuples::ignore) = add_edge(from, to, g);
29     tie(back, tuples::ignore) = add_edge(to, from, g);
30     capacity[there] = cap;
31     capacity[back] = 0;
32     reverse[there] = back;
33     reverse[back] = there;
34 }
35
36 void testcase() {
37     cin >> N >> M >> S;
38     int source = N;
39     int sink = N+1;
40     Graph g(N+2);
41     vi starts(N, 0), exits(N, 0);
42
43     for(int s = 0; s < S; ++s) {
44         int room; cin >> room;
45         ++starts[room];
46     }
47
48     for(int s = 0; s < S; ++s) {
49         int room; cin >> room;
50         ++exits[room];
51     }
52
53     for(int m = 0; m < M; ++m) {
54         int v1, v2; cin >> v1 >> v2;
55         add_edge(v1, v2, 1, g);
56         add_edge(v2, v1, 1, g);
57     }
58
59     for(int n = 0; n < N; ++n) {
60         if(starts[n] > 0) add_edge(source, n, starts[n], g);
61         if(exits[n] > 0) add_edge(n, sink, exits[n], g);
62     }
63
64     bool isEulerian = true;
65     bool isConnected = false;
66     graph_traits<Graph>::vertex_iterator viter, vend;
67     for (tie(viter, vend) = vertices(g); viter != vend; ++viter) {
68         if(*viter == source || *viter == sink) continue;
69         int count = out_degree(*viter, g);
70         if(starts[*viter] > 0) ++count;
71         if(exits[*viter] > 0) ++count;
72         count = count/2;
73         if(count % 2 == 1) {
74             isEulerian = false;
```

```

75         break;
76     }
77 }
78
79 if(!isEulerian) {
80     cout << "no\n";
81     return;
82 }
83
84 int maxflow = push_relabel_max_flow(g, source, sink);
85 if(maxflow != S)
86     cout << "no\n";
87 else
88     cout << "yes\n";
89 }
90
91 int main() {
92     int TC; cin >> TC;
93     while(TC--) testcase();
94 }

```


The Bracelet

```
1  #include <iostream>
2  #include <stack>
3  #include <set>
4  #include <boost/tuple/tuple.hpp>
5  #include <boost/graph/adjacency_list.hpp>
6  #include <boost/graph/connected_components.hpp>
7  using namespace std;
8  using namespace boost;
9
10 typedef vector<pair<int, int> > vpi;
11 typedef adjacency_list<vecS, vecS, undirectedS, no_property, property<edge_weight_t, int> > Graph;
12 typedef graph_traits<Graph>::vertex_iterator VI;
13 typedef graph_traits<Graph>::out_edge_iterator EI;
14 typedef graph_traits<Graph>::edge_descriptor Edge;
15 typedef property_map<Graph, edge_weight_t>::type WeightMap;
16
17 void printEulerGraph(int v, Graph& g) {
18     WeightMap weight = get(edge_weight, g);
19     stack<int> fifo;
20     fifo.push(v);
21     vector<int> sol;
22     while(!fifo.empty()) {
23         int v = fifo.top();
24         EI ebegin, eend;
25         bool hasFreeEdge = false;
26         for(tie(ebegin, eend) = out_edges(v, g); ebegin != eend; ++ebegin) {
27             if(weight[*ebegin] == 0) {
28                 hasFreeEdge = true;
29                 weight[*ebegin] = 1;
30                 fifo.push(boost::target(*ebegin, g));
31                 break;
32             }
33         }
34         if(!hasFreeEdge) {
35             sol.push_back(v);
36             fifo.pop();
37         }
38     }
39     for(int s = 0; s < sol.size()-1; ++s) {
40         cout << sol[s] << "□" << sol[s+1] << "\n";
41     }
42     cout << "\n";
43 }
44
45 void testcase(int TC) {
46     cout << "Case_□#" << ++TC << "\n";
47     int N; cin >> N;
48
49     Graph g(50);
50     WeightMap weight = get(edge_weight, g);
51     set<int> colors;
52
53     for(int n = 0; n < N; ++n) {
54         int v1, v2; cin >> v1 >> v2;
55         colors.insert(v1); colors.insert(v2);
56         Edge e;
57         tie(e, tuples::ignore) = add_edge(v1, v2, g);
58         weight[e] = 0;
59     }
60
61     vector<int> component(num_vertices(g));
62     int num = connected_components(g, &component[0]) - (51 - colors.size());
63     int start = -1;
64     VI vbegin, vend;
65     for(tie(vbegin, vend) = vertices(g); vbegin != vend; ++vbegin) {
66         int deg = out_degree(*vbegin, g);
67         if(deg % 2 == 1 || num > 1) {
68             cout << "some_□beads_□may_□be_□lost\n\n";
69             return;
70         }
71         if(deg > 0) start = *vbegin;
72     }
73
74     printEulerGraph(start, g);
```

```
75 }  
76  
77 int main() {  
78     int TC; cin >> TC;  
79     for(int t = 0; t < TC; ++t) testcase(t);  
80 }
```

Knights

```
1 #include <iostream>
2 #include <boost/tuple/tuple.hpp>
3 #include <boost/graph/adjacency_list.hpp>
4 #include <boost/graph/push_relabel_max_flow.hpp>
5 using namespace std;
6 using namespace boost;
7
8 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
9 typedef adjacency_list<vecS, vecS, directedS, no_property,
10     property<edge_capacity_t, long,
11     property<edge_residual_capacity_t, long,
12     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
13 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
14 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
15 typedef graph_traits<Graph>::edge_descriptor Edge;
16
17 int M;
18 int N;
19 int K;
20
21 int index(int x, int y) {
22     return y*M + x;
23 }
24
25 void add_edges(int from, int to, Graph& g) {
26     EdgeCapacityMap capacity = get(edge_capacity, g);
27     ReverseEdgeMap reverse = get(edge_reverse, g);
28
29     Edge there, back;
30     tie(there, tuples::ignore) = add_edge(from, to, g);
31     tie(back, tuples::ignore) = add_edge(to, from, g);
32     capacity[there] = 1;
33     capacity[back] = 0;
34     reverse[there] = back;
35     reverse[back] = there;
36 }
37
38 void testcase() {
39     cin >> M >> N >> K;    // M: cols, N: rows, K: #knights
40
41     int graph_size = 2*(M*N)+2;    // M*N for each coordinate, 2*(M*N) because we need vertex-disjoint paths ↴
42     ↵ only.
43     Graph g(graph_size);
44     int source = graph_size-2;
45     int sink = graph_size-1;
46     for(int y = 0; y < N; ++y) {
47         for(int x = 0; x < M; ++x) {
48             int v_in = index(x, y);
49             int v_out = index(x, y) + M*N;
50
51             add_edges(v_in, v_out, g);
52
53             if(x+1 < M) {
54                 add_edges(v_out, index(x+1, y), g);
55                 add_edges(index(x+1, y)+(M*N), v_in, g);
56             }
57             if(y+1 < N) {
58                 add_edges(v_out, index(x, y+1), g);
59                 add_edges(index(x, y+1)+(M*N), v_in, g);
60             }
61             if(x-1 < 0 || x+1 >= M || y-1 < 0 || y+1 >= N) {
62                 add_edges(v_out, sink, g);
63             }
64         }
65     }
66
67     for(int k = 0; k < K; ++k) {
68         int x, y; cin >> x >> y;
69         add_edges(source, index(x, y), g);
70     }
71
72     int maxflow = push_relabel_max_flow(g, source, sink);
73     cout << maxflow << "\n";
74 }
```

```
74 |
75 | int main() {
76 |     int TC; cin >> TC;
77 |     while(TC--) testcase();
78 | }
```

Next Path

```
1  #include <iostream>
2  #include <vector>
3  #include <queue>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/dijkstra_shortest_paths.hpp>
7  using namespace std;
8  using namespace boost;
9
10 const int MAX_LENGTH = 100000000; // do not pick INT_MAX otherwise overflow resulting in -INT_MAX confusing ↴
    ↴ min.
11
12 typedef vector<int> vi;
13 typedef adjacency_list<vecS, vecS, directedS, no_property, property<edge_weight_t, int> > Graph;
14 typedef graph_traits<Graph>::edge_descriptor Edge;
15 typedef graph_traits<Graph>::vertex_descriptor Vertex;
16 typedef property_map<Graph, edge_weight_t>::type WeightMap;
17 typedef graph_traits<Graph>::out_edge_iterator OutEdgeIterator;
18
19 int BFS(int start, int end, Graph& g) {
20     if(start == end) return 0;
21     vi distances(num_vertices(g), -1);
22     std::queue<int> fifo;
23     fifo.push(start);
24     distances[start] = 0;
25     while(!fifo.empty()) {
26         int v = fifo.front(); fifo.pop();
27         OutEdgeIterator ebegin, eend;
28         for(tie(ebegin, eend) = out_edges(v, g); ebegin != eend; ++ebegin) {
29             int u = target(*ebegin, g);
30             if(distances[u] == -1) {
31                 distances[u] = distances[v] + 1;
32                 fifo.push(u);
33                 if(u == end) return distances[u];
34             }
35         }
36     }
37     return MAX_LENGTH;
38 }
39
40 void testcase() {
41     int N, M, s, t; cin >> N >> M >> s >> t;
42     --t; --s;
43
44     Graph g(N);
45     WeightMap weights = get(edge_weight, g);
46
47     for(int m = 0; m < M; ++m) {
48         int v1, v2; cin >> v1 >> v2;
49         Edge edge;
50         tie(edge, tuples::ignore) = add_edge(v1-1, v2-1, g);
51         weights[edge] = 1;
52     }
53
54     vi d(N);
55     vector<Vertex> p(N);
56     dijkstra_shortest_paths(g, s, predecessor_map(&p[0]).distance_map(&d[0]));
57
58     if(d[t] == INT_MAX) { cout << "no\n"; return; } // there is no path from s to t.
59
60     int sp = MAX_LENGTH;
61     int b = t;
62     int prev = t;
63     while(true) {
64         OutEdgeIterator ebegin, eend;
65         for(tie(ebegin, eend) = out_edges(b, g); ebegin != eend; ++ebegin) {
66             if(target(*ebegin, g) == prev && prev != s && b != t) continue; // do not pick the edge in P, start ↴
                ↴ end end path are special states.
67             sp = min(sp, d[source(*ebegin, g)] + 1 + BFS(target(*ebegin, g), t, g));
68         }
69         if(b == s || sp == d[t]) break;
70         prev = b;
71         b = p[b];
72     }
```

```
73     (sp == MAX_LENGTH) ? cout << "no\n" : cout << sp << "\n";
74 }
75
76 int main() {
77     ios_base::sync_with_stdio(false);
78     int TC; cin >> TC;
79     while(TC--) testcase();
80 }
```

Odd Route

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/dijkstra_shortest_paths.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <climits>
7  using namespace std;
8  using namespace boost;
9
10 typedef adjacency_list<vecS, vecS, directedS, no_property, property<edge_weight_t, int> > Graph;
11 typedef property_map<Graph, edge_weight_t>::type EdgeWeightMap;
12 typedef graph_traits<Graph>::edge_descriptor Edge;
13 typedef graph_traits<Graph>::vertex_descriptor Vertex;
14
15 void add_edges(Graph& g, int u, int v, int w) {
16     int uee = u*4;    int vee = v*4;
17     int ueo = uee+1;   int veo = vee+1;
18     int uoe = uee+2;   int vov = vee+2;
19     int uoo = uee+3;   int voo = vee+3;
20
21     EdgeWeightMap weights = get(edge_weight, g);
22
23     Edge edge;
24     if(w % 2 == 0) {
25         tie(edge, tuples::ignore) = add_edge(uee, vov, g); weights[edge] = w;
26         tie(edge, tuples::ignore) = add_edge(ueo, voo, g); weights[edge] = w;
27         tie(edge, tuples::ignore) = add_edge(uoe, vee, g); weights[edge] = w;
28         tie(edge, tuples::ignore) = add_edge(uoo, veo, g); weights[edge] = w;
29     } else {
30         tie(edge, tuples::ignore) = add_edge(uee, voo, g); weights[edge] = w;
31         tie(edge, tuples::ignore) = add_edge(ueo, vov, g); weights[edge] = w;
32         tie(edge, tuples::ignore) = add_edge(uoe, veo, g); weights[edge] = w;
33         tie(edge, tuples::ignore) = add_edge(uoo, vee, g); weights[edge] = w;
34     }
35 }
36
37 void testcase() {
38     int N, M, s, t; cin >> N >> M >> s >> t;
39     Graph g(N*4);
40
41     for(int m = 0; m < M; ++m) {
42         int u, v, w; cin >> u >> v >> w;
43         add_edges(g, u, v, w);
44     }
45
46     vector<int> d(num_vertices(g), -1);
47     dijkstra_shortest_paths(g, s*4, distance_map(&d[0]));
48     (d[4*t+3] < INT_MAX) ? cout << d[4*t+3] : cout << "no";
49     cout << "\n";
50 }
51
52 int main() {
53     int TC; cin >> TC;
54     while(TC--) testcase();
55     return 0;
56 }
```

Radiation 2

Missing.