

AlgoLab ETH 2013

name	problem	solution	P
Dominoes	Given a list of tiles of different heights, determine how many tiles will fall after toppling the left-most tile.	-	14
Aliens	Given a set of intervals, count those that have an element that is not contained in any other interval.	-	19
Shelves	Given two different types of shelves with length m and n , $m \leq n$ and an empty space with length l , determine the optimal number of shelves x and y such that $x * m + y * n = l - \epsilon$, $\epsilon > 0$, epsilon is minimized. Second objective is minimizing y .	clever loop with branching that reduces runtime to $O(\sqrt{l})$	15
False Coin	Given a series weighing outcomes of several coins, determine which coin has a different weight than the other coins.	-	23
Light Pattern	Given a sequence of n bulbs that are in the states "on" or "off", determine the minimal number of "changes" that are necessary such that each interval $i * k$ to $(i + 1) * k$ of the bulbs follows a given pattern. A "change" is either changing the state of a single bulb or change the state of every bulb from 0 up to $t * k - 1$.	-	34
Divisor Distance	Given a number n . Let G_n be a graph with 1 to n as vertices. Further, in G_n there is an (undirected) edge between vertices i and j with $i > j$ iff j is the largest proper divisor of i . Determine the minimal distance of two given vertices in this graph.	-	100
Formula One	Given a sequence of integers, determine the minimum number of "swaps" of numbers at position i and $i + 1$ are necessary to sort the list.	merge sort and count swaps	25
Boats	Given a set of boat lengths l_i and positions of rings p_i , determine the maximum number of boats that can be tied.	Greedy (Boat with earliest end then longest)	21
Checking Change	Given a number of different coin-values c_i , output the minimum number of coins that are necessary to represent m_i .	DP	11
Even Pairs	Given a list x_1, \dots, x_n , count the number of pairs $1 \leq i \leq j \leq n$ for which the sum is even.	DP	17
Burning Coins	Given a sequence of coins c_1, \dots, c_n with values v_1, \dots, v_n . Each player $\in \{A, B\}$ is alternately allowed to remove the leftmost or rightmost coin of the sequence until the sequence is empty. Output the maximum value of coins that A can remove.	DP	32
Jump	Given n cells, a number representing how far the agent can jump and the cost a_i to land on a cell. Determine the minimum cost to get from cell 1 to cell n .	DP	33

Poker Chips	Given some stacks S_i with chips c_{ij} each having a color. An agent A is allowed to remove the topmost chip from each stack provided they have the same color. If A removed $k > 1$ chips, he is awarded with 2^{k-2} points. Determine the maximum number of points for the given S_i .	DP	88
Connecting capitals	Given a tree. Determine the largest set of vertex disjoint edges.	DP	lec. 12
Race Tracks	Given a rectangular grid with obstacles, a start S and goal position. An agent A starts at S , has a x - y -velocity (a, b) $-3 \leq a, b \leq 3$. After each move A can adjust $a' = a + n_a, b' = b + n_b, n_a, n_b \in \{-1, 0, 1\}$. Determine the minimum number of moves necessary for A to reach the goal.	represent $(x, y, (a, b))$ as a node in a graph, BFS	28
Longest Path	Determine the length of the longest path in a tree.	DFS while recording tree height	36
Odd Route	Given a directed weighted graph G and two vertices s, t of G . Find the shortest path from s to t such that both its number of edges and total weight are odd.	Construct G' , then Dijkstra	114
Build The Graph		MST and Dijkstra	41
Ants	Given a graph G , and nodes S_i of subgraphs i . Build the subgraphs i by starting at S_i and do a uniform cost search until all nodes are explored. Find the cheapest path by combining all S_i (not G) from node a to b .	MST, then Dijkstra	37
Deleted Entries	Given a graph G . Determine whether it is possible to divide the graph into k groups such that every node can reach every node in every other group after deleting the in-group edges.	MST and BFS to k -color	42
Monkey Island	Let G be a graph (V, E) with costs on vertices. Let S be a subset of vertices, such that $\forall v \in V, \exists s \in S$ and there is a path from s to v . Find S that minimises $\sum_{s \in S} cost(s)$	Strongly connected components	80
Bridges	Given a connected graph G , find the edges whose lacking would result in two connected components	Biconnected components	39
Shy Programmers	Given a graph G , decide if it is outerplanar, i.e., you can draw it in a plane so that all vertices lie on a circle and all edges are straight and don't intersect.	construct G' then planarity test	45
Buddy Selection	Given n students with c hobbies each. Determine if they can be matched in pairs such that each pair shares at least f hobbies.	Maximum matching size	49
Tiles	Given a two-dimensional array of where each entry is either marked as "obstacle" or "no obstacle". Determine the maximum number of "tiles" consisting of two neighboring cells fit in the array. No cell of a tile can be placed on an "obstacle" cell.	Maximum matching	101
Consecutive Constructions	Given a DAG. Determine the maximum number of edges that can be packed in vertex-disjoint paths.	Maximum matching	lec. 12

Satellites	Minimum vertex cover of unweighted bipartite graph.	Compute maximum matching and use Konigs Theorem	50
Placing Knights	Determine the maximum number of chess-knights on a field with given size and obstacles.	Maximum independent set (n -maximum matching)	81
Algocoon	Given a directed graph G find the global minimum (directed) cut.	Global minimum cut: find source/sink that minimize flow. Start BFS from source to get the cut.	46
Coin Tossing	Given a sequence of m games, some with known result, some without and s_1, \dots, s_n the number of won games for each player. Determine if it is possible to assign outcomes to unknown games and get standings.	Maximum flow	54
Shopping Trip	Given a Graph and a set of nodes S and a node s . Determine if its possible to find $ S $ edge disjoint paths from s to $S_i \forall S_i \in S$.	Maximum flow	84
Tetris	Given an interval of width w and a list B of intervals with coordinates $[a_i, b_i], 0 \leq a_i, b_i \leq w$ each. A "full line" L is a sequence of intervals of B such that $[0, w]$ is contained in the concatenation of L . Determine the maximum number of "full lines" F that can be constructed using the intervals of B while each interval can only be used once. Moreover each interval border in F is only allowed to occur once in F .	Maximum flow	94
Kingdom Defense	Given graph with maximum and minimum edge capacities and starting and minimum ending vertex budget. Determine if its possible to send have a flow in the network such that min and max edge capacities and the minimum ending vertex budget holds.	Model minimal edge capacities, then maximum flow problem	52
Sweepers	Given an undirected graph G , a list of start vertices S and a list of end vertices $E, S = E $. Determine if it is possible to find $ S $ paths each starting at a vertex of S and end at a vertex of E , (where every start and end vertex can only be used in one path) such that all edges of the graph occur in exactly one path.	Maximum flow and eulerian path check	107
Knights	Given an undirected graph G , a list of start vertices S and a list of end vertices E . Determine the maximum number of edge and vertex disjoint paths from S to E .	Maximum flow	111
The Bracelet	Given a list B of tuples $t_i = (c_{i,1}, c_{i,2})$ and a set of colors $c_{i,j} \in C \subset \mathbb{R}$. Determine if it is possible to construct a strongly connected directed graph such that all tuples in B occur once as vertices, each tuple has exactly one ingoing and exacly one outgoing edge and the following edges are allowed: There can be an edge from t_i to t_k or from t_k to t_i if $c_{i,l_1} = c_{k,l_2}, l_1, l_2 \in \{1, 2\}$.	Eulerian path construction	109
Hit	Given a ray and some line segments. Determine if ray intersects any segment.	loop & test intersection	59

First Hit	Given a ray and some line segments, where does the ray first intersect a segment?	randomize segment order, loop while minimizing intersection	60
Antenna	Given a set of points, find the minimum enclosing circle.	Minimum enclosing circle	56
Almost Antenna	Given a set of points, find the minimum circle that encloses all but one point.	Minimum enclosing circle	57
Theev	Given a set of points P and the center of a circle C_1 in the plane. Determine the radius of two circles with centers C_1 and C_2 such that all points in P are covered.	Sorting and Min circle	86
Search Snippets	Given a set of numbers and their 1D-positions (many for a single number) in a sequence, find the minimum length of a sequence such that all numbers are occurring.	Sweepine	62
Search Snippets	Given a set of numbers and their 1D-positions (many for a single number) in a sequence, find the minimum length of a sequence such that all numbers are occurring.	Sweepine	62
Beach Bar	Given a set of points P in the line. Determine the integral position of a point x such that $ P_x $ is maximum, where P_x are the points in P that are closer than 100 units away from x . Further, if multiple x are possible minimize the distance d_x to the farthest point in P_x . Output all optimal positions, $ P_x $ and d_x	Sweepine	96
Hiking Maps	Given a polygonal path p_0, \dots, p_{m-1} and triangles t_0, \dots, t_{n-1} , what is the minimum length of an interval $[b, e)$ contained in $[0, n)$ such that each leg $p_i p_{i+1}$ of the path is contained in at least one of t_b, \dots, t_{e-1}	Fast triangle intersection test and Sweepine	71
Bistro	Given a set of points in the plane S and a set of points T . Determine for each point in T the distance to the closest point in S .	Delaunay triangulation on S	64
Graypes	Given a set of points G find the shortest distance between any pair of the points.	Delaunay triangulation	67
Collisions	Given a set P of points in the plane and a number d , how many points from P have at least one other point from P in distance $< d$?	Delaunay triangulation	76
Germes	Given a rectangle R and a set of points G inside the rectangle. For every point determine the minimal distance between either any other point or the rectangle boundary.	Delaunay triangulation, then find shortest incident triangulation edge	65
H1N1	How to move a disk without colliding with a given point set?	Precompute for each Delaunay-face the escape radius using DFS.	68
Cover	Given a rectangle and the center of n disks. Determine the minimal radius s.t. the rectangle is fully covered.	Delaunay triangulation (Voronoi)	98

Light the Stage	Given a set D of m disks (players) in the plane, a number h and a sequence I_1, \dots, I_n of n disks of radius h (lamps), denote by $A_i, i \in \{0, \dots, i\}$ the set of all disks $d \in D$ such that d does not overlap with I_j , for any $j \in \{1, \dots, i\}$. Determine the largest k such that A_k is not empty. Output A_k	Delaunay and binary search	103
Diet	Given the price of a food product and some nutritional constraints, calculate the cheapest diet.	Linear Programming	77
Inball	Given a cave $C = \{x \in \mathbb{R}^d a_i^T x \leq b_i, i = 1, \dots, n\}$. Find the ball with the largest radius that is contained in C .	Linear Programming	79
Radiation	Given a set of points H and a set of points T in the plane. Determine the smallest number d , such that a polynomial of degree d can completely distinguish all points in H from all points T .	Linear programming	105
Missing Roads	Given a weighted undirected graph and a number k , determine the matching M consisting of k edges where the sum of the weights in M is minimized.	Linear programming.	117
Software update	Given a list of centers of disks in the plane. Determine the maximal sum of the radii such that no two disks overlap	Linear programming.	lec.13
Maximize It	Solve two quadratic programs.	Quadratic Programming	74
Portfolios	Given price, expected return and the covariance matrix of some assets and the minimum expected portfolio return, maximum portfolio cost and maximum portfolio variance of some investor. Determine if a portfolio for the investor exists.	Quadratic Programming	78
Stamp Exhibition	Given a set of stamps S , a set of lamps L and a set of segments W in the plane. Each $s_i \in S$ has a maximal allowed light intensity M_i . Determine if its possible to set the power p_i of the i -th lamp such that each stamp is illuminated with intensity > 1 but smaller M_i .	Quadratic Programming	92
Portfolios revisited	Given price, expected return and the covariance matrix of some assets and the maximum portfolio cost and maximum portfolio variance of some investor. Determine the maximum possible expected return.	Quadratic Programming and Binary search	90

Misc

Methods

- -
- Sorting
- Binary search
- Greedy
- Dynamic programming (Trigger: current computation does not depend on previous computation)
- BFS/DFS
- Shortest path/Dijkstra
- Minimum spanning tree
- (strongly) Connected components
- Biconnected components
- Planarity test
- Maximum matching (Biconnected: Max Vertex Cover/Maximum Independent Set)
- (global) Minimum cut
- Network flows
- Eulerian path
- Minimum enclosing circle
- Sweepline
- Delaunay triangulation
- Linear Programming / Quadratic Programming
- Backtracking

Potential problems: too slow

- `std::ios_base::sync_with_stdio(false);`
- check if there is possibility for a cache over testcases
- check if every non-primitive variable is called by reference
- find upper/lower bound
- try binary search or combination of binary search and linear search
- If CGAL: try randomization of input
- If QP/LP:solve LP with **linear** program solver
- If QP/LP:use nonnegative program where possible

Potential problems: error

- Assertion Error: off-by-one/memory
- CGAL: Think of infinite vertex
- Input size requirements

Useful Code Snippets

```
1  #include <iostream>
2  #include <vector>
3  #include <sstream>
4  #include <string.h>
5  #include <stdio.h>
6
7  using namespace std;
8
9  /*
10   * debug macro
11   */
12  #define DEBUG
13  #ifdef DEBUG
14  #define D(x) x
15  #else
16  #define D(x)
17  #endif
18
19  /*
20   * fast I/O
21   */
22  ios_base::sync_with_stdio(false);
23
24  /*
25   * output floating point numbers in fixed point notation
26   * setprecision: number of digits after the decimal point
27   */
28  std::cout<<std::setiosflags(std::ios::fixed) << std::setprecision(0)<< ceil_to_double(sqrt(CGAL::to_double(maxDist)))
29          <<std::endl;
30
31  /*
32   * number to string
33   */
34  template <typename T>
35      string NumberToString ( T Number )
36      {
37          ostringstream ss;
38          ss << Number;
39          return ss.str();
40      }
41
42  /*
43   * highest and lowest of orderable types
44   */
45  #include <limits>
46  int max = numeric_limits<int>::max();
47  int min = numeric_limits<int>::min();
48
49  /*
50   * enums
51   */
52  enum enumeration_name {
53      value1,
54      value2,
55      value3,
56  };
57
58  /*
59   * power
60   */
61  #include <math.h>
62  pow(7,3) //7^3
63
64  /*
65   * sqrt
66   */
67  #include <math.h>
68  double result = sqrt(1024.0);
69
70  #include <cstdlib>
71  double result = std::abs(-1024.0);
72
73  /*
74   * sum vector contents
```

```

75  */
76  #include<numeric>
77  std::accumulate(newTopChipPosition.begin(),
78                  newTopChipPosition.end(),0);
79
80  /*
81   * sort array
82   */
83  #include<algorithm>
84  std::sort(parasols.begin(), parasols.end());
85
86  /*
87   * find in vector
88   */
89  std::find(aVector.begin(), aVector.end(), item)!=aVector.end()
90
91  /*
92   * get index of max/min element in vector
93   */
94  #include <algorithm>
95  std::vector<int> v(10,0);
96  int a[] = {1,2,3,2};
97  int maxIndex = std::max_element(v.begin(), v.end());
98  int maxIndex2 = std::max_element(a, a+4);
99
100 /*
101  * set intersection
102  */
103 std::vector<string> inters;
104 std::set_intersection(chars[i].begin(), chars[i].end(),
105                       chars[j].begin(), chars[j].end(),
106                       std::back_inserter(inters));
107
108 /*
109  * queue reverse order
110  */
111 priority_queue<int, vector<int>, greater<int>> Q;
112
113 /*
114  * comparator
115  */
116 struct faceComparator {
117     bool operator() (const Face_handle &x, const Face_handle &y) {
118         return (x->info() < y->info());
119     }
120 };
121 std::set<Face_handle, faceComparator> faces;
122
123 /*
124  * non-static comparator
125  */
126 struct CityComparator{
127     P mainCity;
128     bool operator()(P x, P y) {
129         K::FT d1 = S(mainCity, x).squared_length();
130         K::FT d2 = S(mainCity, y).squared_length();
131         return(d1 <d2);
132     }
133 };
134
135 /*
136  * Binary Search
137  */
138 int midpoint(int lowerBound, int upperBound) {
139     return lowerBound + (upperBound-lowerBound)/2;
140 }
141
142 int binary_search(int A[], int key, int imin, int imax)
143 {
144     // continue searching while [imin,imax] is not empty
145     while (imax >= imin)
146     {
147         // calculate the midpoint for roughly equal partition
148         int imid = midpoint(imin, imax);
149         if(A[imid] == key)
150

```



```

151         // key found at index imid
152         return imid;
153     // determine which subarray to search
154     else if (A[imid] < key)
155         // change min index to search upper subarray
156         imin = imid + 1;
157     else
158         // change max index to search lower subarray
159         imax = imid - 1;
160 }
161 // key was not found
162 return KEY_NOT_FOUND;
163 }
164
165
166
167 /*
168  * BOOST
169  */
170 /*
171  * print graph
172  */
173 void printGraph(Graph g, WeightMap weight) {
174     graph_traits<Graph>::edge_iterator eiter, eiter_end;
175     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
176         std::cout << source(*eiter, g) << " <--> " << target(*eiter, g)
177             << " with weight of " << weight[*eiter]
178             << std::endl;
179     }
180 }
181
182 /*
183  * shortest path BFS
184  */
185 int shortestPath(const Graph &g, int x, int y) {
186     //BFS
187     int n=num_vertices(g);
188     vector<bool> visited(n, false);
189     vector<int> distance(n, -1);
190     std::queue<int> bfs_queue;
191
192     vector<int> bfs_num(n);
193     bfs_queue.push(x);
194     visited[x] = true;
195     distance[x] = 0;
196     while (!bfs_queue.empty()) {
197         int v = bfs_queue.front();
198         bfs_queue.pop();
199         //cerr << "visit : " << v << "\n";
200         GraphTraits::out_edge_iterator e, e_end;
201         for (tie(e, e_end) = out_edges(v, g); e != e_end; ++e) {
202             Vertex t = target(*e, g);
203             if (!visited[t]) {
204                 visited[t] = true;
205                 distance[t] = distance[v] + 1;
206                 //cerr << "enqueue " << t << "\n";
207                 if(t==y) return distance[t];
208                 bfs_queue.push(t);
209             }
210         }
211     }
212     return 0;
213 }
214
215 /*
216  * non-recursive DFS
217  */
218 int main ()
219 {
220     int n;
221     vector<vector<int> > edges;
222     read_graph(n, edges);
223     /* 8< */
224     vector<bool> visited(n, false);
225     vector<int> dfs_stack;
226     vector<int> dfs_neighbor_pos;

```

```

227     int next_num = 0;
228     vector<int> dfs_num(n);
229     for (int u = 0; u < n; u++) {
230         if (visited[u])
231             continue;
232         dfs_stack.push_back(u);
233         dfs_neighbor_pos.push_back(0);
234         visited[u] = true;
235         dfs_num[u] = next_num++;
236         cerr << "visit_" << dfs_num[u] << ":\n" << u << "\n";
237         while (!dfs_stack.empty()) {
238             int v = dfs_stack.back();
239             int i = dfs_neighbor_pos.back();
240             dfs_stack.pop_back();
241             dfs_neighbor_pos.pop_back();
242             vector<int>& neighbors = edges[v];
243             for (; i < (int)neighbors.size(); i++) {
244                 int w = neighbors[i];
245                 if (!visited[w]) {
246                     /* defer looking at v */
247                     dfs_stack.push_back(v);
248                     dfs_neighbor_pos.push_back(i+1);
249                     /* look at w next */
250                     visited[w] = true;
251                     dfs_num[w] = next_num++;
252                     dfs_stack.push_back(w);
253                     dfs_neighbor_pos.push_back(0);
254                     cerr << "visit_" << dfs_num[w] << ":\n" << w << "\n";
255                     break;
256                 }
257                 /* if we fall off this loop (as opposed to break), we
258                  * are done looking at v */
259             }
260         }
261     }
262     /* >8 */
263 }
264
265 /*
266  * QP Debugging
267  */
268 cout<<qp.get_n()<<std::endl;
269 cout<<qp.get_m()<<std::endl;
270 CGAL::print_quadratic_program(std::cerr, qp, "qp");
271
272 CGAL::Quadratic_program_options options;
273 options.set_pricing_strategy(CGAL::QP_BLAND);
274 Solution s = CGAL::solve_linear_program(qp, ET(), options);

```

Checking Change

```
1  #include <iostream>
2  #include <vector>
3  #include <utility>
4  #include <limits>
5  #include <stdio.h>
6  #include <string.h>
7
8  using namespace std;
9
10 /*
11  * c[] coin denominations
12  * ci |c[]|
13  * n change
14  */
15 int *change(int c[], int ci, int n) {
16     int *C = new int[n+1];
17     C[0] = 0;
18     for(int p=1; p <= n; p++) {
19         int min = numeric_limits<int>::max() - 1;
20         for(int i=0; i < ci; i++) {
21             if(c[i] <= p) {
22                 if (1 + C[p-c[i]] < min) {
23                     min = 1 + C[p-c[i]];
24                 }
25             }
26         }
27         C[p] = min;
28     }
29     return C;
30 }
31
32 int changeRec(int c[], int ci, int n) {
33     if(n==0) {
34         return 0;
35     } else {
36         int min = numeric_limits<int>::max() - 1;
37         for(int i=ci-1; i >= 0; i--) {
38             if(c[i] <= n) {
39                 int tryChange = changeRec(c, ci, n-c[i]);
40                 if (1 + tryChange < min) {
41                     min = 1 + tryChange;
42                 }
43             }
44         }
45         return min;
46     }
47 }
48
49
50 //C[n] initialised with -1
51 int changeFast(vector<int> &C, int c[], int ci, int n) {
52     if(n==0) {
53         C[n] = 0;
54     } else if(C[n] == -1) {
55         int min = numeric_limits<int>::max() - 1;
56         for(int i=ci-1; i >= 0; i--) {
57             if(c[i] <= n) {
58                 int tryChange = changeFast(C, c, ci, n-c[i]);
59                 if (1 + tryChange < min) {
60                     min = 1 + tryChange;
61                 }
62             }
63         }
64         C[n] = min;
65     }
66     return C[n];
67 }
68
69 void reverse(int *word, int len)
70 {
71     int temp;
72     for (int i=0;i<len/2;i++)
73     {
```

```

74         temp=word[i];
75         word[i]=word[len-i-1];
76         word[len-i-1]=temp;
77     }
78 }
79
80 int *changeFaster(int c[],int n, const int A, int **C) {
81     reverse(c, n);
82     for(int j=0; j<A; j++) {
83         C[n-1][j] =j;
84     }
85     for(int i=n-2; i>=0; i--) {
86         for(int j=0; j<A; j++) {
87             if(c[i] > j || C[i+1][j] < 1 + C[i][j-c[i]]) {
88                 C[i][j] = C[i+1][j];
89             } else {
90                 C[i][j] = 1 + C[i][j-c[i]];
91             }
92         }
93     }
94 }
95
96
97 int count( int S[], int m, int n )
98 {
99     // table[i] will be storing the number of solutions for
100    // value i. We need n+1 rows as the table is constructed
101    // in bottom up manner using the base case (n = 0)
102    int table[n+1];
103
104    // Initialize all table values as 0
105    memset(table, 0, sizeof(table));
106
107    // Base case (If given value is 0)
108    table[0] = 0;
109
110    // Pick all coins one by one and update the table[] values
111    // after the index greater than or equal to the value of the
112    // picked coin
113    for(int i=0; i<m; i++)
114        for(int j=S[i]; j<=n; j++)
115            table[j] += table[j-S[i]];
116
117    return table[n];
118 }
119
120 // fill vector up such that all indices n - former C.size() are -1
121 void fillVector(vector<int> &C, int n) {
122     for(int i=C.size(); i < n+1; i++) {
123         C.push_back(-1);
124     }
125 }
126
127 void printVector(vector<int> &C) {
128     for(int i=0; i < C.size(); i++) {
129         cout << C[i] << " ";
130     }
131     cout << endl;
132 }
133
134 int main() {
135     cin.sync_with_stdio(false);
136     cout.sync_with_stdio(false);
137     int testCases;
138     cin >> testCases;
139
140     for(int i=0; i < testCases; i++) {
141         int ci, mi;
142         cin >> ci >> mi;
143         int c[ci];
144         for(int j=0; j < ci; j++) {
145             int coinValue;
146             cin >> coinValue;
147             c[j] = coinValue;
148         }
149         vector<int> C;

```

```

150     for(int k=0; k < mi; k++) {
151         int n;
152         cin >> n;
153         fillVector(C, n);
154
155         changeFast(C, c, ci, n);
156         int numCoins = C[n];
157         if(numCoins == numeric_limits<int>::max() - 1) {
158             cout << "not_possible" << endl;
159         } else {
160             cout << numCoins << endl;
161         }
162         // delete C;
163     }
164 }
165 }

```

Dominoes

```
1  #include <iostream>
2  #include <vector>
3  #include <utility>
4  #include <limits>
5  #include <algorithm>
6
7  using namespace std;
8
9  int main() {
10     std::ios_base::sync_with_stdio(false);
11     int testCases;
12     cin >> testCases;
13
14     for(int k=0; k < testCases; k++) {
15         int n;
16         cin >> n;
17         int numFall = 0;
18
19         int h0; //height of the first dominoe which is surely falling
20         cin >> h0;
21         int accH = h0; //accH is the currently highest falling dominoe
22
23         for(numFall=1; numFall < n; numFall++) {
24             int h;
25             cin >> h;
26             accH= accH-1;
27             if(accH > 0) {
28                 accH = max(accH, h);
29             } else {
30                 break; //this dominoe does not fall
31             }
32         }
33         //read rest of the file
34         for(int r=numFall+1; r<n;r++) {
35             int h;
36             cin >> h;
37         }
38
39         cout << numFall << endl;
40     }
41 }
```

Shelves

```
1  #include <iostream>
2  #include <vector>
3  #include <utility>
4  #include <limits>
5  #include <math.h>
6
7  using namespace std;
8
9  struct triple {
10     int first;
11     int second;
12     int third;
13 };
14
15 void computeSlow(triple &result, int lTotal, int lM, int lN) {
16     for(int uncovered = 0; uncovered < lTotal; uncovered++) {
17         int rest = lTotal - uncovered;
18         // cout << uncovered << " rest:" << rest << " ";
19         for(int numN = rest/lN; numN >= 0; numN--) {
20             rest = lTotal - uncovered - numN*lN;
21             // cout << " numN: " << numN << " rest:"<< rest << " ";
22             for(int numM = rest/lM; numM >= 0; numM--) {
23                 rest = lTotal - uncovered - numN*lN - numM*lM;
24                 // cout << " numM: " << numM << " rest:"<< rest << " "<< endl;
25                 if(rest==0) {
26                     result.first=numM;
27                     result.second=numN;
28                     result.third=uncovered;
29
30                     return;
31                 }
32             }
33         }
34     }
35     result.first = 0;
36     result.second = 0;
37     result.third = lTotal;
38 }
39
40 void computeFast(triple &result, int lTotal, int lM, int lN) {
41     int rest = lTotal;
42     int a, b = 0;
43     for(int bp=0; bp<=lTotal/lN; bp++) {
44         int ap = (lTotal-bp*lN)/lM;
45         int restp = lTotal - ap*lM - bp*lN;
46         if(restp <= rest) {
47             rest = restp;
48             b = bp;
49             a = ap;
50         }
51     }
52     result.first = a;
53     result.second = b;
54     result.third = rest;
55     return;
56 }
57
58 // runtime sqrt(lTotal)
59 void computeVeryFast(triple &result, int lTotal, int lM, int lN) {
60     int rest = lTotal;
61     int a, b = 0;
62     if(lN < sqrt(lTotal)) { // lTotal is big
63         for(int ap=lN-1; ap >=0; ap--) {
64             int bp = (lTotal-ap*lM)/lN;
65             int restp = lTotal - ap*lM - bp*lN;
66             if(restp <= rest) {
67                 rest = restp;
68                 b = bp;
69                 a = ap;
70             }
71         }
72     } else { //lN > sqrt(lTotal) => loop iterates < lTotal/sqrt(lTotal) < sqrt(lTotal)
```

```

74         for(int bp=0; bp<=lTotal/lN; bp++) {
75             int ap = (lTotal-bp*lN)/lM;
76             int restp = lTotal - ap*lM - bp*lN;
77             if(restp <= rest) {
78                 rest = restp;
79                 b = bp;
80                 a = ap;
81             }
82         }
83     }
84     result.first = a;
85     result.second = b;
86     result.third = rest;
87     return;
88 }
89
90
91 int main() {
92     int testCases;
93
94     cin >> testCases;
95
96     for(int i=0; i < testCases; i++) {
97         int lTotal, lM, lN, nM, nN, uncovered;
98         cin >> lTotal >> lM >> lN;
99         triple result;
100         computeVeryFast(result, lTotal, lM, lN);
101         cout << result.first << "␣" << result.second << "␣" << result.third << endl;
102     }
103
104     return 0;
105 }

```


Even Pairs

```
1  #include <iostream>
2  #include <vector>
3  #include <utility>
4  #include <limits>
5  #include <math.h>
6
7  using namespace std;
8
9  struct triple {
10     int first;
11     int second;
12     int third;
13 };
14
15 void computeSlow(triple &result, int lTotal, int lM, int lN) {
16     for(int uncovered = 0; uncovered < lTotal; uncovered++) {
17         int rest = lTotal - uncovered;
18         // cout << uncovered << " rest:" << rest << " ";
19         for(int numN = rest/lN; numN >= 0; numN--) {
20             rest = lTotal - uncovered - numN*lN;
21             // cout << " numN: " << numN << " rest:"<< rest << " ";
22             for(int numM = rest/lM; numM >= 0; numM--) {
23                 rest = lTotal - uncovered - numN*lN - numM*lM;
24                 // cout << " numM: " << numM << " rest:"<< rest << " "<< endl;
25                 if(rest==0) {
26                     result.first=numM;
27                     result.second=numN;
28                     result.third=uncovered;
29
30                     return;
31                 }
32             }
33         }
34     }
35     result.first = 0;
36     result.second = 0;
37     result.third = lTotal;
38 }
39
40 void computeFast(triple &result, int lTotal, int lM, int lN) {
41     int rest = lTotal;
42     int a, b = 0;
43     for(int bp=0; bp<=lTotal/lN; bp++) {
44         int ap = (lTotal-bp*lN)/lM;
45         int restp = lTotal - ap*lM - bp*lN;
46         if(restp <= rest) {
47             rest = restp;
48             b = bp;
49             a = ap;
50         }
51     }
52     result.first = a;
53     result.second = b;
54     result.third = rest;
55     return;
56 }
57
58 // runtime sqrt(lTotal)
59 void computeVeryFast(triple &result, int lTotal, int lM, int lN) {
60     int rest = lTotal;
61     int a, b = 0;
62     if(lN < sqrt(lTotal)) { // lTotal is big
63         for(int ap=lN-1; ap >=0; ap--) {
64             int bp = (lTotal-ap*lM)/lN;
65             int restp = lTotal - ap*lM - bp*lN;
66             if(restp <= rest) {
67                 rest = restp;
68                 b = bp;
69                 a = ap;
70             }
71         }
72     } else { //lN > sqrt(lTotal) => loop iterates < lTotal/sqrt(lTotal) < sqrt(lTotal)
```

```

74         for(int bp=0; bp<=lTotal/lN; bp++) {
75             int ap = (lTotal-bp*lN)/lM;
76             int restp = lTotal - ap*lM - bp*lN;
77             if(restp <= rest) {
78                 rest = restp;
79                 b = bp;
80                 a = ap;
81             }
82         }
83     }
84     result.first = a;
85     result.second = b;
86     result.third = rest;
87     return;
88 }
89
90
91 int main() {
92     int testCases;
93
94     cin >> testCases;
95
96     for(int i=0; i < testCases; i++) {
97         int lTotal, lM, lN, nM, nN, uncovered;
98         cin >> lTotal >> lM >> lN;
99         triple result;
100         computeVeryFast(result, lTotal, lM, lN);
101         cout << result.first << "␣" << result.second << "␣" << result.third << endl;
102     }
103
104     return 0;
105 }

```

Aliens

```
1  #include <iostream>
2  #include <limits>
3  #include <set>
4  #include <vector>
5  #include <algorithm>
6
7  using namespace std;
8
9  int numSuperior(vector<pair<int, int> > &interval, int numHumans) {
10     sort(interval.begin(), interval.end());
11     int rightmost = 0;
12     for(int i=0; i<interval.size(); i++) {
13         if(interval[i].first > rightmost + 1)
14             return 0;
15         else
16             rightmost = max(rightmost, interval[i].second);
17     }
18     if(rightmost < numHumans)
19         return 0;
20
21     rightmost = 0;
22     int rightMostI = -1;
23     int beforeLeft = 0;
24     int numSuperiorAliens;
25     int beforeI;
26     vector<bool> isSuperior(interval.size(), true);
27
28     for(int i=0; i<interval.size(); i++) {
29         if(interval[i].first != beforeLeft) {
30             if(interval[i].second <= rightmost) {
31                 isSuperior[i] = false;
32                 // cout << "right intervall smaller equal rightmost" << endl;
33             }
34             else {
35                 if(interval[i].second < rightmost) {
36                     isSuperior[i] = false;
37                     // cout << "right intervall smaller equal rightmost" << endl;
38                 }
39                 else if(interval[i].second == rightmost) {
40                     isSuperior[i] = false;
41                     isSuperior[beforeI] = false;
42                     //cout << "right intervall equal rightmost";
43                 }
44                 else {
45                     isSuperior[beforeI] = false;
46                 }
47             }
48             if(rightmost <= interval[i].second) {
49                 rightmost = interval[i].second;
50             }
51             beforeI = i;
52             beforeLeft = interval[i].first;
53         }
54         numSuperiorAliens=0;
55         for(int i=0; i<isSuperior.size(); i++) {
56             // cout << "alien: " << interval[i].first << " " << interval[i].second << " ";
57             if(isSuperior[i]) {
58                 numSuperiorAliens++;
59                 // cout << "is superior!!";
60             }
61             // cout << endl;
62         }
63     }
64
65     return numSuperiorAliens;
66 }
67
68 int main() {
69     ios_base::sync_with_stdio(false);
70     int testCases;
71     cin >> testCases;
72
73     for(int t=0; t < testCases; t++) {
74         int numHumans, numAliens;
75         cin >> numAliens >> numHumans;
```

```

74     vector<pair<int, int> > interval;
75     for(int i=0; i < numAliens; i++) {
76         int intervalLeft;
77         int intervalRight;
78         cin >> intervalLeft >> intervalRight;
79         if(intervalLeft != 0 && intervalRight!=0) {
80             pair<int, int> anInterval = pair<int, int>(intervalLeft, intervalRight);
81             interval.push_back(anInterval);
82         }
83     }
84     cout << numSuperior(interval, numHumans) << endl;
85 }
86 }

```

Boats

```
1  #include <iostream>
2  #include <limits>
3  #include <set>
4  #include <vector>
5  #include <algorithm>
6  using namespace std;
7
8  class boat {
9  public:
10     int length;
11     int position;
12     boat(int len, int pos) {
13         length = len;
14         position = pos;
15     }
16     bool operator< (const boat& other) const {
17         return position < other.position;
18     }
19     bool operator== (const boat& other) const {
20         return length == other.length
21             && position == other.position;
22     }
23 };
24
25 int numBoats(int numWizards, set<boat> &boats) {
26     int curPos = numeric_limits<int>::min();
27     int numBoats = 0;
28     int i = 0;
29     while(boats.size() > 0 ) {
30         set<boat>::iterator it;
31         for(it=boats.begin(); (*it).position < curPos; it++) {
32             boats.erase(it);
33         }
34         // if(it==boats.end()) {
35         //     return numBoats;
36         // }
37         int bestEnd = numeric_limits<int>::max();
38         // boat bestBoat(bestEnd, bestEnd);
39         const boat *bestBoat = NULL;
40         set<boat>::iterator bestBoatIterator;
41         for(it=boats.begin(); it!=boats.end(); it++) {
42             int begin = ((*it).position - (*it).length > curPos) ? ((*it).position-(*it).length) : curPos;
43             int end = begin + (*it).length;
44             if(end < bestEnd) {
45                 bestEnd = end;
46                 bestBoat = &(*it);
47                 bestBoatIterator = it;
48             }
49             if((*it).position > bestEnd) {
50                 break;
51             }
52         }
53         curPos=bestEnd;
54         bestBoat = bestBoat;
55         numBoats+=1;
56         i++;
57         // cout << "boat " << i << " with p:" << bestBoat->position << " l:" << bestBoat->length << " , end is at " <<
58         //     << curPos << endl;
59         boats.erase(bestBoatIterator);
60     }
61     return numBoats;
62 }
63
64 int numBoatsFast(int numWizards, vector<boat> &boats) {
65     int i = 0;
66     sort(boats.begin(), boats.end());
67     // int curPos = (*boats.begin()).position;
68     int curPos = numeric_limits<int>::min();
69     // i++;
70     // int numBoats = 1;
71     int numBoats = 0;
72     while(i < numWizards) {
```

```

73     for(;i < numWizards && boats[i].position < curPos; i++);
74     if(i==numWizards) break;
75     int newMaxPos = numeric_limits<int>::max();
76     int j = i;
77     while(j < numWizards && boats[j].position < newMaxPos){
78         int proposed = max(boats[j].position, curPos + boats[j].length);
79         if(proposed < newMaxPos) {
80             newMaxPos = proposed;
81         }
82         j++;
83     }
84     curPos = newMaxPos;
85     // cout << "boat " << j-1 << " with p:" << boats[j-1].position << " l:" << boats[j-1].length << " , end is at ↵
86         ↵ " << curPos << endl;
87     numBoats++;
88     i+=(j-i);
89     // i++;
90 }
91 return numBoats;
92 }
93 int main() {
94     ios_base::sync_with_stdio(false);
95     int testCases;
96     cin >> testCases;
97
98     for(int i=0; i < testCases; i++) {
99         int numWizards;
100         cin >> numWizards;
101         vector<boat> boats (numWizards, boat(0,0));
102         for(int j=0; j < numWizards; j++) {
103             int length;
104             int position;
105             cin >> length >> position;
106             boats[j] = boat(length, position);
107         }
108         cout << numBoatsFast(numWizards, boats) << endl;
109     }
110 }

```

False Coin

```
1  #include <iostream>
2  #include <vector>
3  #include <utility>
4  #include <limits>
5  #include <stdio.h>
6  #include <string.h>
7  #include <sstream>
8
9  using namespace std;
10
11 bool *initializeArray(bool init, int n) {
12     bool *array = new bool[n];
13     for(int i=0; i < n; i++) {
14         array[i] = init;
15     }
16     return array;
17 }
18
19 string falseCoin(bool suspicious[], int numCoins) {
20     int fCoin = -1;
21     for(int i=0; i<numCoins; i++) {
22         if(suspicious[i]) {
23             if(fCoin!=-1) {
24                 return "0";
25             } else {
26                 fCoin = i+1;
27             }
28         }
29     }
30     return static_cast<ostringstream*>( &(ostringstream() << fCoin) )->str();
31 }
32
33 int main() {
34     cin.sync_with_stdio(false);
35     int testCases;
36     cin >> testCases;
37
38     for(int i=0; i < testCases; i++) {
39         // char newline;
40         // cin >> newline;
41
42         int numCoins, numWeighings;
43         cin >> numCoins >> numWeighings;
44         bool *suspicious = initializeArray(true, numCoins);
45
46         for(int j=0; j < numWeighings; j++) {
47             int amountInPan;
48             cin >> amountInPan;
49             bool *weighingCoins = initializeArray(false, numCoins);
50             // read currently weighted coins
51             for(int k=0; k < 2*amountInPan; k++) {
52                 int currentCoin;
53                 cin >> currentCoin;
54                 weighingCoins[currentCoin-1] = true;
55             }
56
57             char outcome;
58             cin >> outcome;
59             if(outcome == '=') {
60                 //every weighing coin true, is false in coins
61                 for(int k=0; k<numCoins; k++) {
62                     if(weighingCoins[k]) {
63                         suspicious[k] = false;
64                     }
65                 }
66             } else {
67                 //set all others to false
68                 for(int k=0; k<numCoins; k++) {
69                     if(!weighingCoins[k]) {
70                         suspicious[k] = false;
71                     }
72                 }
73             }
74         }
75     }
```

```
74         delete weighingCoins;
75     }
76
77     cout << falseCoin(suspicious, numCoins) << endl;
78     delete suspicious;
79 }
80 }
```


Formula One

```
1  #include <iostream>
2  #include <iterator>
3  #include <vector>
4
5  using namespace std;
6
7  void swap(int* array, int i, int j) {
8      int tmp;
9      tmp = array[j];
10     array[j] = array[i];
11     array[i] = tmp;
12 }
13
14 int overpasses;
15
16 /// \brief Merges two sorted vectors into one sorted vector
17 /// \param left A sorted vector of integers
18 /// \param right A sorted vector of integers
19 /// \return A sorted vector that is the result of merging two sorted
20 /// vectors.
21 vector<int> merge(const vector<int>& left, const vector<int>& right)
22 {
23     // Fill the resultant vector with sorted results from both vectors
24     vector<int> result;
25     unsigned left_it = 0, right_it = 0;
26
27     while(left_it < left.size() && right_it < right.size())
28     {
29         // If the left value is smaller than the right it goes next
30         // into the resultant vector
31         if(left[left_it] < right[right_it])
32         {
33             result.push_back(left[left_it]);
34             left_it++;
35             overpasses= (overpasses + right_it) % 10000;
36         }
37         else
38         {
39             result.push_back(right[right_it]);
40             right_it++;
41         }
42     }
43
44     // Push the remaining data from both vectors onto the resultant
45     while(left_it < left.size())
46     {
47         result.push_back(left[left_it]);
48         overpasses= (overpasses + right_it) % 10000;
49         left_it++;
50     }
51
52     while(right_it < right.size())
53     {
54         result.push_back(right[right_it]);
55         right_it++;
56     }
57
58     return result;
59 }
60 /// \brief Performs a recursive merge sort on the given vector
61 /// \param vec The vector to be sorted using the merge sort
62 /// \return The sorted resultant vector after merge sort is
63 /// complete.
64 vector<int> merge_sort(vector<int>& vec)
65 {
66     // Termination condition: List is completely sorted if it
67     // only contains a single element.
68     if(vec.size() == 1)
69     {
70         return vec;
71     }
72
73     // Determine the location of the middle element in the vector
```

```

74     std::vector<int>::iterator middle = vec.begin() + (vec.size() / 2);
75
76     vector<int> left(vec.begin(), middle);
77     vector<int> right(middle, vec.end());
78
79     // Perform a merge sort on the two smaller vectors
80     left = merge_sort(left);
81     right = merge_sort(right);
82
83     return merge(left, right);
84 }
85
86 /*
87  * return number of bubble sort steps necessary
88  */
89 int bubbleSort(int* order, int numRacers) {
90     bool swapped = false;
91     int numSwaps = 0;
92     int n = numRacers;
93
94     do {
95         int newN = 0;
96         swapped = false;
97         for(int i=1; i<n; i++) {
98             if(order[i-1] > order[i]) {
99                 swap(order, i-1, i);
100                 swapped = true;
101                 newN = i;
102                 numSwaps++;
103             }
104         }
105         n = newN;
106     } while(!n==0);
107
108     return numSwaps;
109 }
110
111 // uses bubbleSort to control for correctness of the merge sort overpasses counting
112 void controlIfCorrect(vector<int> order) {
113     int orderArray[order.size()];
114     copy(order.begin(), order.end(), orderArray);
115
116     int overpBubble = bubbleSort(orderArray, order.size());
117
118     if(overpBubble == overpasses) {
119         // cout << "ok: " << overpasses << endl;
120     } else {
121         cout << "different_answer: bubble: " << overpBubble << "merge: " << overpasses << endl;
122         cout << "testset: " << endl;
123         copy(order.begin(), order.end(), ostream_iterator<int>(cout, " "));
124     }
125 }
126
127 int main() {
128     cin.sync_with_stdio(false);
129     int testCases;
130     cin >> testCases;
131
132     for(int i=0; i < testCases; i++) {
133         int numRacers;
134         cin >> numRacers;
135
136         // int order[numRacers];
137         vector<int> order;
138         for(int j=0; j < numRacers; j++) {
139             int racer;
140             cin >> racer;
141             order.push_back(racer);
142         }
143
144         overpasses = 0;
145         merge_sort(order);
146
147         // controlIfCorrect(order);
148
149         cout << overpasses % 10000 << endl;

```

```
150  
151  
152 }
```

Race Tracks

```
1  #include <iostream>
2  #include <limits>
3  #include <vector>
4  #include <queue>
5  #include <set>
6  #include <sstream>
7  #include <cstdlib>
8
9  using namespace std;
10
11 template <typename T>
12     string NumberToString ( T Number )
13     {
14         ostringstream ss;
15         ss << Number;
16         return ss.str();
17     }
18
19 class point {
20     private:
21         int x;
22         int y;
23
24     public:
25         point(int X, int Y) {
26             x = X;
27             y = Y;
28         }
29         point(const point &p) {
30             x = p.x;
31             y = p.y;
32         }
33         bool operator== (const point &other) const {
34             return (x == other.getX() &&
35                     y == other.getY());
36         }
37         bool operator!= (const point &other) const {
38             return !(*this == other);
39         }
40         bool operator< (const point &other) const {
41             if(x < other.x) {
42                 return true;
43             } else if((x == other.x) && (y < other.y)) {
44                 return true;
45             }
46             return false;
47         }
48         int getX() const { return x; }
49         int getY() const { return y; }
50         string str() const { return "(" + NumberToString(x) + "□" + NumberToString(y) + ")"; }
51 };
52
53 class vertex {
54     private:
55         point position;
56         point velocity;
57         int distance;
58     public:
59         vertex(point &i_position, point &i_velocity) :
60             position(0,0), velocity(0,0) {
61             position = i_position;
62             velocity = i_velocity;
63             distance = numeric_limits<int>::max();
64         }
65         bool operator== (const vertex &other) const {
66             return (position == other.position
67                     && velocity == other.velocity
68                     );
69         }
70         bool operator!= (const vertex &other) const {
71             return !(*this == other);
72         }
73         bool operator < (const vertex& other) const {
```

```

74         if(position < other.getPosition()) {
75             return true;
76         } else if(position == other.position) {
77             return (velocity < other.velocity);
78         }
79         return false;
80     }
81     point getPosition() const { return position; }
82     point getVelocity() const { return velocity; }
83     int getDistance() const { return distance; }
84     void setDistance(int distance_arg) { distance = distance_arg; return;}
85     string str() const { return "(" + NumberToString(distance) + "," + position.str() + "," + velocity.str() + "\n"; }
86 };
87
88 struct OrderByDistance {
89     bool operator() (const vertex& v1, const vertex& v2) const {
90         return (v1.getDistance() > v2.getDistance());
91     }
92 };
93
94 struct Obstacle {
95     int x1;
96     int x2;
97     int y1;
98     int y2;
99 };
100
101 bool validPosition(point p, int width, int height, Obstacle obstacles[], int numObstacles) {
102     if(!((0<=p.getX()) && (p.getX()<width) && (0<=p.getY()) && (p.getY()<height))) {
103         return false;
104     }
105     for(int i=0; i < numObstacles; i++) {
106         Obstacle o = obstacles[i];
107         if((o.x1 <= p.getX()) && (p.getX() <= o.x2) &&
108            (o.y1 <= p.getY()) && (p.getY() <= o.y2)) {
109             // cout << o.x1 << " " << p.getX() << " " << o.x2 << endl;
110             // cout << o.y1 << " " << p.getY() << " " << o.y2 << endl;
111             return false;
112         }
113     }
114     return true;
115 }
116
117 void printQueue(priority_queue<vertex,vector<vertex>,OrderByDistance> queue) {
118     cout << "Queue: ";
119     while(queue.size() > 0) {
120         cout << queue.top().str() << ","; queue.pop();
121     }
122     cout << endl;
123 }
124
125 void printSet(set<vertex> visit) {
126     cout << "Visited: ";
127     while(visit.size() > 0) {
128         set<vertex>::iterator firstEle = visit.begin();
129         cout << (*firstEle).str() << ","; visit.erase(firstEle);
130     }
131     cout << endl;
132 }
133
134 int vertexToHash(vertex v, int width, int height) {
135     // x y xa ya
136     return (v.getPosition().getX() * (height * 7 * 7)
137            + v.getPosition().getY() * 7 * 7
138            + (v.getVelocity().getX()+3) * 7
139            + (v.getVelocity().getY()+3));
140 }
141
142 vertex hashToVertex(int hash, int width, int height) {
143     int ya = (hash%7)-3;
144     hash = hash/7;
145     int xa = (hash%7)-3;
146     hash = hash/7;
147     int y = hash%height;

```

```

149     hash = hash/height;
150     int x = hash;
151     point pos =point(x,y);
152     point vel = point(xa,ya);
153     return vertex(pos,vel);
154 }
155
156 void printVisited(bool *visit, int width, int height) {
157     int n = width*height*7*7;
158     cout << "Visited:␣";
159     for(int i=0; i < n; i++) {
160         if(visit[i]) {
161             cout << hashToVertex(i, width, height).str() << ",";
162         }
163     }
164 }
165
166
167 int shortestPath(point start, point end, int width, int height, Obstacle obstacles[], int numObstacles) {
168     // set<vertex> visit;
169     int numVisit = width*height*7*7;
170     bool visit[numVisit];
171     for(int v=0; v < numVisit; v++) {
172         visit[v] = false;
173     }
174     // flags to set nodes state to    visited
175     priority_queue<vertex,vector<vertex>,OrderByDistance> queue ;
176
177     point zero(0,0);
178     vertex startVertex(start, zero);
179     startVertex.setDistance(-1);
180     queue.push(startVertex);
181
182     while (!queue.empty()) {
183         vertex cur = queue.top(); queue.pop();
184         if(visit[vertexToHash(cur,width,height)])
185             continue;
186
187         // printQueue(queue);
188         // cout<<"current vertex: " << cur.str() << endl;
189         // printVisited(visit, width, height);
190         visit[vertexToHash(cur,width,height)] = true;
191         if(cur.getPosition() == end) {
192             return cur.getDistance();
193         }
194
195         point newPosition(cur.getPosition().getX() + cur.getVelocity().getX(),
196                           cur.getPosition().getY() + cur.getVelocity().getY());
197
198         if(validPosition(newPosition, width, height, obstacles, numObstacles)) {
199             for(int xa=-1; xa <=1; xa++) {
200                 for(int ya=-1; ya <= 1; ya++) {
201                     // if(xa == 0 && ya == 0 && ) {
202                     //     continue;
203                     // }
204                     if(abs(cur.getVelocity().getX() + xa) > 3
205                        || abs(cur.getVelocity().getY() + ya) > 3) {
206                         continue;
207                     }
208
209                     point newVelocity(cur.getVelocity().getX()+xa,
210                                       cur.getVelocity().getY()+ya);
211                     vertex to = vertex(newPosition, newVelocity);
212                     int altDistance = cur.getDistance() + 1;
213                     if((!visit[vertexToHash(to,width,height)]) //if not in visited set
214                        && altDistance < to.getDistance() ) {
215                         to.setDistance(altDistance);
216                         queue.push(to); //push again to the queue? not bad I think
217                     }
218                 }
219             }
220         }
221     }
222 }
223
224 }

```

```

225     return -2;
226 }
227
228
229 int main() {
230     cin.sync_with_stdio(false);
231     int testCases;
232     cin >> testCases;
233
234     for(int i=0; i < testCases; i++) {
235
236         int width, height;
237         cin >> width >> height;
238         int sx, sy, ex, ey;
239         cin >> sx >> sy >> ex >> ey;
240         point start(sx,sy), end(ex,ey);
241
242         int numObstacles;
243         cin >> numObstacles;
244         Obstacle obstacles[numObstacles];
245         for(int j=0; j<numObstacles; j++) {
246             cin >> obstacles[j].x1 >> obstacles[j].y1 >> obstacles[j].x2 >> obstacles[j].y2;
247         }
248         int sp = shortestPath(start, end, width, height, obstacles, numObstacles);
249         if(sp<-1) {
250             cout << "No solution." << endl;
251         } else if(sp==-1) {
252             cout << "Optimal solution takes 0 hops." << endl;
253         } else {
254             cout << "Optimal solution takes " << sp << " hops." << endl;
255         }
256     }
257 }

```

Burning Coins

```
1  #include <iostream>
2  using namespace std;
3
4  int main() {
5      ios_base::sync_with_stdio(false);
6      int testCases;
7      cin >> testCases;
8
9      for(int i=0; i < testCases; i++) {
10         int numCoins;
11         cin >> numCoins;
12         int minOpt[numCoins][numCoins];
13         for(int j=0; j < numCoins; j++) {
14             cin >> minOpt[j][j];
15         }
16         for(int j=0; j < numCoins-1; j++) {
17             minOpt[j][j+1] = max(minOpt[j][j], minOpt[j+1][j+1]);
18             // cout << j << " " << j+1 << " " << minOpt[j][j+1] << endl;
19         }
20         for(int m=2; m < numCoins; m++) {
21             for(int j=0; j < numCoins-m; j++) {
22                 int k= j+m;
23
24                 minOpt[j][k]
25                     = max(minOpt[j][j] + ((minOpt[j+2][k] > minOpt[j+1][k-1]) ? minOpt[j+1][k-1] : minOpt[j+2][k]),
26                           minOpt[k][k] + ((minOpt[j+1][k-1] > minOpt[j][k-2]) ? minOpt[j][k-2] : minOpt[j+1][k-1]));
27                 // cout << j << " " << k << " " << minOpt[j][k] << endl;
28             }
29         }
30         cout << minOpt[0][numCoins-1] << endl;
31     }
32 }
33 }
```


Jump

```
1  #include <iostream>
2  #include <limits>
3
4  using namespace std;
5
6  int main() {
7      ios_base::sync_with_stdio(false);
8      int testCases = 0;
9      cin >> testCases;
10     for(int testCase=0; testCase < testCases; testCase++) {
11         int numCells, maxJump;
12         cin >> numCells >> maxJump;
13
14         int vCell[numCells];
15         long long minCost[numCells];
16
17         minCost[0] = 0;
18         cin >> vCell[0];
19         int globalBestPos = 0;
20
21         for(int curCell=1; curCell < numCells; curCell++) {
22             if(globalBestPos < curCell-maxJump) {
23                 // find minCost
24                 long long min = numeric_limits<long long>::max();
25                 long long pos = curCell-maxJump;
26                 for(int k=curCell-maxJump; k < curCell; k++) {
27                     long long curMin = minCost[k];
28                     if(curMin < min) {
29                         min = curMin;
30                         pos = k;
31                     }
32                 }
33                 globalBestPos = pos;
34
35             }
36             cin >> vCell[curCell];
37             long long curMinPos = minCost[globalBestPos] + vCell[curCell];
38             minCost[curCell] = curMinPos;
39             if(minCost[globalBestPos] >= curMinPos) {
40                 globalBestPos = curCell;
41             }
42
43             // cout << "Min on pos " << i << " is " << minCost[curCell] << endl;
44         }
45
46         cout << minCost[numCells-1] << endl;
47     }
48     return 0;
49 }
```

Light Pattern

```
1  #include <iostream>
2  #include <vector>
3
4  using namespace std;
5
6  void decToBin(int dec, vector<int> &bin, int binLen) {
7      int i=binLen-1;
8      while(dec > 1) {
9          if(dec%2==0) {
10             bin[i]=0;
11         } else {
12             bin[i]=1;
13         }
14         dec=dec/2;
15         i--;
16     }
17     bin[i] = (dec==0) ? 0 : 1;
18     i--;
19     while(i >=0) {
20         bin[i] = 0;
21         i--;
22     }
23 }
24
25 void printVector(vector<int> &v) {
26     for(vector<int>::iterator it = v.begin(); it != v.end(); it++) {
27         cout << *it << "□";
28     }
29     cout << endl;
30 }
31
32 int computeSteps(vector<int> &bulb, vector<int> &resultPattern, int numBulbs, int patternLength) {
33     int numPatterns = numBulbs/patternLength;
34     int curReplacesToPattern = 0;
35     int curReplacesToOpposite = 0;
36     //go over every pattern
37     for(int i=0; i<numPatterns; i++) {
38         int replacesToPattern=0;
39         int replacesToOpposite=0;
40         for(int j=0; j<patternLength; j++) {
41             int iBulb = i*patternLength+j;
42             if(bulb[iBulb] != resultPattern[j]) {
43                 replacesToPattern++;
44                 // cout << "bulb " << iBulb << " is like opposite" << endl;
45             } else {
46                 replacesToOpposite++;
47                 // cout << "bulb " << iBulb << " is like pattern" << endl;
48             }
49         }
50         // cout << "pattern " << i << " needs " << replacesToPattern << " and " << replacesToOpposite << endl;
51         int bothReplacesToPattern = curReplacesToPattern+replacesToPattern;
52         int bothReplacesToOpposite = curReplacesToOpposite+replacesToOpposite;
53         curReplacesToPattern = (bothReplacesToPattern < bothReplacesToOpposite + 1)
54             ? bothReplacesToPattern : bothReplacesToOpposite+1;
55         curReplacesToOpposite = (bothReplacesToPattern+1 < bothReplacesToOpposite)
56             ? bothReplacesToPattern+1 : bothReplacesToOpposite;
57     }
58
59     return curReplacesToPattern;
60 }
61
62 int main() {
63     ios_base::sync_with_stdio(false);
64     int testCases;
65     cin >> testCases;
66
67     for(int i=0; i < testCases; i++) {
68         int numBulbs, patternLength, x;
69         cin >> numBulbs >> patternLength >> x;
70
71         vector<int> bulb(numBulbs);
72         for(int j=0; j<numBulbs; j++) {
73             int state;
```

```

74         cin >> state;
75         bulb[j] = state;
76     }
77     // cout << "bulbs: " ;
78     // printVector(bulb);
79
80     vector<int> binX(patternLength);
81     decToBin(x, binX, patternLength);
82     // cout << "result pattern: " ;
83     // printVector(binX);
84     cout << computeSteps(bulb, binX, numBulbs, patternLength) << endl;
85
86 }
87 }

```

Longest Path

```
1  #include <iostream>
2  #include <vector>
3
4  using namespace std;
5
6  pair<int, int> longestPath(int node, int ancestor, const vector<vector<int> > &adjList) {
7      const vector<int> *neighbors = &adjList[node];
8      if(neighbors->size() == 1 && ancestor != -1) {
9          return pair<int, int>(1,1);
10     } else if (neighbors->size() == 2 && ancestor != -1) {
11         for(vector<int>::const_iterator it = neighbors->begin(); it != neighbors->end(); it++) {
12             if(*it != ancestor) {
13                 pair<int, int> child = longestPath(*it, node, adjList);
14                 if(child.first + 1 > child.second) {
15                     return pair<int, int>(child.first+1, child.first+1);
16                 } else {
17                     return pair<int, int>(child.first+1, child.second);
18                 }
19             }
20         }
21     } else {
22         int maxHeight = 0;
23         int secondMaxHeight = 0;
24         int maxPath = 0;
25         for(vector<int>::const_iterator it = neighbors->begin(); it != neighbors->end(); it++) {
26             if(*it != ancestor) {
27                 pair<int, int> child = longestPath(*it, node, adjList);
28                 if(child.first > maxHeight) {
29                     secondMaxHeight = maxHeight;
30                     maxHeight = child.first;
31                 } else if(child.first > secondMaxHeight) {
32                     secondMaxHeight = child.first;
33                 }
34                 if(child.second > maxPath) {
35                     maxPath = child.second;
36                 }
37             }
38         }
39         int altMaxPath = maxHeight+secondMaxHeight+1;
40         if(altMaxPath > maxPath) {
41             return pair<int, int>(maxHeight+1, altMaxPath);
42         } else {
43             return pair<int, int>(maxHeight+1, maxPath);
44         }
45     }
46 }
47
48 int main() {
49     ios_base::sync_with_stdio(false);
50     int testCases = 0;
51     cin >> testCases;
52     for(int testCase=0; testCase < testCases; testCase++) {
53         int numVertices;
54         cin >> numVertices;
55         vector<vector<int> > adjList(numVertices);
56         int accArray[numVertices];
57
58         for(int i=0; i<numVertices-1; i++) {
59             int v1, v2;
60             cin >> v1 >> v2;
61             adjList[v1].push_back(v2);
62             adjList[v2].push_back(v1);
63             accArray[i] = -1;
64         }
65         accArray[numVertices-1] = -1;
66         cout << longestPath(0, -1, adjList).second << endl;
67     }
68     return 0;
69 }
```

Ants

```
1  // would be faster, when not every species has its own graph but only the property maps change.
2  #include <iostream>
3  #include <vector>
4  #include <boost/config.hpp>
5  #include <boost/graph/adjacency_list.hpp>
6  #include <boost/tuple/tuple.hpp>
7  #include <boost/graph/graphviz.hpp>
8  #include <boost/graph/kruskal_min_spanning_tree.hpp>
9  #include <boost/graph/dijkstra_shortest_paths.hpp>
10
11 using namespace std;
12 using namespace boost;
13
14 typedef adjacency_list<vecS, vecS, undirectedS, no_property,
15 property<edge_weight_t, int> > Graph;
16 typedef graph_traits<Graph> Traits;
17 typedef Traits::vertex_descriptor Vertex;
18 typedef Traits::edge_descriptor Edge;
19 typedef property_map<Graph, edge_weight_t>::type WeightMap;
20
21 void printGraph(Graph g, WeightMap weight) {
22     graph_traits<Graph>::edge_iterator eiter, eiter_end;
23     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
24         std::cout << source(*eiter, g) << " <--> " << target(*eiter, g)
25             << " with weight of " << weight[*eiter]
26             << std::endl;
27     }
28 }
29
30
31 int main() {
32     ios_base::sync_with_stdio(false);
33     int testCases = 0;
34     cin >> testCases;
35     for(int testCase=0; testCase < testCases; testCase++) {
36         int numTreeNode, numTreeEdges;
37         int numSpecies, startTree, finishTree;
38         cin >> numTreeNode >> numTreeEdges >> numSpecies
39             >> startTree >> finishTree;
40
41         //construct graph for each species
42         Graph speciesGraph[numSpecies];
43         WeightMap weightMap[numSpecies];
44         for(int i=0; i < numSpecies; i++) {
45             speciesGraph[i] = Graph(numTreeNode);
46             weightMap[i] = get(edge_weight, speciesGraph[i]);
47         }
48         for(int e=0; e < numTreeEdges; e++) {
49             int v1, v2;
50             cin >> v1 >> v2;
51             for(int i=0; i < numSpecies; i++) {
52                 Edge e;
53                 int w;
54                 cin >> w;
55                 tie(e, tuple::ignore) = add_edge(v1, v2, speciesGraph[i]);
56                 weightMap[i][e] = w;
57             }
58         }
59
60         int hive[numSpecies];
61         for(int i=0; i < numSpecies; i++) {
62             int aHive;
63             cin >> aHive;
64             hive[i] = aHive;
65             // cout << "species " << i << endl;
66             // printGraph(speciesGraph[i], weightMap[i]);
67         }
68
69         // compute minimum spanning tree for each species
70         vector<Edge> spanning_tree[numSpecies];
71         Graph speciesMST[numSpecies];
72         WeightMap weightMapMST[numSpecies];
73         for(int i=0; i < numSpecies; i++) {
```

```

74         kruskal_minimum_spanning_tree(speciesGraph[i], back_inserter(spanning_tree[i]));
75         //construct new tree
76         for(vector<Edge>::iterator it=spanning_tree[i].begin(); it!=spanning_tree[i].end(); it++) {
77             Edge e;
78             tie(e,tuples::ignore) = add_edge(source(*it,speciesGraph[i]),
79                                             target(*it,speciesGraph[i]),
80                                             speciesMST[i]);
81             weightMapMST[i][e] = weightMap[i][*it];
82         }
83         // cout << "species MST" << i << endl;
84         // printGraph(speciesMST[i], weightMapMST[i]);
85     }
86
87     // build combined graph
88     Graph combinedGraph(numTreeNode);
89     WeightMap combinedWeightMap;
90     combinedWeightMap = get(edge_weight, combinedGraph);
91
92     graph_traits<Graph>::edge_iterator eiter, eiter_end;
93     //iterate over all possible edges
94     for (tie(eiter, eiter_end) = edges(speciesGraph[0]); eiter != eiter_end; ++eiter) {
95         Vertex u = get(vertex_index, speciesGraph[0], source(*eiter, speciesGraph[0]));
96         Vertex v = get(vertex_index, speciesGraph[0], target(*eiter, speciesGraph[0]));
97
98         int minWeight = numeric_limits<int>::max();
99         for(int s=0; s < numSpecies;s++) {
100             Edge speciesEdge;
101             bool hasEdge = false;
102             tie(speciesEdge, hasEdge) = edge(u,v,speciesMST[s]);
103             if(hasEdge) {
104                 int weight = get(weightMapMST[s],speciesEdge);
105                 if(weight < minWeight) {
106                     minWeight = weight;
107                 }
108             }
109         }
110         if(minWeight < numeric_limits<int>::max()) {
111             Edge e;
112             tie(e,tuples::ignore) = add_edge(u,v,combinedGraph);
113             combinedWeightMap[e] = minWeight;
114         }
115     }
116 }
117
118
119 // cout << "combined graph" << endl;
120 // printGraph(combinedGraph, combinedWeightMap);
121
122 // dijkstra
123 vector<int> distances(num_vertices(combinedGraph));
124 dijkstra_shortest_paths(combinedGraph, startTree,
125                        distance_map(&distances[0]));
126 // for(vector<int>::iterator it=distances.begin(); it!=distances.end(); it++) {
127 //     cout << "in dlist: " << *it << endl;
128 // }
129 cout << distances[finishTree] << endl;
130 }
131 }

```

Bridges

```
1  #include <iostream>
2  #include <vector>
3  #include <map>
4  #include <set>
5  #include <boost/config.hpp>
6  #include <boost/graph/adjacency_list.hpp>
7  #include <boost/tuple/tuple.hpp>
8  #include <boost/graph/biconnected_components.hpp>
9  #include <boost/graph/connected_components.hpp>
10
11 using namespace std;
12 using namespace boost;
13
14 namespace boost
15 {
16     struct edge_component_t
17     {
18         enum
19         { num = 555 };
20         typedef edge_property_tag kind;
21     }
22     edge_component;
23 }
24
25
26 typedef adjacency_list<setS, vecS, undirectedS, no_property,
27     property<edge_component_t, std::size_t> > Graph;
28 typedef graph_traits<Graph> Traits;
29 typedef Traits::vertex_descriptor Vertex;
30 typedef Traits::edge_descriptor Edge;
31 typedef property_map<Graph, vertex_index_t>::type IndexMap;
32 typedef property_map<Graph, edge_component_t>::type ComponentMap;
33
34 void bridgesWithBiconnected(Graph &g, std::set<pair<int, int> > &criticalBridges) {
35     ComponentMap componentMap = get(edge_component, g);
36     size_t num_comps = biconnected_components(g, componentMap);
37     vector<vector<Edge> > numEleOfComp(num_comps, vector<Edge>());
38
39     IndexMap index = get(vertex_index, g);
40     Traits::edge_iterator ei, ei_end;
41     // cout << "new:"<<endl;
42     for (tie(ei, ei_end) = edges(g); ei != ei_end; ++ei) {
43         // std::cout << "(" << index[source(*ei, g)]
44         //         << "," << index[target(*ei, g)] << ") ";
45         // cout << " comp: " << componentMap[*ei] << endl;
46         numEleOfComp[componentMap[*ei]].push_back(*ei);
47     }
48
49
50     //every edge that is alone in a biconnected component is an important bridge
51     for(int i=0; i<num_comps; i++) {
52         if(numEleOfComp[i].size() ==1) {
53             Edge e = numEleOfComp[i][0];
54             int u = index[source(e, g)];
55             int v = index[target(e, g)];
56             pair<int,int> uv = (u<v)?pair<int,int>(u, v):pair<int,int>(v, u);
57             criticalBridges.insert(uv);
58         }
59     }
60 }
61
62 void bridgesWithBruteForce(Graph &g, std::set<pair<int, int> > &criticalBridges) {
63     vector<Edge> edgeVector;
64     std::vector<int> componentMap(num_vertices(g));
65     int components = connected_components(g, &componentMap[0]);
66
67     Traits::edge_iterator ei, ei_end;
68     for (tie(ei, ei_end) = edges(g); ei != ei_end; ++ei) {
69         edgeVector.push_back(*ei);
70     }
71     for(int i=0; i<edgeVector.size(); i++) {
72         Edge anEdge = edgeVector[i];
73         int sourceNode = source(anEdge, g);
74         int targetNode = target(anEdge, g);
```

```

74     remove_edge(sourceNode, targetNode, g);
75     if (connected_components(g, &componentMap[0]) > components)
76         criticalBridges.insert(pair<int,int>(source(anEdge, g), target(anEdge,g)));
77     Edge e;
78     tie(e, tuples::ignore) = add_edge(sourceNode,targetNode,g);
79 }
80
81 }
82
83 int main() {
84     ios_base::sync_with_stdio(false);
85     int testCases = 0;
86     cin >> testCases;
87     for(int testCase=0; testCase < testCases; testCase++) {
88         int numCities, numBridges;
89         cin >> numCities >> numBridges;
90
91         Graph g(numCities);
92         for(int i=0; i < numBridges; i++) {
93             Edge e;
94             int u,v;
95             cin >> u >> v;
96             tie(e, tuples::ignore) = add_edge(u,v,g);
97         }
98
99         std::set<pair<int, int> > criticalBridges;
100
101         // if(numCities > 50) {
102             bridgesWithBiconnected(g,criticalBridges);
103         // } else {
104             // bridgesWithBruteForce(g,criticalBridges);
105         // }
106
107         int nCriticalBridges = criticalBridges.size();
108         cout << nCriticalBridges << endl;
109         for(set<pair<int,int> >::iterator eit=criticalBridges.begin();
110             eit!=criticalBridges.end(); eit++){
111             cout << (*eit).first
112                 << " " << (*eit).second << endl;
113         }
114     }
115 }

```


Build The Graph

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/graphviz.hpp>
7  #include <boost/graph/kruskal_min_spanning_tree.hpp>
8  #include <boost/graph/dijkstra_shortest_paths.hpp>
9
10 using namespace std;
11 using namespace boost;
12
13 typedef adjacency_list<vecS, vecS, undirectedS, no_property,
14 property<edge_weight_t, int> > Graph;
15 typedef graph_traits<Graph> Traits;
16 typedef Traits::vertex_descriptor Vertex;
17 typedef Traits::edge_descriptor Edge;
18 typedef property_map<Graph, edge_weight_t>::type WeightMap;
19
20 pair<int, int> computeTask(Graph &g, WeightMap &weightMap) {
21     vector<Edge> spanning_tree;
22     kruskal_minimum_spanning_tree(g, back_inserter(spanning_tree));
23
24     int sumMSTWeights = 0;
25     // cout << "Print the edges in the MST:" << endl;
26     for (vector< Edge >::iterator ei = spanning_tree.begin();
27          ei != spanning_tree.end(); ++ei) {
28         // cout << source(*ei, g) << " <--> " << target(*ei, g) << " with weight of " << weightMap[*ei] << endl;
29         sumMSTWeights += weightMap[*ei];
30     }
31
32     //get vertex 0
33     graph_traits<Graph>::vertex_iterator vert_0;
34     tie(vert_0, tuples::ignore) = vertices(g);
35     vector<int> distances(num_vertices(g));
36     vector<Vertex> predecessor(num_vertices(g));
37
38     dijkstra_shortest_paths(g, 0,
39                             predecessor_map(&predecessor[0]).distance_map(&distances[0]));
40     return pair<int, int>(sumMSTWeights, *max_element(distances.begin(), distances.end()));
41 }
42
43 int main() {
44     ios_base::sync_with_stdio(false);
45     int testCases = 0;
46     cin >> testCases;
47     for(int testCase=0; testCase < testCases; testCase++) {
48         int numVertices, numEdges;
49         cin >> numVertices >> numEdges;
50         Graph g(numVertices);
51         WeightMap weightMap = get(edge_weight, g);
52         for(int edgeIndex=0; edgeIndex < numEdges; edgeIndex++) {
53             int vo,vi,w;
54             cin >> vo >> vi >> w;
55             Edge e;
56             tie(e,tuples::ignore) = add_edge(vi,vo,g);
57             weightMap[e] = w;
58         }
59         // cout << computeTask(g) << endl;
60         pair<int, int> result = computeTask(g, weightMap);
61         cout << result.first << "␣" << result.second << endl;
62
63     }
64
65     return 0;
66 }
67 }
```

Deleted Entries

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/graphviz.hpp>
7  #include <boost/graph/kruskal_min_spanning_tree.hpp>
8  #include <boost/graph/dijkstra_shortest_paths.hpp>
9  #include <boost/graph/sequential_vertex_coloring.hpp>
10
11 using namespace std;
12 using namespace boost;
13
14 typedef adjacency_list<vecS, vecS, undirectedS > Graph;
15 typedef graph_traits<Graph> Traits;
16 typedef Traits::vertex_descriptor Vertex;
17 typedef Traits::edge_descriptor Edge;
18 typedef property_map<Graph, vertex_index_t::type IndexMap;
19
20 void printGraph(Graph g) {
21     graph_traits<Graph>::edge_iterator eiter, eiter_end;
22     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
23         std::cout << source(*eiter, g) << " <--> " << target(*eiter, g)
24             << std::endl;
25     }
26 }
27
28 // typedef vector<Vertex> PredecessorMap;
29 // typedef vector<int> ColorMap;
30
31 // class colorize : public default_bfs_visitor {
32 //     private:
33 //         PredecessorMap m_predecessor;
34 //         ColorMap m_colorMap;
35 //         ColorMap m_prevColorMap;
36 //         int maxColors;
37 //     public:
38 //         //give numColors as parameter
39 //         colorize(PredecessorMap p, ColorMap c, ColorMap prevC, int numColors)
40 //             : m_predecessor(p), m_colorMap(c),
41 //               m_prevColorMap(prevC) {
42 //             maxColors = numColors;
43 //         }
44 //         int newColor(int c) {
45 //             return (c+1)%maxColors;
46 //         }
47 //         void tree_edge(Edge e, Graph g) {
48 //             Vertex s = source(e, g);
49 //             Vertex t = target(e, g);
50 //             put(m_predecessor, t, s);
51 //             int color = newColor(m_prevColorMap[s]);
52 //             if(color == m_colorMap[s]) {
53 //                 color = newColor(color);
54 //             }
55 //             put(m_colorMap, t, color);
56 //             put(m_prevColorMap, s, color);
57 //         }
58 //         //void on_start_vertex default color
59 //     };
60
61 void colorize(Graph &g, int numColors, vector<int> &color) {
62     IndexMap index = get(vertex_index, g);
63     vector<bool> visited(num_vertices(g), false);
64     std::queue<Vertex> bfs_queue;
65
66     //get start vertex
67     Traits::vertex_iterator vi;
68     tie(vi, tuples::ignore) = vertices(g);
69     Vertex startV = *vi;
70
71     color[index[startV]] = 0;
72     visited[index[startV]] = true;
```

```

74     bfs_queue.push(startV);
75
76     int curColor = 0;
77     while (!bfs_queue.empty()) {
78         Vertex v = bfs_queue.front();
79         bfs_queue.pop();
80         int parentColor = color[index[v]];
81         // cout << "current " << index[v] << " col:" << color[index[v]] << endl;
82
83         Traits::adjacency_iterator adjV, adEnd;
84         tie(adjV, adEnd) = adjacent_vertices(v, g);
85         for (; adjV != adEnd; adjV++) {
86             int vIndex = index[*adjV];
87             if(!visited[vIndex]) {
88                 visited[vIndex] = true;
89                 curColor=(curColor+1)%numColors;
90                 if(curColor==parentColor)
91                     curColor=(curColor+1)%numColors;
92                 color[vIndex] = curColor;
93                 bfs_queue.push(*adjV);
94             }
95         }
96     }
97 }
98
99
100 int main() {
101     ios_base::sync_with_stdio(false);
102     int testCases = 0;
103     cin >> testCases;
104     for(int testCase=0; testCase < testCases; testCase++) {
105         int numStudents, numEdges, numGroups;
106         cin >> numStudents >> numEdges >> numGroups;
107         Graph g(numStudents);
108         for(int i = 0; i < numEdges; i++) {
109             Edge e;
110             int u,v;
111             cin >> u >> v;
112             tie(e, tuples::ignore) =add_edge(u,v,g);
113         }
114         // cout << "whole graph: " << endl;
115         // printGraph(g);
116
117         // vector<Edge> spanning_tree;
118         // //connected components
119         // kruskal_minimum_spanning_tree(g, back_inserter(spanning_tree));
120
121         // vector<vector<int> > groupList(numGroups);
122         Graph MST = g;
123         // Graph MST(spanning_tree.begin(), spanning_tree.end(), numStudents);
124         // for(vector<Edge>::iterator it=spanning_tree.begin(); it !=spanning_tree.end(); it++) {
125         //     Edge e;
126         //     tie(e, tuples::ignore) =add_edge(source(*it,g),target(*it,g),MST);
127         // }
128
129         // cout << "MS tree: " << endl;
130         // printGraph(MST);
131
132         //not enough vertices? -> no
133         if(num_vertices(MST) < numGroups) {
134             cout << "no" << endl;
135             continue;
136         }
137         vector<int> color(num_vertices(g), -1);
138         colorize(MST, numGroups, color);
139
140         // not connected? -> no
141         if(find(color.begin(), color.end(), -1) != color.end()) {
142             cout << "no" << endl;
143             continue;
144         }
145
146         vector< vector<int> > groups(numGroups, vector<int>());
147         for(int i=0; i<numStudents; i++) {
148             int studGroup = color[i];

```

```

150         groups[studGroup].push_back(i);
151     }
152
153     cout << "yes" << endl;
154     for(vector<vector<int> >::iterator it=groups.begin(); it != groups.end(); it++) {
155         cout << (*it).size();
156         for(int i=0; i < (*it).size(); i++) {
157             cout << "□" << (*it)[i];
158         }
159         cout << endl;
160     }
161
162 }
163 return 0;
164 }

```

Shy Programmers

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/boyer_myrvold_planar_test.hpp>
7
8  using namespace std;
9  using namespace boost;
10
11 typedef adjacency_list<vecS, vecS, undirectedS> Graph;
12 typedef graph_traits<Graph> Traits;
13 typedef Traits::vertex_descriptor Vertex;
14 typedef Traits::edge_descriptor Edge;
15
16 int main() {
17     ios_base::sync_with_stdio(false);
18     int testCases = 0;
19     cin >> testCases;
20     for(int testCase=0; testCase < testCases; testCase++) {
21         int numCoders, numFriends;
22         cin >> numCoders >> numFriends;
23         Graph g(numCoders+1);
24
25         for(int i=0; i<numFriends; i++) {
26             Edge e;
27             int u,v;
28             cin >> u >> v;
29             tie(e, tuples::ignore) =add_edge(u,v,g);
30         }
31
32         //add vertex, connected to all vertices
33         for(int i=0; i<numCoders; i++) {
34             Edge e;
35             tie(e, tuples::ignore) = add_edge(numCoders,i,g);
36         }
37         if(boyer_myrvold_planarity_test(g)){
38             cout << "yes" << endl;
39         } else {
40             cout << "no" << endl;
41         }
42     }
43     return 0;
44 }
45 }
```

Algocoon Group

```
1  #include <boost/config.hpp>
2  #include <boost/tuple/tuple.hpp>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/push_relabel_max_flow.hpp>
5  #include <iostream>
6  #include <limits>
7  #include <queue>
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
13 typedef adjacency_list<vecS, vecS, directedS, no_property,
14     property<edge_capacity_t, long,
15     property<edge_residual_capacity_t, long,
16     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
17 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
18 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
19 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
20 typedef property_map<Graph, vertex_index_t>::type IndexMap;
21
22 typedef graph_traits<Graph>::vertex_descriptor Vertex;
23 typedef graph_traits<Graph>::edge_descriptor Edge;
24 typedef graph_traits<Graph> GraphTraits;
25
26 void printGraph(Graph g) {
27     graph_traits<Graph>::edge_iterator eiter, eiter_end;
28     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
29         std::cout << source(*eiter, g) << "↔" << target(*eiter, g)
30             << std::endl;
31     }
32 }
33
34 void findCut(Graph &g, EdgeCapacityMap &capacity,
35     ResidualCapacityMap &res_capacity,
36     std::set<Vertex> &ret,
37     Vertex sourceV, Vertex sinkV) {
38     IndexMap index = get(vertex_index, g);
39     vector<bool> visited(num_vertices(g), false);
40     std::queue<Vertex> bfs_queue;
41
42     //get start vertex
43     Vertex startV = sourceV;
44
45     visited[index[startV]] = true;
46     bfs_queue.push(startV);
47     ret.insert(startV);
48
49     while (!bfs_queue.empty()) {
50         Vertex v = bfs_queue.front();
51         bfs_queue.pop();
52
53         graph_traits<Graph>::adjacency_iterator adjV, adjEnd;
54         GraphTraits::out_edge_iterator out_i, out_end;
55         for (tie(out_i, out_end) = out_edges(v, g);
56             out_i != out_end; ++out_i) {
57             Edge e = *out_i;
58             Vertex src = source(e, g), targ = target(e, g);
59             int flow = capacity[e] - res_capacity[e];
60             // cout << "edge " << src << " " << targ << " c:" << capacity[e] << " f:" << flow << endl;
61             int vIndex = index[targ];
62             if (flow < capacity[e] && !visited[vIndex]) {
63                 bfs_queue.push(targ);
64                 visited[vIndex] = true;
65                 ret.insert(targ);
66             }
67         }
68     }
69 }
70
71 int cutCapacity(Graph &g, set<Vertex> &sSet, EdgeCapacityMap &capacity) {
72     int cutCapacity=0;
73     for(set<Vertex>::iterator it=sSet.begin();
```

```

74         it != sSet.end(); it++) {
75     Vertex v = *it;
76     GraphTraits::out_edge_iterator out_i, out_end;
77     for (tie(out_i, out_end) = out_edges(v, g);
78         out_i != out_end; ++out_i) {
79         Edge e = *out_i;
80         Vertex targ = target(e, g);
81         if(find(sSet.begin(), sSet.end(), targ) == sSet.end()) {
82             //in T set
83             cutCapacity+=capacity[e];
84         }
85     }
86 }
87 return cutCapacity;
88 }
89
90 pair<int, int> findBestSourceSinkSlow(Graph &g, int numFigures) {
91     pair<int, int> bestSourceSink;
92     int minMaxFlow = numeric_limits<int>::max();
93     for(int i=0; i<numFigures; i++) {
94         for(int j=i+1; j<numFigures; j++) {
95             long flow = push_relabel_max_flow(g, i, j);
96             if(flow < minMaxFlow) {
97                 bestSourceSink = pair<int, int>(i, j);
98                 minMaxFlow = flow;
99             }
100             flow = push_relabel_max_flow(g, j, i);
101             if(flow < minMaxFlow) {
102                 bestSourceSink = pair<int, int>(j, i);
103                 minMaxFlow = flow;
104             }
105         }
106     }
107     return bestSourceSink;
108 }
109
110
111 pair<int, int> findBestSourceSinkFast(Graph &g, int numFigures) {
112     pair<int, int> bestSourceSink;
113     int minMaxFlow = numeric_limits<int>::max();
114     int u = 0;
115     for(int i=1; i<numFigures; i++) {
116         long flow = push_relabel_max_flow(g, u, i);
117         if(flow < minMaxFlow) {
118             bestSourceSink = pair<int, int>(u,i);
119             minMaxFlow = flow;
120         }
121     }
122     for(int i=1; i<numFigures; i++) {
123         long flow = push_relabel_max_flow(g, i, u);
124         if(flow < minMaxFlow) {
125             bestSourceSink = pair<int, int>(i,u);
126             minMaxFlow = flow;
127         }
128     }
129     return bestSourceSink;
130 }
131 int main() {
132     ios_base::sync_with_stdio(false);
133     int testCases = 0;
134     cin >> testCases;
135     for(int testCase=0; testCase < testCases; testCase++) {
136         int numFigures, numLimbs;
137         cin >> numFigures >> numLimbs;
138         Graph g(numFigures);
139         EdgeCapacityMap capacity = get(edge_capacity, g);
140         ReverseEdgeMap rev_edge = get(edge_reverse, g);
141         ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
142
143         for(int i=0; i<numLimbs;i++) {
144             int u, v, c;
145             cin >> u >> v >> c;
146             Edge e, reverseE;
147             tie(e, tuples::ignore) = add_edge(u,v,g);
148             tie(reverseE, tuples::ignore) = add_edge(v, u, g);
149             capacity[e] = c;

```

```

150         capacity[reverseE] = 0;
151         rev_edge[e] = reverseE;
152         rev_edge[reverseE] = e;
153     }
154
155     pair<int, int> bestSourceSink = findBestSourceSinkFast(g, numFigures);
156     int sourceV = bestSourceSink.first;
157     int sinkV = bestSourceSink.second;
158     long flow = push_relabel_max_flow(g, sourceV, sinkV);
159     cout << flow << endl;
160     std::set<Vertex> oneSet;
161     findCut(g, capacity, res_capacity, oneSet, sourceV, sinkV);
162     IndexMap index = get(vertex_index, g);
163     cout << oneSet.size() << "␣";
164     for(set<Vertex>::iterator it=oneSet.begin();
165         it != oneSet.end(); it++) {
166         cout << index[*it] << "␣";
167     }
168     cout << endl;
169     // cout << "cut capacity " << cutCapacity(g, oneSet, capacity) << endl;
170
171 }
172 }

```


Buddy Selection

```
1  #include <boost/config.hpp>
2  #include <boost/tuple/tuple.hpp>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/max_cardinality_matching.hpp>
5  #include <iostream>
6  #include <set>
7
8  using namespace std;
9  using namespace boost;
10
11 typedef adjacency_list<vecS, vecS, undirectedS > Graph;
12 typedef graph_traits<Graph> Traits;
13 typedef Traits::vertex_descriptor Vertex;
14 typedef Traits::edge_descriptor Edge;
15 typedef property_map<Graph, vertex_index_t>::type IndexMap;
16
17 int main() {
18     ios_base::sync_with_stdio(false);
19     int testCases = 0;
20     cin >> testCases;
21     for(int testCase=0; testCase < testCases; testCase++) {
22         int numStudents, numChars, numCommChar;
23         cin >> numStudents >> numChars >> numCommChar;
24
25         Graph g(numStudents);
26         vector<set<string> > chars(numStudents, set<string>());
27
28         // cout << "testset:" << testCase << endl;
29         for(int i=0; i < numStudents; i++) {
30             for(int j=0; j < numChars; j++) {
31                 string characteristic;
32                 cin >> characteristic;
33                 chars[i].insert(characteristic);
34             }
35             for(int j=0; j < i; j++) {
36                 std::vector<string> inters;
37                 std::set_intersection(chars[i].begin(), chars[i].end(),
38                                     chars[j].begin(), chars[j].end(),
39                                     std::back_inserter(inters));
40                 if(inters.size() > numCommChar) {
41                     // cout << "v:" << i << " u:" << j << endl;
42                     //add edge
43                     Edge e;
44                     tie(e, tuples::ignore)=add_edge(i,j,g);
45                 }
46             }
47         }
48         vector<Vertex> mate(numStudents);
49         bool foundMatching = checked_edmonds_maximum_cardinality_matching(g, &mate[0]);
50         if(matching_size(g, &mate[0])*2 >= numStudents) {
51             cout << "not_optimal" << endl;
52         } else {
53             cout << "optimal" << endl;
54         }
55     }
56 }
```

Satellites

```
1  /* minimum vertex cover */
2  #include <iostream>
3  #include <vector>
4  #include <boost/config.hpp>
5  #include <boost/graph/adjacency_list.hpp>
6  #include <boost/tuple/tuple.hpp>
7  #include <boost/graph/max_cardinality_matching.hpp>
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list<vecS, vecS, undirectedS > Graph;
13 typedef graph_traits<Graph> Traits;
14 typedef Traits::vertex_descriptor Vertex;
15 typedef Traits::edge_descriptor Edge;
16 typedef property_map<Graph, vertex_index_t::type> IndexMap;
17
18 void minVCoverBipDfs(Graph &g, vector<Vertex> &mate, vector<bool> &visited,
19     int node, vector<bool> &isLeft) {
20     visited[node] = true;
21     Traits::out_edge_iterator out_i, out_end;
22     for (tie(out_i, out_end) = out_edges(node, g);
23         out_i != out_end; ++out_i) {
24         Vertex targ = target(*out_i, g);
25         int targetNode = get(vertex_index, g)[targ];
26         if(visited[targetNode])
27             continue;
28         if(isLeft[node]) {
29             if(mate[node] != targ) {
30                 minVCoverBipDfs(g, mate, visited, targetNode, isLeft);
31             }
32         } else {
33             if(mate[node] == targ) {
34                 minVCoverBipDfs(g, mate, visited, targetNode, isLeft);
35             }
36         }
37     }
38 }
39
40
41 /* takes bipartite graph and a vector that specifies whether
42  * a node is on the left side.
43  * Returns a vector containing the min vertex cover
44  */
45 vector<int> findMinVertexCoverBipartite(Graph &g, vector<bool> &isLeft) {
46     int numNodes = isLeft.size();
47     vector<Vertex> mate(numNodes);
48     edmonds_maximum_cardinality_matching(g, &mate[0]);
49
50     vector<bool> visited(numNodes, false);
51     const Vertex NULL_VERTEX = graph_traits<Graph>::null_vertex();
52     for(int i=0; i<numNodes; i++) {
53         if(isLeft[i] && mate[i] == NULL_VERTEX) {
54             visited[i]=true;
55         }
56     }
57
58     for(int i = 0; i < numNodes; i++) {
59         if(isLeft[i] && visited[i]) {
60             vector<bool> dfsVisited(numNodes, false);
61             minVCoverBipDfs(g, mate, visited, i, isLeft);
62         }
63     }
64
65     vector<int> minVertexCover;
66     for(int i = 0; i < numNodes; i++) {
67         if(isLeft[i] && !visited[i]) {
68             minVertexCover.push_back(i);
69         } else if(!isLeft[i] && visited[i]){
70             minVertexCover.push_back(i);
71         }
72     }
73     return minVertexCover;
74 }
```

```

74 }
75
76 int main() {
77     ios_base::sync_with_stdio(false);
78     int testCases = 0;
79     cin >> testCases;
80     for(int testCase=0; testCase < testCases; testCase++) {
81         int numStations, numSatellites, numLinks;
82         cin >> numStations >> numSatellites >> numLinks;
83         Graph g(numStations + numSatellites);
84         vector<bool> isLeft(numStations+numSatellites,false);
85         for(int i=0; i<numLinks; i++) {
86             int station, satellite;
87             cin >> station >> satellite;
88             Edge e;
89             tie(e, tuples::ignore) =add_edge(station,numStations+satellite,g);
90             isLeft[station] = true;
91         }
92
93         vector<int> minVertexCover = findMinVertexCoverBipartite(g, isLeft);
94
95         vector<int> minStations;
96         vector<int> minSatellites;
97
98         for(int i=0; i<minVertexCover.size(); i++) {
99             int node = minVertexCover[i];
100             if(node<numStations)
101                 minStations.push_back(node);
102             else
103                 minSatellites.push_back(node-numStations);
104         }
105
106         cout << minStations.size() << " " << minSatellites.size() << endl;
107         for(vector<int>::iterator it=minStations.begin(); it!=minStations.end(); it++) {
108             cout << *it << " ";
109         }
110         for(vector<int>::iterator it=minSatellites.begin(); it!=minSatellites.end(); it++) {
111             cout << *it << " ";
112         }
113
114         cout << endl;
115     }
116 }

```

Kingdom Defense

```
1  #include <boost/config.hpp>
2  #include <boost/tuple/tuple.hpp>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/push_relabel_max_flow.hpp>
5  #include <iostream>
6  #include <limits>
7  #include <queue>
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
13 typedef adjacency_list<vecS, vecS, directedS, no_property,
14     property<edge_capacity_t, long,
15     property<edge_residual_capacity_t, long,
16     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
17 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
18 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
19 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
20 typedef property_map<Graph, vertex_index_t>::type IndexMap;
21
22 typedef graph_traits<Graph>::vertex_descriptor Vertex;
23 typedef graph_traits<Graph>::edge_descriptor Edge;
24 typedef graph_traits<Graph> GraphTraits;
25
26 void printGraph(Graph g, EdgeCapacityMap &capacity, vector<pair<int, int> > &locProps) {
27     graph_traits<Graph>::edge_iterator eiter, eiter_end;
28     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
29         if(capacity[*eiter] > 0) {
30             int aSource = source(*eiter, g);
31             int aTarget = target(*eiter, g);
32             std::cout << aSource << ":␣("
33                 << locProps[aSource].first<< "|" << locProps[aSource].second << ")" <<
34                 "␣-" << capacity[*eiter] << "->␣" << aTarget
35                 << "␣(" << locProps[aTarget].first<< "|" << locProps[aTarget].second << ")"
36                 << std::endl;
37         }
38     }
39 }
40
41 void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
42     Edge e, reverseE;
43     tie(e, tuples::ignore) = add_edge(u,v,g);
44     tie(reverseE, tuples::ignore) = add_edge(v, u, g);
45     capacity[e] = c;
46     capacity[reverseE] = 0;
47     rev_edge[e] = reverseE;
48     rev_edge[reverseE] = e;
49 }
50
51 int main() {
52     ios_base::sync_with_stdio(false);
53     int testCases = 0;
54     cin >> testCases;
55     for(int testCase=0; testCase < testCases; testCase++) {
56         int numVertices, numEdges;
57         cin >> numVertices >> numEdges;
58         vector<pair<int, int> > locProp(numVertices, pair<int, int>(0,0));
59
60         for(int i=0; i<numVertices; i++) {
61             int numStationed,numNeeded;
62             cin >> numStationed >> numNeeded;
63             locProp[i] = pair<int, int>(numStationed, numNeeded);
64         }
65
66         Graph g(numVertices);
67         EdgeCapacityMap capacity = get(edge_capacity, g);
68         ReverseEdgeMap rev_edge = get(edge_reverse, g);
69         ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
70         for(int i=0; i<numEdges; i++) {
71             int from,to, minPassing, maxPassing;
72             cin >> from >> to >> minPassing >> maxPassing;
73         }
```

```

74         //force soldiers to walk along
75         locProp[from].first = locProp[from].first - minPassing;
76         locProp[to].first = locProp[to].first + minPassing;
77         maxPassing-=minPassing;
78
79         //build actual graph
80         addFlowEdge(g, capacity, rev_edge, from, to, maxPassing);
81     }
82
83     // printGraph(g, capacity, locProp);
84
85     const int SOURCE = numVertices;
86     const int SINK = numVertices+1;
87     int numNonForcedSoldiers=0;
88     //add source and sink
89     for(int i=0; i<numVertices; i++) {
90         int soldiersStationed = locProp[i].first;
91         int soldiersNeeded = locProp[i].second;
92         if(soldiersStationed > 0) {
93             addFlowEdge(g, capacity, rev_edge, SOURCE, i, soldiersStationed);
94             addFlowEdge(g, capacity, rev_edge, i, SINK, soldiersNeeded);
95         } else {
96             soldiersNeeded-=soldiersStationed;
97             addFlowEdge(g, capacity, rev_edge, i, SINK, soldiersNeeded);
98         }
99         numNonForcedSoldiers+=soldiersNeeded;
100     }
101     // cout << "after adding source and sink:" << endl;
102     // printGraph(g, capacity, locProp);
103
104     //compute maxFlow
105     long flow = push_relabel_max_flow(g, SOURCE, SINK);
106     // long flow = 0;
107
108     // cout << numNonForcedSoldiers << endl;
109     if(flow==numNonForcedSoldiers) {
110         cout << "yes";
111     } else {
112         cout << "no";
113     }
114     cout << endl;
115 }
116 }

```

Coin Tossing

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/push_relabel_max_flow.hpp>
7
8  using namespace std;
9  using namespace boost;
10
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
17 typedef graph_traits<Graph> GraphTraits;
18 typedef GraphTraits::vertex_descriptor Vertex;
19 typedef GraphTraits::edge_descriptor Edge;
20 typedef property_map<Graph, vertex_index_t>::type IndexMap;
21 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
22 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
23 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
24
25
26
27 void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
28     Edge e, reverseE;
29     tie(e, tuples::ignore) = add_edge(u,v,g);
30     tie(reverseE, tuples::ignore) = add_edge(v, u, g);
31     capacity[e] = c;
32     capacity[reverseE] = 0;
33     rev_edge[e] = reverseE;
34     rev_edge[reverseE] = e;
35 }
36
37 int sum(vector<int> &aVector) {
38     int sum_of_elems = 0;
39     for(std::vector<int>::iterator j=aVector.begin();j!=aVector.end();++j)
40         sum_of_elems += *j;
41     return sum_of_elems;
42 }
43
44
45 int main() {
46     ios_base::sync_with_stdio(false);
47     int testCases = 0;
48     cin >> testCases;
49     for(int testCase=0; testCase < testCases; testCase++) {
50         int numPlayers, numRounds;
51         int outcome = 0; //-1 false, 0 don't know, 1 true
52         cin >> numPlayers >> numRounds;
53
54         vector<int> scoreBoard(numPlayers, 0);
55         const int SOURCE = numPlayers;
56         const int SINK = numPlayers+1;
57         vector<vector<int>> > helperNode(numPlayers, vector<int>(numPlayers, -1));
58         Graph g;
59         EdgeCapacityMap capacity = get(edge_capacity, g);
60         ReverseEdgeMap rev_edge = get(edge_reverse, g);
61         ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
62         int outOfSink = 0;
63
64         for(int i=0; i<numRounds;i++) {
65             int playerA, playerB, outcome;
66             cin >> playerA >> playerB >> outcome;
67             if(outcome == 1) {
68                 scoreBoard[playerA] -=1;
69             } else if(outcome == 2) {
70                 scoreBoard[playerB] -=1;
71             } else {
72                 //construct graph
73                 if(helperNode[playerA][playerB] == -1) {
```

```

74         //no helper node before
75         int aHelperNode = SINK+1+i;
76         helperNode[playerA][playerB] = aHelperNode;
77         helperNode[playerB][playerA] = aHelperNode;
78
79         addFlowEdge(g, capacity, rev_edge, SOURCE, aHelperNode, 1);
80         addFlowEdge(g, capacity, rev_edge, aHelperNode, playerA, 1);
81         addFlowEdge(g, capacity, rev_edge, aHelperNode, playerB, 1);
82     } else {
83         int aHelperNode = helperNode[playerA][playerB];
84         Edge sourceToHelper, helperToA, helperToB;
85         sourceToHelper = edge(SOURCE, aHelperNode, g).first;
86         helperToA = edge(aHelperNode, playerA, g).first;
87         helperToB = edge(aHelperNode, playerB, g).first;
88         capacity[sourceToHelper] += 1;
89         capacity[helperToA] += 1;
90         capacity[helperToB] += 1;
91     }
92     outOfSink++;
93 }
94 }
95 for(int i=0; i<numPlayers; i++) {
96     int desiredScore;
97     cin >> desiredScore;
98     scoreBoard[i] += desiredScore;
99     if(scoreBoard[i] < 0) {
100         //a player won more often than in the desired scoreboard
101         outcome = -1;
102     }
103 }
104 if(outcome >= 0 && outOfSink==sum(scoreBoard)) {
105
106     // if(scoreBoard.sum() < outCapacitySource) {
107     //     outcome = -1;
108     // }
109
110     // add edges to sink
111     for(int i=0; i<numPlayers; i++) {
112         if(scoreBoard[i] > 0) {
113             addFlowEdge(g, capacity, rev_edge, i, SINK, scoreBoard[i]);
114         }
115     }
116
117
118     long flow = push_relabel_max_flow(g, SOURCE, SINK);
119     if(flow != sum(scoreBoard)) {
120         // cout << "flow != sum(scoreBoard)" << endl;
121         cout << "no" << endl;
122     } else {
123         cout << "yes" << endl;
124         // cout << flow << " " << sum(scoreBoard) << endl;
125     }
126 } else {
127     // cout << "a player won more often than in the desired scoreboard" << endl;
128     cout << "no" << endl;
129 }
130 }
131 }

```

Antenna

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel_with_sqrt.h>
2  #include <CGAL/Min_circle_2.h>
3  #include <CGAL/Min_circle_2_traits_2.h>
4  #include <iostream>
5
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 floor_to_double(const K::FT& x) {
13     double a = std::floor(CGAL::to_double(x));
14     while(a>x) a-=1;
15     while(a+1<=x) a+=1;
16     return a;
17 }
18
19 double ceil_to_double(const K::FT& x) {
20     double a = std::ceil(CGAL::to_double(x));
21     while(a<x) a+=1;
22     while(a-1>=x) a-=1;
23     return a;
24 }
25
26
27 int main() {
28     ios_base::sync_with_stdio(false);
29
30     while(true) {
31         int numCitizens;
32         cin >> numCitizens;
33         if(numCitizens == 0)
34             break;
35
36         K::Point_2 P[numCitizens];
37         for(int i=0; i<numCitizens; i++) {
38             double x,y;
39             cin >> x >> y;
40             P[i] = K::Point_2(x, y);
41         }
42         Min_circle radio(P, P+numCitizens, true);
43         Traits::Circle c = radio.circle();
44         K::FT radius = sqrt(c.squared_radius());
45         cout << std::setiosflags(std::ios::fixed) << setprecision(0) << ceil_to_double(radius) << endl;
46         // cout << std::round(CGAL::to_double(radius)) << endl;
47     }
48 }
```


Almost Antenna

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel_with_sqrt.h>
2  #include <CGAL/Min_circle_2.h>
3  #include <CGAL/Min_circle_2_traits_2.h>
4  #include <iostream>
5
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 floor_to_double(const K::FT& x) {
13     double a = std::floor(CGAL::to_double(x));
14     while(a>x) a-=1;
15     while(a+1<=x) a+=1;
16     return a;
17 }
18
19 double ceil_to_double(const K::FT& x) {
20     double a = std::ceil(CGAL::to_double(x));
21     while(a<x) a+=1;
22     while(a-1>=x) a-=1;
23     return a;
24 }
25
26 double computeSlow(vector<K::Point_2> P) {
27     K::FT radius;
28     for(vector<K::Point_2>::iterator it = P.begin();
29         it != P.end(); it++) {
30         vector<K::Point_2> tmpP(P.begin(), it);
31         tmpP.insert(tmpP.end(), it+1, P.end());
32
33         Min_circle radio(tmpP.begin(), tmpP.end(), true);
34         Traits::Circle c = radio.circle();
35         K::FT aRadius = c.squared_radius();
36         if(it!=P.begin()) {
37             if(aRadius < radius)
38                 radius = aRadius;
39         } else {
40             radius = aRadius;
41         }
42     }
43     return ceil_to_double(sqrt(radius));
44 }
45
46 //remove only the defining points of the whole minCircle
47 double computeFast(vector<K::Point_2> P) {
48     Min_circle radio(P.begin(), P.end(), true);
49
50     K::FT radius;
51     for(int i=0; i<radio.number_of_support_points(); i++) {
52         K::Point_2 sp = radio.support_point(i);
53         vector<K::Point_2> tmpP(P.begin(), P.end());
54         vector<K::Point_2>::iterator toSp = find(tmpP.begin(),tmpP.end(),sp);
55         tmpP.erase(toSp);
56
57         Min_circle partRadio(tmpP.begin(), tmpP.end(), true);
58         Traits::Circle c = partRadio.circle();
59         K::FT aRadius = c.squared_radius();
60         if(i!=0) {
61             if(aRadius < radius)
62                 radius = aRadius;
63         } else {
64             radius = aRadius;
65         }
66     }
67
68     return ceil_to_double(sqrt(radius));
69 }
70
71 int main() {
72     ios_base::sync_with_stdio(false);
73 }
```

```

74
75 while(true) {
76     int numCitizens;
77     cin >> numCitizens;
78     if(numCitizens == 0)
79         break;
80
81     vector<K::Point_2> P(numCitizens);
82     for(int i=0; i<numCitizens; i++) {
83         double x,y;
84         cin >> x >> y;
85         P[i] = K::Point_2(x, y);
86     }
87     cout << std::setiosflags(std::ios::fixed) << setprecision(0)
88         << computeFast(P) << endl;
89 }
90 }

```

Hit

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
2  #include <iostream>
3
4  using namespace std;
5
6  typedef CGAL::Exact_predicates_exact_constructions_kernel K;
7
8
9  bool hitsObstacle(int numObstacles) {
10
11     bool ret = false;
12     double x, y, a, b;
13     cin >> x >> y >> a >> b;
14     K::Ray_2 phil(K::Point_2(x,y), K::Point_2(a,b));
15     // cout << "Phil " << phil << endl;
16
17     for(int i=0; i<numObstacles; i++) {
18         double r,s,t,u;
19         cin >> r >> s >> t >> u;
20         K::Segment_2 obstacle(K::Point_2(r,s), K::Point_2(t,u));
21         if(!ret && CGAL::do_intersect(phil, obstacle)) {
22             ret=true;
23         }
24     }
25
26     return ret;
27 }
28
29 int main() {
30     ios_base::sync_with_stdio(false);
31
32     while(true) {
33         int numObstacles;
34         cin >> numObstacles;
35         // cout << "numObstacles " << numObstacles << endl;
36         if(numObstacles == 0) {
37             return 0;
38         }
39         if(hitsObstacle(numObstacles)) {
40             cout << "yes" << endl;
41         } else {
42             cout << "no" << endl;
43         }
44     }
45 }
```

First Hit

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
2  #include <iostream>
3
4  using namespace std;
5
6  typedef CGAL::Exact_predicates_exact_constructions_kernel K;
7  typedef K::Point_2 P;
8  typedef K::Segment_2 S;
9
10 double floor_to_double(const K::FT& x) {
11     double a = std::floor(CGAL::to_double(x));
12     while(a>x) a-=1;
13     while(a+1<=x) a+=1;
14     return a;
15 }
16
17 bool hitsObstacle(int numObstacles, K::Point_2 &isPos) {
18
19     bool isHit = false;
20     double x, y, a, b;
21     cin >> x >> y >> a >> b;
22     P philStart(x,y);
23     K::Ray_2 phil(philStart, K::Point_2(a,b));
24     P minIntersectionPoint;
25     // cerr << "Phil " << phil << endl;
26
27     for(int i=0; i<numObstacles; i++) {
28         // cerr << "Loop " << i << endl;
29         double r,s,t,u;
30         cin >> r >> s >> t >> u;
31         K::Segment_2 obstacle(K::Point_2(r,s), K::Point_2(t,u));
32         if(CGAL::do_intersect(phil, obstacle)) {
33             // cerr << "Intersection " << i << endl;
34             P intersectionPoint;
35             CGAL::Object o = CGAL::intersection(phil, obstacle);
36             if(const P* op = CGAL::object_cast<P>(&o)) {
37                 intersectionPoint = *op;
38             } else if(const S* os = CGAL::object_cast<S>(&o)) {
39                 //take the segment end that is nearer
40                 intersectionPoint = CGAL::squared_distance(philStart, os->source())
41                                     < CGAL::squared_distance(philStart, os->target())
42                                     ? os->source() : os->target();
43             }
44             else {
45                 throw std::runtime_error("strange_segment_intersection");
46             }
47
48             // cerr << "Know Intersection " << i << endl;
49             if(isHit) {
50                 if(CGAL::squared_distance(philStart, intersectionPoint)
51                    < CGAL::squared_distance(philStart, minIntersectionPoint)) {
52                     // cerr << "new intersection" << i << endl;
53                     minIntersectionPoint = intersectionPoint;
54                 }
55             } else {
56                 // cerr << "min intersection NULL " << i << endl;
57                 minIntersectionPoint = intersectionPoint;
58             }
59
60             // cerr << "end of loop" << i << endl;
61             isHit=true;
62         }
63     }
64
65     // cerr << "return" << endl;
66     if(isHit) {
67         isPos = minIntersectionPoint;
68     }
69     // cerr << "return" << endl;
70     return isHit;
71 }
72
73 int main() {
```

```

74 ios_base::sync_with_stdio(false);
75
76 while(true) {
77     // cerr << "beginLoop" << endl;
78     int numObstacles;
79     cin >> numObstacles;
80     // cerr << "numObstacles " << numObstacles << endl;
81     if(numObstacles == 0) {
82         return 0;
83     }
84     K::Point_2 isPos;
85     if(hitsObstacle(numObstacles, isPos)) {
86         // cerr << "afterreturn" << endl;
87         cout << std::setiosflags(std::ios::fixed) << setprecision(0)
88             << floor_to_double(isPos.x())
89             << "□"
90             << floor_to_double(isPos.y()) << endl;
91         // cerr << "afterout" << endl;
92     } else {
93         cout << "no" << endl;
94     }
95     // cerr << "endloop" << endl;
96 }
97 }

```

Search Snippets

```
1  #include <iostream>
2  #include <queue>
3  #include <vector>
4  #include <limits>
5
6  using namespace std;
7
8  const int MAX = numeric_limits<int>::max();
9
10 pair<int,int> minOfVector(vector<int> &v) {
11     int min = MAX;
12     int minPos;
13     for(vector<int>::iterator it=v.begin(); it!= v.end(); it++) {
14         if(min > *it) {
15             min = *it;
16             minPos = it-v.begin();
17         }
18     }
19     return pair<int,int>(min,minPos);
20 }
21
22 int computeInterval(priority_queue<pair<int,int> > &Q, int numWords) {
23     vector<int> currentPosition(numWords);
24     vector<bool> hasObserved(numWords, false);
25     int numNotObserved = numWords;
26
27     int minInterval = MAX;
28     int interval1 = 0;
29     int interval2 = 0;
30     while(Q.size() > 0){
31         pair<int, int> occurence = Q.top();
32         Q.pop();
33         int word = occurence.second;
34         int pos = -occurence.first;
35         // cout << "current wordpos of " << word << " is " << pos << endl;
36
37         currentPosition[word] = pos;
38         if(hasObserved[word] == false) {
39             hasObserved[word] = true;
40             numNotObserved--;
41         }
42         if(numNotObserved > 0)
43             continue;
44
45         pair<int,int> aMinOfVector = minOfVector(currentPosition);
46         int curInterval = pos - aMinOfVector.first +1;
47
48         if(curInterval<minInterval) {
49             minInterval=curInterval;
50             interval1 =aMinOfVector.second;
51             interval2 =pos;
52             // cout << minInterval << " between ["<< interval1<< " "<< interval2<< "]" << endl;
53         }
54     }
55
56     return minInterval;
57 }
58
59 int main() {
60     ios_base::sync_with_stdio(false);
61     int testCases;
62     cin >> testCases;
63     for(int i=0; i<testCases; i++) {
64         int numWords;
65         cin >> numWords;
66         int numAppears[numWords];
67         for(int j=0; j<numWords; j++) {
68             int num;
69             cin >> num;
70             numAppears[j] = num;
71         }
72
73         priority_queue<pair<int,int> > Q;
```

```

74
75     for(int j=0;j<numWords; j++) {
76         for(int k=0; k<numAppears[j]; k++) {
77             pair<int, int> occurrence;
78             int position;
79             cin>>position;
80             Q.push(pair<int,int>(-position, j));
81         }
82     }
83     cout << computeInterval(Q, numWords) << endl;
84
85 }
86 }

```

Bistro

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <iostream>
4  #include <cmath>
5
6  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
7  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
8  typedef Triangulation::Edge_iterator Edge_iterator;
9  typedef CGAL::Segment_2<K> Segment;
10 int main() {
11     std::ios_base::sync_with_stdio(false);
12
13     int numBistros;
14     while(std::cin >> numBistros) {
15         if(numBistros==0) break;
16
17         // std::cout << numBistros << std::endl;
18         std::vector<K::Point_2> bistro(numBistros);
19         Triangulation t;
20         for(int i=0; i<numBistros;i++) {
21             double x, y;
22             std::cin >> x >> y;
23             bistro[i] = K::Point_2(x,y);
24             // std::cout << bistro[i] << std::endl;
25         }
26         t.insert(bistro.begin(), bistro.end());
27
28         int numNewBistros;
29         std::cin >> numNewBistros;
30         // std::cout << numNewBistros << std::endl;
31         for(int i=0; i<numNewBistros;i++) {
32             double x, y;
33             std::cin >> x >> y;
34             K::Point_2 newBistro(x,y);
35             Triangulation::Vertex_handle nearestBistro = t.nearest_vertex(newBistro);
36             Segment shortestPath(nearestBistro->point(), newBistro);
37             std::cout << std::setiosflags(std::ios::fixed) << std::setprecision(0)
38                 << shortestPath.squared_length() << std::endl;
39         }
40
41     }
42 }
43 }
```


Germes

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <iostream>
4  #include <cmath>
5  #include <queue>
6
7  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
8  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
9  typedef Triangulation::Edge_iterator Edge_iterator;
10 typedef CGAL::Segment_2<K> Segment;
11 typedef K::Point_2 Point;
12
13 double ceil_to_double(const K::FT& x) {
14     double a = std::ceil(CGAL::to_double(x));
15     while(a<x) a+=1;
16     while(a-1>=x) a-=1;
17     return a;
18 }
19
20 int main() {
21     std::ios_base::sync_with_stdio(false);
22
23     int numBacteria;
24     while(std::cin >> numBacteria) {
25         if(numBacteria==0) break;
26         int l,b,r,t;
27         std::cin >> l >> b >> r >> t;
28         std::vector<Segment> dish(4);
29         dish[0] = Segment(Point(l,b),Point(r,b));
30         dish[1] = Segment(Point(r,b),Point(r,t));
31         dish[2] = Segment(Point(r,t),Point(l,t));
32         dish[3] = Segment(Point(l,t),Point(l,b));
33
34
35         std::vector<K::Point_2> bacteria(numBacteria);
36         for(int i=0;i<numBacteria;i++) {
37             int x,y;
38             std::cin >> x >> y;
39             bacteria[i] = K::Point_2(x,y);
40         }
41
42         std::priority_queue<K::FT> q;
43         if(numBacteria > 1) {
44             Triangulation tria;
45             tria.insert(bacteria.begin(), bacteria.end());
46
47             Triangulation::Vertex_iterator v = tria.finite_vertices_begin();
48             for(Triangulation::Vertex_iterator v = tria.finite_vertices_begin();
49                 v != tria.finite_vertices_end(); ++v) {
50                 bool firstEdge = true;
51                 K::FT minDist;
52
53
54                 Triangulation::Edge_circulator c = tria.incident_edges(v);
55                 do {
56                     if(!tria.is_infinite(c)) {
57                         Triangulation::Vertex_handle v1 = c->first->vertex((c->second + 1) % 3);
58                         Triangulation::Vertex_handle v2 = c->first->vertex((c->second + 2) % 3);
59
60                         K::FT candidateDist = Segment(v1->point(),v2->point()).squared_length();
61                         if(firstEdge == true || minDist > candidateDist) {
62                             minDist = candidateDist;
63                             // std::cout << "candidate minimal distance for "<< v->point() << " between " << v2
64                             // << v1->point() << " and " << v2->point() << ": " << minDist << std::endl;
65                             firstEdge = false;
66                         }
67                     } while(++c != tria.incident_edges(v));
68                     //other bacterium extends as well
69                     minDist = sqrt(minDist)/2;
70                     // std::cout << "tentative minimal distance for "<< v->point() << ": " << minDist << std::endl;
71
72                     //compare with dish
```

```

73         for(std::vector<Segment>::iterator s = dish.begin(); s!=dish.end(); s++) {
74             K::FT candidateDist = sqrt(squared_distance(v->point(),*s));
75             if(firstEdge == true || minDist > candidateDist) {
76                 minDist = candidateDist;
77                 firstEdge = false;
78             }
79         }
80         //compute time
81         K::FT time = sqrt(minDist-0.5);
82
83         q.push(-time);
84         // std::cout << "minimal distance for "<< v->point() <<": " << minDist << std::endl;
85
86     }
87
88 } else {
89     bool firstEdge = true;
90     K::FT minDist;
91
92     //compare with dish
93     for(std::vector<Segment>::iterator s = dish.begin(); s!=dish.end(); s++) {
94         K::FT candidateDist = squared_distance(bacteria[0],*s);
95         if(firstEdge == true || minDist > candidateDist) {
96             minDist = candidateDist;
97             bool firstEdge = false;
98         }
99     }
100
101     // std::cout << "minimal distance: " << minDist << std::endl;
102     //compute time
103     K::FT time = sqrt(sqrt(minDist)-0.5);
104
105     q.push(-time);
106
107 }
108
109 std::cout << ceil_to_double(-q.top()) << "┐";
110 int mid = numBacteria/2;
111 for(int i=0; i < mid; i++) {
112     q.pop();
113     // std::cout << "1popped" << std::endl;
114 }
115 std::cout << ceil_to_double(-q.top()) << "┐";
116 // std::cout << "mid: " << mid << "numBacteria: " << numBacteria << std::endl;
117 for(int i=mid; i < numBacteria-1; i++) {
118     q.pop();
119     // std::cout << "2popped" << std::endl;
120 }
121 std::cout << ceil_to_double(-q.top());
122 std::cout << std::endl;
123 }
124 }
125 }

```

Graypes

```
1 // #include <CGAL/Exact_predicates_exact_constructions_kernel_with_sqrt.h>
2 #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
3 #include <CGAL/Delaunay_triangulation_2.h>
4 #include <iostream>
5 #include <cmath>
6
7 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
8 typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
9 typedef Triangulation::Edge_iterator Edge_iterator;
10 typedef CGAL::Segment_2<K> Segment;
11
12 double ceil_to_double(const K::FT& x) {
13     double a = std::ceil(CGAL::to_double(x));
14     while(a<x) a+=1;
15     while(a-1>=x) a-=1;
16     return a;
17 }
18
19 int main() {
20     std::ios_base::sync_with_stdio(false);
21
22     int numGraypes;
23     while(std::cin >> numGraypes) {
24         if(numGraypes==0) break;
25         std::vector<K::Point_2> graype(numGraypes);
26         Triangulation t;
27         for(int i=0; i<numGraypes;i++) {
28             double x, y;
29             std::cin >> x >> y;
30             graype[i] = K::Point_2(x,y);
31         }
32         t.insert(graype.begin(), graype.end());
33
34         Segment minEdge;
35         bool firstEdge = true;
36         // output all edges
37         for(Edge_iterator e = t.finite_edges_begin(); e != t.finite_edges_end(); ++e) {
38             if(firstEdge == true || minEdge.squared_length() > t.segment(e).squared_length()) {
39                 firstEdge = false;
40                 minEdge = t.segment(e);
41             }
42         }
43         std::cout << ceil_to_double(50*sqrt(minEdge.squared_length())) << std::endl;
44     }
45 }
```

H1N1

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <CGAL/Triangulation_face_base_with_info_2.h>
4  #include <iostream>
5  #include <vector>
6  #include <algorithm>
7
8  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
9  typedef CGAL::Triangulation_vertex_base_2<K> Vb;
10 typedef CGAL::Triangulation_face_base_with_info_2<K::FT,K> Fb;
11 typedef CGAL::Triangulation_data_structure_2<Vb,Fb> Tds;
12 typedef CGAL::Delaunay_triangulation_2<K,Tds> Triangulation;
13 typedef Triangulation::Face_iterator Face_iterator;
14 typedef Triangulation::All_vertices_iterator Vertex_iterator;
15 typedef Triangulation::Face_handle Face_handle;
16 typedef Triangulation::Edge Edge;
17 typedef CGAL::Point_2<K> Point;
18
19
20 struct faceComparator {
21     bool operator() (const Face_handle &x, const Face_handle &y) const {
22         return (x->info() > y->info());
23     }
24 };
25
26 bool isInfinite(Triangulation &t, Face_handle &f) {
27     return t.is_infinite(Edge(f,0))
28         || t.is_infinite(Edge(f,1))
29         || t.is_infinite(Edge(f,2));
30 }
31
32 bool has_infinite_vertex(Triangulation &t, Face_handle &f) {
33     return t.is_infinite(f->vertex(0))
34         || t.is_infinite(f->vertex(1))
35         || t.is_infinite(f->vertex(2));
36 }
37
38 void initFaces(Triangulation &t, int startValue) {
39     //initialize escape radius
40     for (Triangulation::All_faces_iterator i = t.all_faces_begin();
41          i != t.all_faces_end(); i++) {
42         i->info() = K::FT(startValue);
43     }
44 }
45
46 void maxEscapeRadiusPerFace(Triangulation &t) {
47     //initialize escape radius
48     for (Face_iterator i = t.finite_faces_begin();
49          i != t.finite_faces_end(); i++) {
50         i->info() = K::FT(0);
51     }
52
53     //initialize boundary
54     Triangulation::Face_circulator fib = t.incident_faces(t.infinite_vertex());
55     Triangulation::Face_circulator fie = fib;
56
57     do {
58         for(int i=0; i<3; i++) {
59             if(!t.is_infinite(fib->neighbor(i))) {
60                 fib->neighbor(i)->info()
61                     = t.segment(Triangulation::Edge(fib,i)).squared_length()/4;
62                 Face_handle mf = fib->neighbor(i);
63                 break;
64             }
65         }
66     } while(++fib != fie);
67
68     //build search data structure -> Dijkstra
69     std::set<Face_handle, faceComparator> faces;
70     for(Face_iterator i=t.finite_faces_begin();
71         i != t.finite_faces_end(); i++) {
72         faces.insert(i);
73     }
```

```

74         i!=t.finite_faces_end(); i++) {
75             faces.insert(Face_handle(i));
76         }
77
78         while(!faces.empty()) {
79             //remove face with the best escape radius
80             Face_handle mf = *(faces.begin());
81             faces.erase(faces.begin());
82             // std::cout << mf->info() << ": " << mf->vertex(1)->point() << ", " << mf->vertex(2)->point() << ", " << ↵
83             ↵ mf->vertex(3)->point() << std::endl;
84             //and relax all edges
85             for(int i=0; i<3; i++) {
86                 if(!t.is_infinite(mf->neighbor(i))) {
87                     K::FT tentativeRadius = t.segment(Edge(mf,i)).squared_length()/4;
88                     K::FT w;
89                     if(mf->info() < tentativeRadius) {
90                         w = mf->info();
91                     } else {
92                         w = tentativeRadius;
93                     }
94
95                     if(w > mf->neighbor(i)->info()) {
96                         faces.erase(mf->neighbor(i));
97                         mf->neighbor(i)->info() = w;
98                         faces.insert(mf->neighbor(i));
99                     }
100                 }
101             }
102         }
103     }
104
105     bool canEscape(Triangulation &t, Point &p, K::FT &squaredRadius) {
106         if(squaredRadius <= 0) {
107             std::cout << "one" << std::endl;
108             return true;
109         }
110
111         Face_handle f = t.locate(p);
112
113         // std::cout << CGAL::squared_distance(p, t.nearest_vertex(p,f)->point()) << " " << squaredRadius << std::endl;
114         if(CGAL::squared_distance(p, t.nearest_vertex(p,f)->point()) < squaredRadius) {
115             // std::cout << "three" << std::endl;
116             return false;
117         }
118
119         if(t.is_infinite(f)) {
120             // std::cout << "two" << std::endl;
121             return true;
122         }
123
124         std::cout << f->info() << ":␣" << f->vertex(0)->point() << ", " << f->vertex(1)->point() << ", " << ↵
125         ↵ f->vertex(2)->point() << (has_infinite_vertex(t,f) ? "␣has␣infinite␣vertex" : "") << std::endl;
126         return(f->info() >= squaredRadius);
127     }
128
129     bool canEscapeSlow(Triangulation &t, Point &s, K::FT &r, int queryNumber) {
130         int i = queryNumber;
131         if(r <= 0)
132             return true;
133         Face_handle f = t.locate(s);
134         if(CGAL::squared_distance(s, t.nearest_vertex(s, f)->point()) < r)
135             return false;
136
137         // DFS
138         std::vector<Face_handle> stack;
139         stack.push_back(f);
140         f->info() = i;
141         while(!stack.empty()) {
142             f = stack.back();
143             stack.pop_back();
144             // std::cout << f->info() << ": " << f->vertex(0)->point() << ", " << f->vertex(1)->point() << ", " << ↵
145             ↵ f->vertex(2)->point() << (has_infinite_vertex(t,f) ? " has infinite vertex" : "") << std::endl;
146             if(t.is_infinite(f))
147                 return true;
148             for(int j = 0; j < 3; ++j) {

```

```

147         if(f->neighbor(j)->info() < i
148             && t.segment(Triangulation::Edge(f,j)).squared_length() >= 4* r) {
149             stack.push_back(f->neighbor(j));
150             // std::cout << "push back" << std::endl;
151             f->neighbor(j)->info() = i;
152         }
153     }
154 }
155 // std::cout << "four" << std::endl;
156 return false;
157 }
158
159 int main() {
160     std::ios_base::sync_with_stdio(false);
161
162     int numVertices;
163     while(std::cin >> numVertices) {
164         if(numVertices <= 0) break;
165
166         std::vector<Point> verticesList(numVertices);
167         for(int i=0; i<numVertices; i++) {
168             int x,y;
169             std::cin >> x >> y;
170             Point p(x,y);
171             verticesList[i] = p;
172         }
173
174         Triangulation t;
175         t.insert(verticesList.begin(), verticesList.end());
176         // maxEscapeRadiusPerFace(t);
177
178         // std::cout << "faces: " << std::endl;
179         // for(Face_iterator i = t.faces_begin(); i !=t.faces_end(); i++) {
180         //     std::cout << i->info() << ": " << i->vertex(1)->point() << ", " << i->vertex(2)->point() << ", " << i->vertex(3)->point() << std::endl;
181         // }
182         // std::cout << "faces end " << std::endl;
183         initFaces(t,-1);
184
185         int numCircles;
186         std::cin >> numCircles;
187         for(int i=0; i<numCircles; i++) {
188             int x,y;
189             K::FT squaredRadius;
190             std::cin >> x >> y >> squaredRadius;
191             Point p(x,y);
192             std::cout << (canEscapeSlow(t, p, squaredRadius,i) ? "y" : "n");
193         }
194
195         std::cout << std::endl;
196     }
197 }

```

Hiking Maps

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <iostream>
3  #include <set>
4  #include <vector>
5  #include <queue>
6  #include <limits>
7
8  using namespace std;
9
10 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
11 typedef K::Point_2 Point;
12 typedef pair<Point, Point> Segment;
13 typedef vector<Point> Triangle;
14
15 pair<int,int> minOfVector(vector<int> &v) {
16     int min = numeric_limits<int>::max();
17     int minPos;
18     for(vector<int>::iterator it=v.begin(); it!= v.end(); it++) {
19         if(min > *it) {
20             min = *it;
21             minPos = it-v.begin();
22         }
23     }
24     return pair<int,int>(min,minPos);
25 }
26
27 bool contained(const Segment &s, const Triangle &t) {
28     //test whether endpoints of the segments have the same orientation to
29     //the points on the side of the triangle as those points have to each
30     //other (same orientation or collinear)
31
32     bool right1 = CGAL::right_turn(t[0], t[1], t[2]);
33     bool right2 = CGAL::right_turn(t[2], t[3], t[4]);
34     bool right3 = CGAL::right_turn(t[4], t[5], t[0]);
35
36     CGAL::Orientation orient1 = !right1 ? CGAL::RIGHT_TURN : CGAL::LEFT_TURN;
37     CGAL::Orientation orient2 = !right2 ? CGAL::RIGHT_TURN : CGAL::LEFT_TURN;
38     CGAL::Orientation orient3 = !right3 ? CGAL::RIGHT_TURN : CGAL::LEFT_TURN;
39
40
41     bool ret = CGAL::orientation(t[0], t[1], s.first) != orient1
42         && CGAL::orientation(t[2], t[3], s.first) != orient2
43         && CGAL::orientation(t[4], t[5], s.first) != orient3
44         && CGAL::orientation(t[0], t[1], s.second) != orient1
45         && CGAL::orientation(t[2], t[3], s.second) != orient2
46         && CGAL::orientation(t[4], t[5], s.second) != orient3;
47     return ret;
48 }
49
50 void myApproach(const vector<Segment>& legs, int numLegs, int numMaps) {
51     vector<Triangle> maps(numMaps, Triangle(6));
52     int minInterval = numeric_limits<int>::max();
53     vector<int> newestCover(numLegs); //map from leg to triangle
54     vector<bool> isCovered(numLegs, false); //for the beginning to test whether all are overed
55     int numNotCovered = numLegs;
56
57     int curInterval = 0;
58     bool mustRecompute = true;
59     int curMinIndex = -1;
60
61     for(int i=0; i<numMaps; i++) {
62         for(int j=0; j<6; j++) {
63             int x,y;
64             cin >> x >> y;
65             maps[i][j] = Point(x,y);
66         }
67
68         //test intersection
69         for(int j=0; j<legs.size(); j++) {
70             if(contained(legs[j], maps[i])) {
71                 newestCover[j] = i;
72                 if(j==curMinIndex) mustRecompute = true;
73                 if(isCovered[j] == false) {
```

```

74         isCovered[j] = true;
75         numNotCovered--;
76     }
77 }
78
79 }
80 if(numNotCovered > 0)
81     continue;
82
83 if(mustRecompute) {
84     pair<int,int> resultOfMin = minOfVector(newestCover);
85     curInterval = i-resultOfMin.first+1;
86     curMinIndex = resultOfMin.second;
87     mustRecompute = false;
88     if(curInterval < minInterval)
89         minInterval=curInterval;
90 }
91 }
92 }
93
94 cout << minInterval << endl;
95
96 }
97
98 void benApproach(const vector<Segment> &legs, int numLegs, int numMaps) {
99     vector<Triangle > maps(numMaps, Triangle(6));
100     int minInterval = numeric_limits<int>::max();
101     vector<queue<int> > coveredBy(numLegs); //map from leg to triangle
102
103     for(int i=0;i<numMaps;i++) {
104         for(int j=0; j<6; j++) {
105             int x,y;
106             cin >> x >> y;
107             maps[i][j] = Point(x,y);
108         }
109
110         //test intersection
111         for(int j=0; j<legs.size(); j++) {
112             if(contained(legs[j], maps[i])) {
113                 // cout<<"leg "<<j<<" covered by map "<< i<<std::endl;
114                 coveredBy[j].push(i);
115             }
116         }
117     }
118
119     //find the shortest interval s.t. all legs are covered
120     priority_queue<int> maxMapSTAllCovered;
121     priority_queue<pair<int,int>,vector<pair<int,int> >, greater<pair<int,int> > >
122     minMapSTAllCovered;
123
124     for(int i=0; i<numLegs; i++) {
125         int val = coveredBy[i].front(); coveredBy[i].pop();
126         maxMapSTAllCovered.push(val);
127         minMapSTAllCovered.push(make_pair(val,i));
128     }
129
130     while(true) {
131         int minMap, minMapLeg;
132         boost::tie(minMap,minMapLeg)
133         = minMapSTAllCovered.top(); minMapSTAllCovered.pop();
134         int maxMap = maxMapSTAllCovered.top(); //maxMapSTAllCovered.pop();
135
136         int curInterval = maxMap - minMap + 1;
137         minInterval = min(curInterval, minInterval);
138
139         if(coveredBy[minMapLeg].empty()) break;
140
141         int newMapInInterval = coveredBy[minMapLeg].front();
142         coveredBy[minMapLeg].pop();
143         maxMapSTAllCovered.push(newMapInInterval);
144         minMapSTAllCovered.push(make_pair(newMapInInterval, minMapLeg));
145     }
146
147     cout << minInterval << endl;
148
149 }

```



```

150
151 int main() {
152     ios_base::sync_with_stdio(false);
153
154     int numTestCases;
155     cin >> numTestCases;
156
157     for(int t=0; t<numTestCases; t++) {
158         int numLegs, numMaps;
159         cin >> numLegs >> numMaps;
160
161         numLegs--;
162         vector<Segment> legs(numLegs);
163         int x,y;
164         cin >> x>>y;
165         Point p1(x,y);
166         for(int i=0;i<numLegs;i++) {
167             cin >> x >> y;
168             Point p2(x,y);
169             legs[i]=Segment(p1,p2);
170             p1 = p2;
171         }
172
173         //100points
174         // myApproach(legs, numLegs, numMaps);
175         //gives only 80 points for me, but interesting sweepline algorithm
176         benApproach(legs, numLegs, numMaps);
177     }
178 }

```

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
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<int> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 double ceil_to_double(const CGAL::Quotient<ET>& x) {
21     double a = std::ceil(CGAL::to_double(x));
22     while(a<x) a+=1;
23     while(a-1>=x) a-=1;
24     return a;
25 }
26
27 double floor_to_double(const CGAL::Quotient<ET>& x) {
28     double a = std::floor(CGAL::to_double(x));
29     while(a>x) a-=1;
30     while(a+1<=x) a+=1;
31     return a;
32 }
33
34 int main() {
35
36     int problemType;
37     while(std::cin >> problemType) {
38         if(problemType==0) break;
39         int a,b;
40         std::cin >> a >> b;
41
42         const int X = 0;
43         const int Y = 1;
44         Program lp (CGAL::SMALLER, false, 0, false, 0);
45
46         if(problemType==1) {
47             //minimize the negative problem
48             lp.set_c(Y, -b);
49             lp.set_d(X,X,2*a);
50
51             lp.set_l(X,true,0);
52             lp.set_l(Y,true,0);
53
54             lp.set_a(X,0,1); lp.set_a(Y,0,1); lp.set_b(0, 4);
55             lp.set_a(X,1,4); lp.set_a(Y,1,2); lp.set_b(1, a*b);
56             lp.set_a(X,2,-1); lp.set_a(Y,2,1); lp.set_b(2, 1);
57         } else {
58             const int Z = 2;
59             lp.set_d(X,X,2*a);
60             lp.set_d(Z,Z,2);
61             lp.set_c(Y, b);
62
63             lp.set_u(X,true,0);
64             lp.set_l(X,false);
65             lp.set_u(Y,true,0);
66             lp.set_l(Y,false);
67             lp.set_u(Z,false);
68             lp.set_l(Z,false);
69
70             lp.set_a(X,0,1); lp.set_a(Y,0,1); lp.set_b(0, -4);
71             lp.set_r(0, CGAL::LARGER);
72             lp.set_a(X,1,4); lp.set_a(Y,1,2); lp.set_a(Z,1,1);
73             lp.set_b(1, -a*b);
```

```

74         lp.set_r(1, CGAL::LARGER);
75         lp.set_a(X,2,-1); lp.set_a(Y,2,1); lp.set_b(2, -1);
76         lp.set_r(2, CGAL::LARGER);
77
78     }
79     Solution s= CGAL::solve_quadratic_program(lp, ET());
80     assert(s.solves_quadratic_program(lp));
81
82     // std::cout << s;
83
84     if(s.is_infeasible())
85         std::cout << "no" << std::endl;
86     else if(s.is_unbounded())
87         std::cout << "unbounded" << std::endl;
88     else {
89         CGAL::Quotient<ET> exactValue = s.objective_value();
90         int value = problemType==1 ?
91             floor_to_double(-exactValue) :
92             ceil_to_double(exactValue);
93
94         std::cout << value << std::endl;
95     }
96 }
97 }

```

Collisions

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <iostream>
4  #include <vector>
5
6  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
7  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
8  typedef Triangulation::Vertex_iterator Vertex_iterator;
9  typedef K::Point_2 Point;
10 typedef CGAL::Segment_2<K> Segment;
11
12 int main() {
13     std::ios_base::sync_with_stdio(false);
14     int testCases;
15     std::cin >> testCases;
16     for(int i=0; i<testCases; i++) {
17         int numPlanes;
18         K::FT minDistance;
19         std::cin >> numPlanes>> minDistance;
20
21         std::vector<Point> planes(numPlanes);
22
23         Triangulation t;
24
25         for(int j=0; j<numPlanes;j++) {
26             int x, y;
27             std::cin >> x >> y;
28             //t.insert(Triangulation::Point(x,y));
29             planes[j] = Point(x,y);
30         }
31
32         t.insert(planes.begin(), planes.end());
33
34         int numEndangered = 0;
35         K::FT minSquaredDistance = minDistance * minDistance;
36
37         for(Vertex_iterator v=t.finite_vertices_begin();
38             v!=t.finite_vertices_end(); v++) {
39             // std::cout<<v->point() << std::endl;
40             Triangulation::Edge_circulator c = t.incident_edges(v);
41             K::FT minDist;
42             bool firstEdge = true;
43
44             do {
45                 if(!t.is_infinite(c)) {
46                     Triangulation::Vertex_handle v1 = c->first->vertex((c->second+1)%3);
47                     Triangulation::Vertex_handle v2 = c->first->vertex((c->second+2)%3);
48
49                     K::FT candidateDist = Segment(v1->point(), v2->point()).squared_length();
50                     // std::cout << "candidate min dist for " << v->point() << " between " << v1->point() << " " << v2->point() << " is " << candidateDist << std::endl;
51                     if(firstEdge == true || minDist > candidateDist) {
52                         minDist = candidateDist;
53                         firstEdge = false;
54                     }
55                 }
56             } while(++c != t.incident_edges(v));
57
58             if(!firstEdge && minDist < minSquaredDistance)
59                 numEndangered++;
60         }
61
62         std::cout << numEndangered << std::endl;
63     }
64 }
65 }
```

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
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<int> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 double ceil_to_double(const CGAL::Quotient<ET>& x) {
21     double a = std::ceil(CGAL::to_double(x));
22     while(a<x) a+=1;
23     while(a-1>=x) a-=1;
24     return a;
25 }
26
27 double floor_to_double(const CGAL::Quotient<ET>& x) {
28     double a = std::floor(CGAL::to_double(x));
29     while(a>x) a-=1;
30     while(a+1<=x) a+=1;
31     return a;
32 }
33
34 int main() {
35
36     int numNutrients, numFoods;
37     while(std::cin >> numNutrients >> numFoods) {
38         if(numNutrients == 0 && numFoods == 0)
39             break;
40         Program lp (CGAL::LARGER, true, 0, false, 0);
41         for(int nutrient=0; nutrient<numNutrients; nutrient++) {
42             int l,u;
43             std::cin >> l >> u;
44             lp.set_b(2*nutrient, l);
45             lp.set_b(2*nutrient+1, u);
46             lp.set_r(2*nutrient+1, CGAL::SMALLER);
47         }
48
49         for(int food=0; food<numFoods; food++) {
50             int price;
51             std::cin >> price;
52             for(int nutrient=0; nutrient<numNutrients; nutrient++) {
53                 int price,C;
54                 std::cin >> C;
55                 lp.set_a(food, 2*nutrient, C);
56                 lp.set_a(food, 2*nutrient+1, C);
57             }
58             lp.set_c(food, price);
59         }
60
61         Solution s= CGAL::solve_quadratic_program(lp, ET());
62         assert(s.solves_quadratic_program(lp));
63
64         if(!s.is_optimal())
65             std::cout << "No such diet." << std::endl;
66         else
67             std::cout << floor_to_double(s.objective_value()) << std::endl;
68     }
69 }
```

Portfolios

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<int> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 int main() {
21
22     int numAssets, numPeople;
23     while(std::cin >> numAssets >> numPeople) {
24         if(numAssets == 0 && numPeople == 0)
25             break;
26
27         Program qp (CGAL::SMALLER, true, 0, false, 0);
28         for(int i=0; i<numAssets; i++) {
29             int cost, expectedReturn;
30             std::cin >> cost >> expectedReturn;
31             qp.set_a(i, 0, expectedReturn);
32             qp.set_r(0, CGAL::LARGER);
33             qp.set_a(i, 1, cost);
34         }
35         for(int i=0; i<numAssets; i++) {
36             for(int j=0; j<numAssets; j++) {
37                 int covariance;
38                 std::cin >> covariance;
39                 if(j<=i)
40                     qp.set_d(i,j,2*covariance);
41             }
42         }
43     }
44     for(int i=0; i<numPeople; i++) {
45         int maxCost, minReturn, maxVariance;
46         std::cin >> maxCost >> minReturn >> maxVariance;
47         qp.set_b(0, minReturn);
48         qp.set_b(1, maxCost);
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() > maxVariance)
53             std::cout << "No." << std::endl;
54         else
55             std::cout << "Yes." << std::endl;
56     }
57 }
58 }
```

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
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<int> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 using namespace std;
21
22 double floor_to_double(const CGAL::Quotient<ET>& x) {
23     double a = std::floor(CGAL::to_double(x));
24     while(a>x) a-=1;
25     while(a+1<=x) a+=1;
26     return a;
27 }
28
29 int main() {
30     ios_base::sync_with_stdio(false);
31
32     int numInequalities, numDimensions;
33     while(true) {
34         cin >> numInequalities;
35         if(numInequalities==0) break;
36         cin >> numDimensions;
37
38         Program lp (CGAL::SMALLER, false, 0, false, 0);
39         for(int i=0; i<numDimensions; i++) {
40             lp.set_c(i,0);
41         }
42         lp.set_c(numDimensions,-1);
43
44         for(int i=0; i<numInequalities; i++) {
45             long normA=0;
46             for(int j=0; j<numDimensions; j++) {
47                 int a;
48                 cin >> a;
49                 normA = normA + a*a;
50                 lp.set_a(j,i,a);
51             }
52             lp.set_a(numDimensions, i, sqrt(normA));
53             int b;
54             cin >> b;
55             lp.set_b(i,b);
56         }
57         lp.set_l(numDimensions, true, 0);
58         Solution s= CGAL::solve_quadratic_program(lp, ET());
59         assert(s.solves_quadratic_program(lp));
60
61         if(s.is_infeasible())
62             std::cout << "none" << std::endl;
63         else if(s.is_unbounded())
64             std::cout << "inf" << std::endl;
65         else {
66             CGAL::Quotient<ET> exactValue = s.objective_value();
67             cout << floor_to_double(-exactValue) << endl;
68         }
69     }
70 }
```

Monkey Island

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/strong_components.hpp>
7
8  using namespace std;
9  using namespace boost;
10
11 typedef adjacency_list<vecS, vecS, directedS> Graph;
12 typedef graph_traits<Graph> Traits;
13 typedef Traits::edge_descriptor Edge;
14 typedef Traits::vertex_descriptor Vertex;
15 typedef Traits::edge_iterator Eit;
16
17 int main() {
18     ios_base::sync_with_stdio(false);
19     int testCases = 0;
20     cin >> testCases;
21     for(int testCase=0; testCase < testCases; testCase++) {
22         int numLocations, numRoads;
23         cin >> numLocations >> numRoads;
24
25         Graph g(numLocations);
26         vector<int> cost(numLocations);
27         for(int i=0; i<numRoads; i++) {
28             Edge e;
29             int u,v;
30             cin >> u >> v;
31             tie(e, tuples::ignore) = add_edge(u-1,v-1,g);
32         }
33         for(int i=0; i<numLocations; i++) {
34             int c;
35             cin >> c;
36             cost[i] = c;
37         }
38
39         vector<int> componentMap(numLocations);
40         int numComponents = strong_components(g, &componentMap[0]);
41         vector<int> componentCosts(numComponents, 100);
42
43         // cout << "numcomp " << numComponents << endl;
44
45         for(int i=0; i<numLocations; i++) {
46             if(cost[i] < componentCosts[componentMap[i]]) {
47                 componentCosts[componentMap[i]] = cost[i];
48             }
49         }
50
51         Eit ei, ei_end;
52         for(tie(ei, ei_end) = edges(g); ei != ei_end; ++ei) {
53             Vertex sV = source(*ei,g);
54             Vertex tV = target(*ei,g);
55
56             if(componentMap[sV] != componentMap[tV]) {
57                 componentCosts[componentMap[tV]] = 0;
58             }
59         }
60
61         int minPStation = 0;
62         for(int i=0; i<numComponents; i++) {
63             minPStation += componentCosts[i];
64         }
65         cout << minPStation << endl;
66     }
67 }
```


Placing Knights

```
1  #include <iostream>
2  #include <vector>
3  #include <set>
4  #include <cstdlib>
5  #include <boost/graph/max_cardinality_matching.hpp>
6  #include <boost/tuple/tuple.hpp>
7  #include <boost/graph/adjacency_list.hpp>
8  #include <boost/config.hpp>
9
10 using namespace std;
11 using namespace boost;
12
13 typedef pair<int,int> Pos;
14 typedef adjacency_list<setS, vecS, undirectedS > Graph;
15 typedef graph_traits<Graph> Traits;
16 typedef Traits::vertex_descriptor Vertex;
17 typedef Traits::edge_descriptor Edge;
18 typedef property_map<Graph, vertex_index_t::type IndexMap;
19
20
21 //returns the knights that the given knight threatens
22 vector<Pos> threatens(vector<vector<int> > &board, Pos &knight) {
23     vector<Pos> ret;
24     for(int i=-2;i<=2;i++) {
25         for(int j=-2;j<=2;j++) {
26             if(!((abs(i)== 1 && abs(j) ==2)
27                 || (abs(i)== 2 && abs(j) ==1))) continue; //move not allowed
28             unsigned int newX = knight.first+i;
29             unsigned int newY = knight.second+j;
30             if(0 <= newX && newX < board.size()
31                && 0 <= newY && newY < board.size()
32                && board[newX][newY] != 0) {
33                 ret.push_back(Pos(newX, newY));
34             }
35         }
36     }
37     return ret;
38 }
39
40 void setToZero(vector<vector<int> > &board, vector<Pos> &threatened) {
41     for(unsigned int i=0; i<threatened.size(); i++) {
42         Pos pos = threatened[i];
43         board[pos.first][pos.second] = 0;
44     }
45 }
46
47 void printBoard(vector<vector<int> > &board) {
48     for(unsigned int i=0; i<board.size(); i++) {
49         for(unsigned int j=0; j<board.size(); j++) {
50             cout << board[i][j];
51         }
52         cout << endl;
53     }
54 }
55
56
57 void reduceNumThreatened(set<pair<int, pair<int, int> > > &Q, vector<vector<int> > &board, vector<vector<int> > &
    &boardThreatening, vector<Pos> &threatened) {
58     for(unsigned int i=0; i<threatened.size(); i++) {
59         Pos pos = threatened[i];
60         int numThreatens = boardThreatening[pos.first][pos.second];
61         Q.erase(pair<int, Pos>(numThreatens, pos));
62
63         vector<Pos> toReduce = threatens(board, pos);
64         for(unsigned int j=0; j<toReduce.size(); j++) {
65             Pos toReducePos = toReduce[j];
66             numThreatens = boardThreatening[toReducePos.first][toReducePos.second];
67             Q.erase(pair<int, Pos>(numThreatens, toReducePos));
68             numThreatens--;
69             Q.insert(pair<int, Pos>(numThreatens, toReducePos));
70             boardThreatening[toReducePos.first][toReducePos.second] = numThreatens;
71         }
72     }
```

```

73 }
74
75 int numKnights(vector<vector<int> > board) {
76     int numKnights = 0;
77     int numPosLoc = 0;
78     set<pair<int, pair<int, int> > > Q;
79     int n = board.size();
80     vector<vector<int> > boardThreatening(n,vector<int>(n));
81
82     for(int i=0;i<n;i++) {
83         for(int j=0;j<n;j++) {
84             if(board[i][j] != 0) {
85                 Pos pos =Pos(i,j);
86                 int numThreatening = threatens(board, pos).size();
87                 Q.insert(pair<int, pair<int, int> >(numThreatening,pos));
88                 boardThreatening[pos.first][pos.second] = numThreatening;
89                 numPosLoc++;
90             }
91         }
92     }
93     while(Q.size() > 0 && numPosLoc > 0) {
94         // cout<< "board" << std::endl;
95         // printBoard(board);
96         // cout<<"num threatening" <<std::endl;
97         // printBoard(boardThreatening);
98         pair<int, pair<int, int> > p = *(Q.begin());
99         Q.erase(Q.begin());
100         pair<int, int> pos = p.second;
101         if(board[pos.first][pos.second] != 0) {
102             vector<Pos> threatened = threatens(board, pos);
103             setToZero(board, threatened);
104             board[pos.first][pos.second] = 0;
105             numPosLoc -= (threatened.size() + 1);
106             numKnights++;
107             threatened.push_back(pos);
108             reduceNumThreatened(Q, board, boardThreatening, threatened);
109         }
110     }
111     return numKnights;
112 }
113
114 int posToInt(pair<int,int> pos, int n) {
115     return pos.first*n+pos.second;
116 }
117
118 int numKnightsCorrect(vector<vector<int> > board) {
119     Graph g;
120     int n = board.size();
121     int numVertices = 0;
122
123     //build bipartite graph
124     for(int i=0;i<n;i++) {
125         for(int j=0;j<n;j++) {
126             if(board[i][j] == 0) continue;
127             Pos curPos(i,j);
128             vector<Pos> threatened = threatens(board, curPos);
129             numVertices++;
130             for(int k=0; k<threatened.size(); k++) {
131                 Edge e;
132                 tie(e, tuples::ignore) = add_edge(
133                     posToInt(curPos,n),
134                     posToInt(threatened[k],n),g);
135             }
136         }
137     }
138     vector<Vertex> mate(num_vertices(g));
139     edmonds_maximum_cardinality_matching(g, &mate[0]);
140     const Vertex NULL_VERTEX = graph_traits<Graph>::null_vertex();
141     int numMatched = 0;
142     for(int i=0; i<mate.size(); i++) {
143         if(mate[i] != NULL_VERTEX) numMatched++;
144     }
145     return numVertices - (numMatched/2);
146 }
147
148 int main() {

```

```

149     ios_base::sync_with_stdio(false);
150     int testCases;
151     cin >> testCases;
152     for(int t=0; t < testCases; t++) {
153         int n;
154         cin >> n;
155         vector<vector<int> > board(n,vector<int>(n));
156
157         for(int i=0;i<n;i++) {
158             for(int j=0;j<n;j++) {
159                 int status;
160                 cin >> status;
161                 board[i][j] = status;
162             }
163         }
164
165         cout << numKnightsCorrect(board) << std::endl;
166
167     }
168     return 0;
169 }

```

Shopping Trip

```
1  #include <boost/config.hpp>
2  #include <boost/tuple/tuple.hpp>
3  #include <boost/graph/adjacency_list.hpp>
4  #include <boost/graph/push_relabel_max_flow.hpp>
5  #include <iostream>
6  #include <limits>
7
8  using namespace std;
9  using namespace boost;
10
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_residual_capacity_t>::type ResidualCapacityMap;
18 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
19 typedef property_map<Graph, vertex_index_t>::type IndexMap;
20
21 typedef graph_traits<Graph>::vertex_descriptor Vertex;
22 typedef graph_traits<Graph>::edge_descriptor Edge;
23 typedef graph_traits<Graph> GraphTraits;
24
25 void printGraph(Graph g, EdgeCapacityMap &capacity) {
26     graph_traits<Graph>::edge_iterator eiter, eiter_end;
27     for (tie(eiter, eiter_end) = edges(g); eiter != eiter_end; ++eiter) {
28         if(capacity[*eiter] > 0) {
29             int aSource = source(*eiter, g);
30             int aTarget = target(*eiter, g);
31             std::cout << aSource << "␣"
32                 << "␣-" << capacity[*eiter] << "->␣" << aTarget
33                 << std::endl;
34         }
35     }
36 }
37
38 void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
39     Edge e, reverseE;
40     tie(e, tuples::ignore) = add_edge(u,v,g);
41     tie(reverseE, tuples::ignore) = add_edge(v, u, g);
42     capacity[e] = c;
43     capacity[reverseE] = 0;
44     rev_edge[e] = reverseE;
45     rev_edge[reverseE] = e;
46 }
47
48
49 int main() {
50     ios_base::sync_with_stdio(false);
51
52     int testCases = 0;
53     cin >> testCases;
54     for(int testCase=0; testCase < testCases; testCase++) {
55         int numVertices, numEdges, numStores;
56         cin >> numVertices >> numEdges >> numStores;
57
58         Graph g(numVertices);
59         EdgeCapacityMap capacity = get(edge_capacity, g);
60         ReverseEdgeMap rev_edge = get(edge_reverse, g);
61         ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
62
63         //add sink
64         const int SOURCE = 0;
65         //addFlowEdge(g, capacity, rev_edge, isStore, SINK, 1);
66         const int SINK = numVertices;
67
68         for(int i=0; i<numStores;i++) {
69             int isStore;
70             cin >> isStore;
71             addFlowEdge(g, capacity, rev_edge, isStore, SINK, 1);
72         }
73     }
```

```

74     for(int i=0; i<numEdges;i++) {
75         int u,v;
76         cin >> u >> v;
77         addFlowEdge(g, capacity, rev_edge, u, v,1);
78         addFlowEdge(g, capacity, rev_edge, v, u,1);
79     }
80
81     //printGraph(g, capacity) ;
82
83     long flow = push_relabel_max_flow(g, SOURCE, SINK);
84
85     cout << ((flow >= numStores) ? "yes" : "no") << endl;
86 }
87 }

```

TheeV

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
2  #include <CGAL/Min_circle_2.h>
3  #include <CGAL/Min_circle_2_traits_2.h>
4  #include <iostream>
5
6  using namespace std;
7
8  typedef CGAL::Exact_predicates_exact_constructions_kernel K;
9  typedef CGAL::Min_circle_2_traits_2<K> Traits;
10 typedef CGAL::Min_circle_2<Traits> Min_circle;
11 typedef K::Point_2 P;
12 typedef K::Segment_2 S;
13
14 double ceil_to_double(const K::FT& x) {
15     double a = std::ceil(CGAL::to_double(x));
16     while(a<x) a+=1;
17     while(a-1>=x) a-=1;
18     return a;
19 }
20
21 struct CityComparator{
22     P mainCity;
23     bool operator()(P x, P y) {
24         K::FT d1 = S(mainCity, x).squared_length();
25         K::FT d2 = S(mainCity, y).squared_length();
26         return(d1 > d2);
27     }
28 };
29
30
31 int main() {
32     ios_base::sync_with_stdio(false);
33     int testCases;
34     cin>>testCases;
35
36     for(int t=0; t<testCases;t++) {
37         int numCities;
38         cin>>numCities;
39         vector<P> cities;
40
41
42         for(int i=0; i<numCities;i++) {
43             int x,y;
44             cin>>x>>y;
45             P p(x,y);
46             cities.push_back(p);
47         }
48
49         P mainCity = cities[0];
50
51         CityComparator comp;
52         comp.mainCity = mainCity;
53
54         sort(cities.begin(), cities.end(), comp);
55         //sort from highest distance to lowest
56
57         K::FT otherRadius;
58         K::FT mainCityRadius;
59         K::FT beforeMainCityRadius;
60         Min_circle otherRadio;
61         for(vector<P>::iterator i = cities.begin();
62             i!=cities.end(); i++) {
63
64             // cout << "begin " << *(cities.begin()) << endl;
65             // cout << "i " << *i << endl;
66             // cout << "end " << *(cities.end()-1) << endl;
67             mainCityRadius = S(*(i+1), mainCity).squared_length();
68
69             otherRadio.insert(*i);
70             Traits::Circle otherCircle = otherRadio.circle();
71             otherRadius = otherCircle.squared_radius();
72
73             // cout << fixed<<setprecision(2)<<"radii " << mainCityRadius << " " << otherRadius << ":" << '\n'
```

```

        ↵ otherRadio.number_of_points() << endl;
74
        if(otherRadius >= mainCityRadius)
75             break;
76         beforeMainCityRadius=mainCityRadius;
77     }
78     cout<<fixed<<setprecision(0)<<ceil_to_double(min(beforeMainCityRadius,otherRadius))<<endl;
79
80 }
81
82
83 }

```

Poker Chips

```
1  #include <iostream>
2  #include <numeric>
3  #include <vector>
4  #include <map>
5  #include <bitset>
6
7  using namespace std;
8
9  int optimalPoints(vector<vector<int> > &chips,
10 map<vector<int>,int> &table, vector<int> topChipPosition){
11     int numStacks = chips.size();
12
13     map<vector<int>,int>::iterator found = table.find(topChipPosition);
14     if(found != table.end()) {
15         return found->second;
16     }
17
18     //return min over all subsets of possible taking
19     int maxPoints = 0;
20     int maxSubset = 0;
21     //iterate over all subsets of taking coins from the top
22     for(int s=1; s < (1<<numStacks); s++) {
23         int numChipsTaken = 0;
24         //s represents a subset of {0,...,n-1}
25         // cout<<"take subset " << std::bitset<5>(s).to_string() << std::endl;
26         vector<int> newTopChipPosition(numStacks);
27         int color=-1;
28         for(int k=0; k<numStacks; k++) {
29             //iterate over all elements of s
30             newTopChipPosition[k] = topChipPosition[k];
31             if((s & (1<<k)) != 0){
32                 // cout<<"stack " << k << " is in subset" << std::endl;
33                 if(topChipPosition[k]<0) {
34                     // cout<<"stack " << k << " is empty" << std::endl;
35                     continue;
36                 }
37
38                 //k is in S
39                 //ensure that colors are the same
40                 int stackColor = chips[k][topChipPosition[k]];
41                 if(color == -1) {
42                     color = stackColor;
43                     // cout<<"take color " << color << std::endl;
44                 } else if (color!=stackColor) {
45                     // cout<<"stack " << k << "has different color"<< std::endl;
46                     continue;
47                 }
48                 // cout<<"remove chip from stack " << k << std::endl;
49                 ++numChipsTaken;
50                 newTopChipPosition[k] = newTopChipPosition[k]-1;
51             }
52         }
53         int sumChips=0;
54         for(int i=0; i< numStacks; i++) {
55             sumChips +=newTopChipPosition[i]+1;
56         }
57
58         int newPoints = 0;
59         if(numChipsTaken > 1)
60             newPoints = (1<<(numChipsTaken-2));
61
62         if(sumChips > 0 && numChipsTaken>0)
63             newPoints = newPoints + optimalPoints(chips, table,
64                 newTopChipPosition);
65
66         // cout<<"points: "<<newPoints<<endl;
67         if(newPoints > maxPoints) {
68             maxPoints = newPoints;
69             maxSubset = s;
70         }
71     }
72     // cout<<"max points for this stack: "<< maxPoints<< " using "
73     // << std::bitset<5>(maxSubset).to_string()<< endl;
```



```

74     table[topChipPosition] = maxPoints;
75     return maxPoints;
76 }
77
78 int main() {
79     std::ios_base::sync_with_stdio(false);
80     int testCases;
81     cin >> testCases;
82
83     for(int k=0; k < testCases; k++) {
84         int numStacks;
85         cin >> numStacks;
86
87         vector< vector<int> > chips(numStacks);
88         vector<int> topChipPosition(numStacks);
89         for(int i=0; i<numStacks; i++) {
90             int stackHeight;
91             cin >> stackHeight;
92             chips[i] = vector<int>(stackHeight);
93             topChipPosition[i] = stackHeight-1;
94         }
95
96         for(int i=0; i<numStacks; i++) {
97             for(int j=0; j<chips[i].size(); j++) {
98                 //the chip at the top of the stack is added last
99                 int c;
100                 cin >> c;
101                 chips[i][j] = c;
102             }
103         }
104         map<vector<int>, int> table;
105         cout << optimalPoints(chips,table,topChipPosition) << endl;
106     }
107 }

```

Portfolios 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
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<int> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 int midPoint(int lowerBound, int upperBound) {
21     return lowerBound + (upperBound-lowerBound)/2;
22 }
23
24 int main() {
25     int numAssets, numPeople;
26     while(std::cin >> numAssets >> numPeople) {
27         if(numAssets == 0 && numPeople == 0)
28             break;
29
30         Program qp (CGAL::SMALLER, true, 0, false, 0);
31         std::vector<int> costs(numAssets);
32         std::vector<int> returns(numAssets);
33         std::vector<double> returnPerCost(numAssets);
34         for(int i=0; i<numAssets; i++) {
35             int cost, expectedReturn;
36             std::cin >> cost >> expectedReturn;
37             qp.set_a(i, 0, expectedReturn);
38             qp.set_r(0, CGAL::LARGER);
39             qp.set_a(i, 1, cost);
40             costs[i] = cost;
41             returns[i] = expectedReturn;
42             returnPerCost[i] = (double)expectedReturn/(double)cost;
43         }
44         for(int i=0; i<numAssets; i++) {
45             for(int j=0; j<numAssets; j++) {
46                 int covariance;
47                 std::cin >> covariance;
48                 if(j<=i)
49                     qp.set_d(i,j,2*covariance);
50             }
51         }
52     }
53     for(int i=0; i<numPeople; i++) {
54         int maxCost, minReturn, maxVariance;
55         std::cin >> maxCost >> maxVariance;
56         qp.set_b(1, maxCost);
57
58         int indexMinCost = std::max_element(returnPerCost.begin(), returnPerCost.end()) - returnPerCost.begin();
59         long returnUpperBound = ceil(returns[indexMinCost]*maxCost/costs[indexMinCost])+1;
60
61         // the following lower bound is not correct, since it might not be possible to buy all high cost assets ↯
62         // ↳ because this might exceed the risk
63         // long returnLowerBound = returns[indexMaxCost]*(double)maxCost/costs[indexMaxCost];
64
65         long returnLowerBound = 0;
66
67         // binary search
68         while(returnLowerBound <= returnUpperBound) {
69             long maxReturn = midPoint(returnLowerBound, returnUpperBound);
70
71             qp.set_b(0, maxReturn);
72             Solution s = CGAL::solve_quadratic_program(qp, ET());
73             assert(s.solves_quadratic_program(qp));
```

```

73         if(s.is_optimal() && s.objective_value() <= maxVariance) {
74             returnLowerBound = maxReturn+1;
75         } else {
76             returnUpperBound = maxReturn-1;
77         }
78     }
79     std::cout << returnUpperBound << std::endl;
80 }
81 }
82 }

```

Stamp Exhibition

```
1  #include <iostream>
2  #include <utility>
3  #include <cmath>
4  #include <cassert>
5  #include <CGAL/basic.h>
6  #include <CGAL/QP_models.h>
7  #include <CGAL/QP_functions.h>
8  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
9
10 // choose exact integral type
11 #ifdef CGAL_USE_GMP
12 #include <CGAL/Gmpzf.h>
13 typedef CGAL::Gmpzf ET;
14 #else
15 #include <CGAL/MP_Float.h>
16 typedef CGAL::MP_Float ET;
17 #endif
18
19 using namespace std;
20
21 // program and solution types
22 typedef pair<int,int> Pos;
23 typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
24 typedef CGAL::Quadratic_program<ET> Program;
25 typedef CGAL::Quadratic_program_solution<ET> Solution;
26 typedef K::Point_2 P;
27 typedef K::Segment_2 S;
28
29
30 int main() {
31     ios_base::sync_with_stdio(false);
32
33     int testCases;
34     cin>>testCases;
35     for(int tcase=0; tcase<testCases; tcase++) {
36         Program lp (CGAL::SMALLER, true, 1, true, 4096);
37
38         int numLights, numStamps, numWalls;
39         cin >> numLights >> numStamps >> numWalls;
40         vector<P> lights(numLights);
41         vector<P> stamps(numStamps);
42         vector<S> walls(numWalls);
43         vector<long> stampIntensity(numStamps);
44
45         for(int l=0; l<numLights; l++) {
46             int x,y;
47             cin>>x>>y;
48             lights[l]=P(x,y);
49             lp.set_c(l,1);
50         }
51
52         for(int s=0; s<numStamps; s++) {
53             int x,y,intensity;
54             cin>>x>>y>>intensity;
55             stamps[s] = P(x,y);
56             stampIntensity[s] = intensity;
57         }
58
59         for(int w=0; w<numWalls; w++) {
60             int x1,y1,x2,y2;
61             cin>>x1>>y1>>x2>>y2;
62             walls[w] = S(P(x1,y1),P(x2,y2));
63         }
64
65
66         for(int s=0; s<numStamps; s++) {
67             for(int l=0; l<numLights; l++) {
68                 S segment =S(stamps[s],lights[l]);
69                 K::FT r2 = segment.squared_length();
70                 double quotient2 = 1.0/r2;
71                 lp.set_a(l,s,quotient2);
72                 lp.set_a(l,numStamps+s,quotient2);
73             }
74         }
75     }
76 }
```

```

74         for(int w=0; w<numWalls; w++) {
75             if(CGAL::do_intersect(walls[w], segment)) {
76                 // cout<<"stamp"<<s<<" lamp"<<l<<" " <<quotient2;
77                 lp.set_a(1,s,0);
78                 lp.set_a(1,numStamps+s,0);
79                 break;
80             }
81         }
82     }
83 }
84 lp.set_b(s, stampIntensity[s]);
85 lp.set_r(numStamps+s, CGAL::LARGER);
86 lp.set_b(numStamps+s, 1);
87 }
88
89 Solution s=CGAL::solve_linear_program(lp,ET());
90 assert(s.solves_quadratic_program(lp));
91 // CGAL::print_linear_program(std::cerr, lp, "lp");
92
93 if(s.is_optimal())
94     cout<< "yes" << endl;
95 else
96     cout << "no" << endl;
97 }
98 }

```

Tetris

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/push_relabel_max_flow.hpp>
7
8  using namespace std;
9  using namespace boost;
10
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
17 typedef graph_traits<Graph> GraphTraits;
18 typedef GraphTraits::vertex_descriptor Vertex;
19 typedef GraphTraits::edge_descriptor Edge;
20 typedef property_map<Graph, vertex_index_t>::type IndexMap;
21 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
22 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
23 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
24
25 void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
26     Edge e, reverseE;
27     tie(e, tuples::ignore) = add_edge(u,v,g);
28     tie(reverseE, tuples::ignore) = add_edge(v, u, g);
29     capacity[e] = c;
30     capacity[reverseE] = 0;
31     rev_edge[e] = reverseE;
32     rev_edge[reverseE] = e;
33 }
34
35 void testCase() {
36     int width, numBricks;
37     cin >> width >> numBricks;
38
39     Graph g;
40     EdgeCapacityMap capacity = get(edge_capacity, g);
41     ReverseEdgeMap rev_edge = get(edge_reverse, g);
42     ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
43
44
45     // does not work for bordercases
46     // for(int i=0; i<numBricks; i++) {
47     //     int u,v;
48     //     cin>>u>>v;
49     //     int from = min(u,v);
50     //     int to = max(u,v);
51     //     addFlowEdge(g, capacity, rev_edge, 2*from+1, 2*to, 1);
52     // }
53     // for(int i=1; i<width; i++) {
54     //     addFlowEdge(g, capacity, rev_edge, 2*i, 2*i+1, 1);
55     // }
56
57     for(int i=0; i<numBricks; i++) {
58         int u,v;
59         cin>>u>>v;
60         int from = min(u,v);
61         int to = max(u,v);
62         if(from == 0) {
63             addFlowEdge(g, capacity, rev_edge, from, to, 1);
64         } else {
65             addFlowEdge(g, capacity, rev_edge, from+width, to, 1);
66         }
67     }
68     for(int i=1; i<width; i++) {
69         addFlowEdge(g, capacity, rev_edge, i, i+width, 1);
70     }
71
72     long flow = push_relabel_max_flow(g, 0, width);
73 }
```

```
74     cout<<flow<<std::endl;
75 }
76
77 int main() {
78     ios_base::sync_with_stdio(false);
79     int testCases = 0;
80     cin >> testCases;
81     while(testCases--) testCase();
82 }
```

Beach Bar

```
1  #include <iostream>
2  #include <queue>
3  #include <set>
4  #include <algorithm>
5  #include <limits>
6
7  using namespace std;
8
9  const int MAX = numeric_limits<int>::max();
10
11 pair<int,int> optimalPosition(vector<int> &parasols, set<int> &bestPos) {
12     int numParasols = parasols.size();
13     sort(parasols.begin(), parasols.end());
14
15     int bestNumParasols = 0;
16     int bestMaxDistToWalk = MAX;
17     priority_queue<int, vector<int>, greater<int> > Q;
18     for(int i=0; i<numParasols; i++) {
19         int rightMostParasol = parasols[i];
20         Q.push(rightMostParasol);
21         while(Q.top() < rightMostParasol-200) {
22             Q.pop();
23         }
24         int leftMostParasol = Q.top();
25         int numCovered = Q.size();
26         int span = rightMostParasol-leftMostParasol;
27         int barPos = (span/2)+ leftMostParasol;
28         int barPos2 = barPos;
29         if(span%2!=0) barPos2 = barPos+1;
30         int maxDistToWalk = max(rightMostParasol-barPos,
31                                 -(leftMostParasol-barPos));
32
33         if(numCovered > bestNumParasols) {
34             bestNumParasols = numCovered;
35             bestMaxDistToWalk = maxDistToWalk;
36             bestPos.clear();
37             bestPos.insert(barPos);
38             bestPos.insert(barPos2);
39         } else if(numCovered == bestNumParasols) {
40             if(maxDistToWalk < bestMaxDistToWalk) {
41                 bestPos.clear();
42                 bestPos.insert(barPos);
43                 bestPos.insert(barPos2);
44                 bestMaxDistToWalk = maxDistToWalk;
45             } else if(maxDistToWalk == bestMaxDistToWalk) {
46                 bestPos.insert(barPos);
47                 bestPos.insert(barPos2);
48             }
49         }
50     }
51
52     return pair<int,int>(bestNumParasols, bestMaxDistToWalk);
53 }
54
55 int main() {
56     ios_base::sync_with_stdio(false);
57     int testCases;
58     cin >> testCases;
59     for(int t=0;t<testCases;t++) {
60         int numParasol;
61         cin >> numParasol;
62         vector<int> parasols(numParasol);
63         for(int i=0;i<numParasol;i++) {
64             int pos;
65             cin >> pos;
66             parasols[i] = pos;
67         }
68         set<int> optimalPos;
69         pair<int, int> optimalValues = optimalPosition(parasols, optimalPos);
70         cout<<optimalValues.first<<" " <<optimalValues.second<<endl;
71         for(set<int>::iterator it = optimalPos.begin();
72             it!=optimalPos.end(); it++) {
73             if(it!=optimalPos.begin()) {
```



```
74         cout<<"□";
75     }
76     cout<<*it;
77 }
78 cout<<endl;
79 }
80 }
```

Cover

```
1  #include <CGAL/Exact_predicates_exact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <iostream>
4  #include <cmath>
5  #include <vector>
6  #include <limits>
7
8  typedef CGAL::Exact_predicates_exact_constructions_kernel K;
9  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
10 typedef Triangulation::Edge_iterator Edge_iterator;
11 typedef CGAL::Segment_2<K> Segment;
12 typedef CGAL::Point_2<K> Point;
13 typedef CGAL::Ray_2<K> Ray;
14 typedef Triangulation::Finite_faces_iterator FFiter;
15 typedef CGAL::Iso_rectangle_2<K> Rect;
16 typedef CGAL::Line_2<K> Line;
17 // typedef CGAL::Triangulation_data_structure_2 Tds;
18 typedef Triangulation::Face_handle Face_handle;
19 typedef Triangulation::Vertex_handle Vertex_handle;
20
21 const int MAX = std::numeric_limits<int>::max();
22
23
24 double ceil_to_double(double x) {
25     double a = std::ceil(x);
26     while(a<x) a+=1;
27     while(a-1>=x) a-=1;
28     return a;
29 }
30
31 K::FT sdistance(Point x, Point y) {
32     return Segment(x,y).squared_length();
33 }
34
35 std::vector<Segment> rectToSegment(Rect r) {
36     std::vector<Segment> v(4);
37     v[0] = Segment(r.vertex(0), r.vertex(1));
38     v[1] = Segment(r.vertex(1), r.vertex(2));
39     v[2] = Segment(r.vertex(2), r.vertex(3));
40     v[3] = Segment(r.vertex(3), r.vertex(0));
41     return v;
42 }
43
44 template<typename T>
45 K::FT check_intersection_segments(T &voronoiEdge, Rect &area, Triangulation &t) {
46     std::vector<Segment> areaSegments = rectToSegment(area);
47     Segment intersectedAreaEdge;
48     bool isIntersected = false;
49     for(int i=0; i<4; i++) {
50         if(CGAL::do_intersect(voronoiEdge, areaSegments[i])) {
51             intersectedAreaEdge = areaSegments[i];
52             isIntersected = true;
53         }
54     }
55     if(!isIntersected) return -1;
56
57     CGAL::Object o2 = CGAL::intersection(voronoiEdge, intersectedAreaEdge);
58     if(const Point* op = CGAL::object_cast<Point>(&o2)) {
59         Vertex_handle vh = t.nearest_vertex(*op);
60         return sdistance(*op, vh->point());
61     } else {
62         std::cerr<<"runtime_error";
63         return -1;
64         throw std::runtime_error("strange_segment_intersection");
65     }
66 }
67
68
69 void testcase(int numAntenna) {
70     double x1,x2,y1,y2;
71     std::cin >> x1 >> y1 >> x2 >> y2;
72     Rect area = Rect(Point(x1,y1),Point(x2,y2));
73 }
```

```

74     std::vector<Point > antennas(numAntenna);
75     Triangulation t;
76     for(int i=0; i<numAntenna; i++) {
77         double x,y;
78         std::cin>>x>>y;
79         antennas[i] = Point(x,y);
80     }
81
82     t.insert(antennas.begin(), antennas.end());
83     K::FT maxDist = -1;
84
85     //case 1: go over finite faces get circumcenter
86     for(FFiter i=t.finite_faces_begin();
87         i!=t.finite_faces_end();
88         i++) {
89         // Point c = t.circumcenter(i);
90         Point c = t.dual(i);
91         if(c.x() >= x1 && c.x() <= x2 && c.y() >= y1 && c.y() <= y2) {
92             K::FT tentativeMax = sdistance(c, i->vertex(1)->point());
93             if(tentativeMax > maxDist)
94                 maxDist = tentativeMax;
95         }
96     }
97     // std::cout<<"maxDist " <<ceil_to_double_sqrt(maxDist) << std::endl;
98
99     //case 2: go over corners of area, get nearest vertex
100    //for every corner
101    for(int i=0; i<4; i++) {
102        Point corner = area.vertex(i);
103        //for every nearestVertex
104        Vertex_handle vh = t.nearest_vertex(corner);
105        K::FT tentMax = sdistance(vh->point(), corner);
106
107        if(tentMax > maxDist) {
108            maxDist = tentMax;
109        }
110    }
111    // std::cout<<"maxDist " <<ceil_to_double_sqrt(maxDist) << std::endl;
112
113    //case 3: go over infinite faces
114    // process all Voronoi edges
115    for(Edge_iterator e = t.finite_edges_begin(); e != t.finite_edges_end(); ++e) {
116        CGAL::Object o = t.dual(e);
117        // o can be a segment, a ray or a line ...
118        Point* areaIntersection;
119        if(const Ray* oray = CGAL::object_cast<Ray>(&o)) {
120            maxDist = max(maxDist, check_intersection_segments(*oray, area, t));
121        } else if(const Line* oray = CGAL::object_cast<Line>(&o)) {
122            maxDist = max(maxDist, check_intersection_segments(*oray, area, t));
123        } else if(const Segment* oray = CGAL::object_cast<Segment>(&o)) {
124            maxDist = max(maxDist, check_intersection_segments(*oray, area, t));
125        }
126    }
127    std::cout<<std::setiosflags(std::ios::fixed) << std::setprecision(0)<< "
    ↵ ceil_to_double(sqrt(CGAL::to_double(maxDist)))
128        <<std::endl;
129    // std::cout<< numAntenna<<std::endl;
130 }
131 int main() {
132     std::ios_base::sync_with_stdio(false);
133     while(true) {
134         int numAntenna;
135         std::cin>>numAntenna;
136         if(numAntenna == 0) return 0;
137         testcase(numAntenna);
138     }
139 }

```

Divisor Distance

```
1  #include <vector>
2  #include <iostream>
3  #include <cmath>
4
5  using namespace std;
6
7  int greatestDivisor(int number) {
8      int i;
9      for (i = 2; i <=sqrt(number); i++) {
10         if (number % i == 0) {
11             return number/i;
12         }
13     }
14     return 1;
15 }
16
17 int cacheDivisor(vector<int> &graph, int i) {
18     if(graph[i] == -1) {
19         int gcd = greatestDivisor(i);
20         graph[i] = gcd;
21         return gcd;
22     } else {
23         return graph[i];
24     }
25 }
26
27 int main() {
28     ios_base::sync_with_stdio(false);
29     int testCases = 0;
30     cin >> testCases;
31
32     const int maxN = 10000000;
33     vector<int> g(maxN,-1);
34     for(int testCase=0; testCase < testCases; testCase++) {
35         int n, numPairs;
36
37         cin >> n;
38
39         cin >> numPairs;
40         for(int i=0; i<numPairs; i++) {
41             int x,y;
42             cin >> x >> y;
43             int pathLen=0;
44             while(true) {
45                 if(x==y) break;
46                 if(x>y) {
47                     x=cacheDivisor(g, x);
48                 } else {
49                     y=cacheDivisor(g, y);
50                 }
51                 ++pathLen;
52             }
53             cout<<pathLen<<endl;
54         }
55     }
56 }
```

Tiles

```
1  #include<iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/max_cardinality_matching.hpp>
7
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list<vecS, vecS, undirectedS > Graph;
13 typedef graph_traits<Graph> Traits;
14 typedef Traits::vertex_descriptor Vertex;
15 typedef Traits::edge_descriptor Edge;
16 typedef property_map<Graph, vertex_index_t>::type IndexMap;
17
18
19 void testCase() {
20     int width,height;
21     cin >> width >> height;
22
23     vector<vector<int> > field =
24         vector<vector<int> >(width, vector<int>(height, -1));
25     int curNumTilable = 0;
26     Graph g;
27
28     for(int i=0; i<height; i++) {
29         for(int j=0; j<width; j++) {
30             char place;
31             cin>>place;
32             if(place == '.') {
33                 field[j][i] = curNumTilable;
34                 if(i>0 && field[j][i-1] != -1) {
35                     Edge e;
36                     tie(e, tuples::ignore)=add_edge(field[j][i-1],curNumTilable,g);
37                 }
38                 if(j>0 && field[j-1][i] != -1) {
39                     Edge e;
40                     tie(e, tuples::ignore)=add_edge(field[j-1][i],curNumTilable,g);
41                 }
42                 curNumTilable++;
43             }
44         }
45     }
46
47     vector<Vertex> mate(curNumTilable);
48     edmonds_maximum_cardinality_matching(g, &mate[0]);
49     // for(i    get(mate,v)
50     // graph_traits::null_vertex();
51     if(matching_size(g,&mate[0])*2 == curNumTilable) {
52         cout<<"yes"<<std::endl;
53     } else {
54         cout<<"no"<<std::endl;
55     }
56 }
57
58
59 int main() {
60     int testCases;
61     cin>>testCases;
62     while(testCases--) testCase();
63     return 0;
64 }
```

Deleted Entries Strike Back

Missing.

Light The Stage

```
1  #include <CGAL/Exact_predicates_inexact_constructions_kernel.h>
2  #include <CGAL/Delaunay_triangulation_2.h>
3  #include <iostream>
4  #include<vector>
5
6  typedef CGAL::Exact_predicates_inexact_constructions_kernel K;
7  typedef CGAL::Delaunay_triangulation_2<K> Triangulation;
8  typedef Triangulation::Face_handle Face;
9  typedef Triangulation::Vertex_handle Vertex;
10 typedef K::Point_2 P;
11 typedef K::Segment_2 S;
12 typedef K::Circle_2 C;
13
14 using namespace std;
15
16 int midpoint(int lowerBound, int upperBound) {
17     return lowerBound + (upperBound-lowerBound)/2;
18 }
19
20 void winnersGivenNumLamps(const vector<P> &lamps, const int numLamps, const int height,
21                           const vector<int> &peopleR, const vector<P> &people,
22                           vector<int> &winners) {
23     // construct triangulation
24     Triangulation t;
25     t.insert(lamps.begin(), lamps.begin()+numLamps+1);
26
27     for(int i=0; i<people.size(); i++) {
28         Vertex nearestLamp = t.nearest_vertex(people[i]);
29
30         K::FT maxDist = height;
31         maxDist+=peopleR[i];
32         maxDist = maxDist * maxDist;
33         K::FT dist = CGAL::squared_distance(nearestLamp->point(),people[i]);
34
35         if(dist >= maxDist) winners.push_back(i);
36     }
37 }
38
39 void testcase() {
40     int numPeople, numLamps;
41     cin >> numPeople >> numLamps;
42
43     vector<P> people(numPeople);
44     vector<int> peopleR(numPeople);
45     for(int i=0; i<numPeople; i++) {
46         int x,y,r;
47         cin>>x>>y>>r;
48         people[i] = P(x,y);
49         peopleR[i] = r;
50     }
51
52     int height;
53     cin >> height;
54     vector<P> lamps(numLamps);
55     for(int i=0; i<numLamps; i++) {
56         int x,y;
57         cin>>x>>y;
58         lamps[i] = P(x,y);
59     }
60
61     vector<int> winners;
62
63     // try all lamps
64     winnersGivenNumLamps(lamps, numLamps, height,
65                           peopleR, people, winners);
66
67     if(winners.size() != 0) {
68         for(int i=0; i< winners.size();i++) {
69             cout<<winners[i]<<" ";
70         }
71         cout<<endl;
72         return;
73     }
```

```

74
75
76 //try binary search
77 int maxLampsMin = 0;
78 int maxLampsMax = lamps.size()-1;
79
80 while (maxLampsMax >= maxLampsMin) {
81     winners.clear();
82
83     int maxLamps = midpoint(maxLampsMin, maxLampsMax);
84
85     winnersGivenNumLamps(lamps, maxLamps, height,
86                          peopleR, people, winners);
87
88     if(winners.size() == 0) {
89         maxLampsMax = maxLamps-1;
90     } else {
91         maxLampsMin = maxLamps+1;
92     }
93 }
94
95 winners.clear();
96 winnersGivenNumLamps(lamps, maxLampsMax, height,
97                      peopleR, people, winners);
98 for(int i=0; i< winners.size();i++) {
99     cout<<winners[i]<<" ";
100 }
101 cout<<endl;
102
103 }
104
105 int main() {
106     ios_base::sync_with_stdio(false);
107     int testcases;
108     cin >> testcases;
109     while(testcases--) testcase();
110
111 }

```


Radiation

```
1  #include <iostream>
2  #include <cassert>
3  #include <CGAL/basic.h>
4  #include <CGAL/QP_models.h>
5  #include <CGAL/QP_functions.h>
6
7  // choose exact integral type
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 // program and solution types
17 typedef CGAL::Quadratic_program<ET> Program;
18 typedef CGAL::Quadratic_program_solution<ET> Solution;
19
20 using namespace std;
21
22
23 vector<vector<double> > powArray(2048,vector<double>(31,-1));
24
25 struct Point3 {
26     int x,y,z;
27 };
28
29 Point3 P(int x, int y, int z) {
30     Point3 p;
31     p.x = x;
32     p.y = y;
33     p.z = z;
34     return p;
35 }
36
37 double getPowerArray(int x, int y) {
38     double tmp;
39     if(powArray[x+1024][y] == -1) {
40         tmp = pow(x,y);
41         powArray[x+1024][y] = tmp;
42         return tmp;
43     } else {
44         return powArray[x+1024][y];
45     }
46 }
47
48 int midpoint(int lowerBound, int upperBound) {
49     return lowerBound + (upperBound-lowerBound)/2;
50 }
51
52 bool testDegree(vector<Point3> &cells, int numHealthy, int degree) {
53     Program lp (CGAL::SMALLER, false, 0, false, 0);
54     for(int c=0; c<cells.size(); c++) {
55         int row = c;
56         int rowIndex = 0;
57         for(int i=0; i <= degree; i++) {
58             for(int j=0; j <= degree-i; j++) {
59                 for(int k=0; k <= degree-i-j; k++) {
60                     lp.set_a(rowIndex, row,
61                             getPowerArray(cells[c].x, i)
62                             * getPowerArray(cells[c].y, j)
63                             * getPowerArray(cells[c].z, k)
64                             );
65                     if(row<numHealthy) {
66                         //healthy cell
67                         lp.set_b(rowIndex,-1);
68                         lp.set_r(rowIndex, CGAL::SMALLER);
69                     } else {
70                         //tumor cell
71                         lp.set_b(rowIndex,1);
72                         lp.set_r(rowIndex, CGAL::LARGER);
73                     }
74                 }
75             }
76         }
77     }
```

```

74         ++rowIndex;
75     }
76 }
77 }
78 }
79 CGAL::Quadratic_program_options options;
80 options.set_pricing_strategy(CGAL::QP_BLAND);
81 Solution s = CGAL::solve_linear_program(lp, ET(), options);
82 assert(s.solves_linear_program(lp));
83
84 return !s.is_infeasible();
85 }
86
87 int findBestDegree(vector<Point3> &cells, int numHealthy) {
88     const int maxLinear = -1;
89     for(int degree = 0; degree <= maxLinear; degree++) {
90         if(testDegree(cells, numHealthy, degree)) {
91             return degree;
92         }
93     }
94
95     int degreeMin = maxLinear+1;
96     int degreeMax = 30;
97     while(degreeMax >= degreeMin) {
98         int degree = midpoint(degreeMin, degreeMax);
99
100         if(testDegree(cells, numHealthy, degree)) {
101             degreeMax = degree-1;
102         } else {
103             degreeMin = degree+1;
104         }
105     }
106
107     return degreeMin;
108 }
109
110 void testCase() {
111     int numHealthy, numTumor;
112     cin>>numHealthy>>numTumor;
113
114     vector<Point3> cells(numHealthy+numTumor);
115
116     for(int i=0; i<cells.size(); i++) {
117         int x,y,z;
118         cin>>x>>y>>z;
119         cells[i] = P(x,y,z);
120     }
121
122     int degree = findBestDegree(cells, numHealthy);
123     if(degree <= 30) {
124         cout<< degree << std::endl;
125     } else {
126         cout << "Impossible!" << std::endl;
127     }
128 }
129
130 int main() {
131     ios_base::sync_with_stdio(false);
132     int testCases;
133     cin >> testCases;
134     while(testCases--) {
135         testCase();
136     }
137 }

```

Sweepers

```
1  #include <iostream>
2  #include <vector>
3  #include <queue>
4  #include <boost/config.hpp>
5  #include <boost/graph/adjacency_list.hpp>
6  #include <boost/tuple/tuple.hpp>
7  #include <boost/graph/push_relabel_max_flow.hpp>
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list_traits<vecS, vecS, directedS> Traits;
13 typedef adjacency_list<vecS, vecS, directedS, no_property,
14     property<edge_capacity_t, long,
15     property<edge_residual_capacity_t, long,
16     property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
17
18 typedef graph_traits<Graph> GraphTraits;
19 typedef GraphTraits::vertex_descriptor Vertex;
20 typedef GraphTraits::edge_descriptor Edge;
21 typedef GraphTraits::out_edge_iterator edge_iterator;
22 typedef property_map<Graph, vertex_index_t>::type IndexMap;
23 typedef property_map<Graph, edge_capacity_t>::type EdgeCapacityMap;
24 typedef property_map<Graph, edge_residual_capacity_t>::type ResidualCapacityMap;
25 typedef property_map<Graph, edge_reverse_t>::type ReverseEdgeMap;
26
27 void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
28     Edge e, reverseE;
29     tie(e, tuples::ignore) = add_edge(u,v,g);
30     tie(reverseE, tuples::ignore) = add_edge(v, u, g);
31     capacity[e] = c;
32     capacity[reverseE] = 0;
33     rev_edge[e] = reverseE;
34     rev_edge[reverseE] = e;
35 }
36
37 void testCase() {
38     int numVertices, numEdges, numSweepers;
39     cin>>numVertices>>numEdges>>numSweepers;
40
41     Graph g(numVertices+2);
42     EdgeCapacityMap capacity = get(edge_capacity, g);
43     ReverseEdgeMap rev_edge = get(edge_reverse, g);
44     ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
45
46     const int SOURCE = numVertices;
47     const int SINK = numVertices+1;
48     vector<int> startLocations, exitLocations;
49
50     //read start and exit locations
51     for(int i=0; i<numSweepers; i++) {
52         int startLocation;
53         cin>>startLocation;
54         startLocations.push_back(startLocation);
55     }
56     for(int i=0; i<numSweepers; i++) {
57         int exitLocation;
58         cin>>exitLocation;
59         exitLocations.push_back(exitLocation);
60     }
61
62     // the following is a incorrect interpretation of the task:
63     // correct: if there are sweepers they should clean every corridor just once
64     // there seems to be no requirement that corridors have to be cleaned
65     // if(numEdges > 0 && numSweepers == 0) {
66     //     cout<< "no"<< std::endl;
67     //     return;
68     // }
69
70     //build flow graph
71     for(int i=0; i<numEdges; i++) {
72         int u,v;
```

```

74         cin>>u>>v;
75         addFlowEdge(g, capacity, rev_edge, u, v, 1);
76         addFlowEdge(g, capacity, rev_edge, v, u, 1);
77     }
78
79     // check if all vertices of non-zero degree are reachable from some source
80     vector<bool> visited(numVertices,false);
81     std::queue<Vertex> Q;
82     for(int i=0; i<startLocations.size(); i++) {
83         int v = startLocations[i];
84         visited[v] = true;
85         Q.push(v);
86         while(Q.size() > 0) {
87             v = Q.front(); Q.pop();
88             edge_iterator out_i, out_end;
89             for(tie(out_i, out_end) = out_edges(v,g);
90                 out_i!=out_end; ++out_i) {
91                 Edge e = *out_i;
92                 int targ = target(e,g);
93                 if(targ<visited.size() && !visited[targ]) {
94                     Q.push(targ);
95                     visited[targ] = true;
96                 }
97             }
98         }
99     }
100
101     for(int i=0; i<visited.size(); i++) {
102         if(!visited[i] && out_degree(i,g)>0) {
103             cout<< "no"<< std::endl;
104             return;
105         }
106     }
107
108     //check eulerian tour
109     for(int i=0; i<numVertices; i++) {
110         int v = vertex(i, g);
111         int numStartLocation = count(startLocations.begin(), startLocations.end(), v);
112         int numExitLocation = count(exitLocations.begin(), exitLocations.end(), v);
113
114         if((out_degree(v,g)/2+numStartLocation+numExitLocation)%2 == 1) {
115             cout<<"no";
116             cout<<std::endl;
117             return;
118         }
119     }
120
121     // add source and sink
122     for(int i=0; i<startLocations.size(); i++) {
123         addFlowEdge(g, capacity, rev_edge, SOURCE, startLocations[i], 1);
124     }
125     for(int i=0; i<exitLocations.size(); i++) {
126         addFlowEdge(g, capacity, rev_edge, exitLocations[i], SINK, 1);
127     }
128
129     //compute flow
130     long flow = push_relabel_max_flow(g, SOURCE, SINK);
131
132     if(flow == numSweepers)
133         cout<<"yes"<<std::endl;
134     else
135         cout<<"no"<<std::endl;
136
137     return;
138 }
139
140
141 int main() {
142     ios_base::sync_with_stdio(false);
143     int testCases = 0;
144     cin >> testCases;
145     while(testCases--) testCase();
146 }

```

The Bracelet

```
1  #include <iostream>
2  #include <vector>
3  #include <stack>
4  #include <map>
5  #include <set>
6  #include <boost/config.hpp>
7  #include <boost/graph/adjacency_list.hpp>
8  #include <boost/tuple/tuple.hpp>
9  #include <boost/graph/connected_components.hpp>
10
11 using namespace std;
12 using namespace boost;
13
14 typedef adjacency_list<vecS, vecS, undirectedS,
15                       no_property, property<edge_weight_t, int> > Graph;
16 typedef graph_traits<Graph> Traits;
17 typedef Traits::vertex_descriptor Vertex;
18 typedef Traits::edge_descriptor Edge;
19 typedef Traits::vertex_iterator vertex_iter;
20 typedef Traits::out_edge_iterator edge_iterator;
21 typedef property_map<Graph, edge_weight_t>::type WeightMap;
22
23 void eulerTourDfs(Graph &g, WeightMap &marked, Vertex v, vector<int> &tour) {
24
25     edge_iterator out_i, out_end;
26     for (tie(out_i, out_end) = out_edges(v, g);
27          out_i!=out_end; ++out_i) {
28         if(marked[*out_i]==0) {
29             marked[*out_i]=1;
30             eulerTourDfs(g,marked,target(*out_i, g),tour);
31         }
32     }
33     tour.push_back(v);
34 }
35
36 void eulerTour(Graph &g, WeightMap &marked, Vertex v, vector<int> &tour) {
37     stack<int> S;
38     S.push(v);
39     while(!S.empty()) {
40         Vertex v = S.top();
41         edge_iterator out_i, out_end;
42         bool hasUnmarkedEdge=false;
43         for (tie(out_i, out_end) = out_edges(v, g);
44              out_i!=out_end; ++out_i) {
45             if(marked[*out_i]==0) {
46                 hasUnmarkedEdge=true;
47                 marked[*out_i]=1;
48                 S.push(target(*out_i,g));
49                 break;
50             }
51         }
52         if(!hasUnmarkedEdge) {
53             S.pop();
54             tour.push_back(v);
55         }
56     }
57 }
58
59
60 void testCase(int num) {
61     cout<<"Case_#"<<num<<std::endl;
62     int numBeads;
63     cin>>numBeads;
64
65     Graph g;
66     WeightMap marked = get(edge_weight, g);
67     vector<int> colorMap(51,-1);
68     int colorIndex = 0;
69
70     for(int i=0;i<numBeads;i++) {
71         int color1, color2;
72         cin>>color1>>color2;
73     }
```

```

74         // map colors to gapless indexes starting with 0
75         if(colorMap[color1] == -1) {
76             colorMap[color1] = colorIndex;
77             ++colorIndex;
78         }
79         if(colorMap[color2] == -1) {
80             colorMap[color2] = colorIndex;
81             ++colorIndex;
82         }
83
84         Edge e;
85         tie(e, tuples::ignore) =add_edge(colorMap[color1],colorMap[color2],g);
86         marked[e]=0;
87     }
88
89     vector<int> componentMap(num_vertices(g));
90     int components = connected_components(g, &componentMap[0]);
91     if(components > 1) {
92         cout<<"some_beads_may_be_lost"<<std::endl;
93         // cout<<"reason 1: "<<components<<std::endl;
94         return;
95     }
96
97     std::pair<vertex_iter,vertex_iter> vi;
98     for(vi=vertices(g); vi.first != vi.second; ++vi.first) {
99         int degree = out_degree(*(vi.first),g);
100         if(degree%2==1) {
101             cout<<"some_beads_may_be_lost"<<std::endl;
102             // cout<<"reason 2"<<std::endl;
103             return;
104         }
105     }
106
107     //print eulerian tour
108     vector<int> tour;
109     // eulerTourDfs(g,marked,0,tour);
110     eulerTour(g,marked,0,tour);
111
112     // reverse colorMap
113     vector<int> inverseColorMap(51,-1);
114     for(int i=0; i<colorMap.size(); i++) {
115         if(colorMap[i] != -1) {
116             inverseColorMap[colorMap[i]] = i;
117         }
118     }
119
120     for(int i=0; i<tour.size()-1; i++) {
121         cout<<inverseColorMap[tour[i]]<<"_ "<<inverseColorMap[tour[i+1]]<<std::endl;
122     }
123 }
124
125 int main() {
126     ios_base::sync_with_stdio(false);
127     int testCases;
128     cin >> testCases;
129     int i = 0;
130     while(testCases--) {
131         testCase(++i);
132         if(testCases>0) cout<<std::endl;
133     }
134 }

```

Knights

```
1  #include <iostream>
2  #include <vector>
3  #include <boost/config.hpp>
4  #include <boost/graph/adjacency_list.hpp>
5  #include <boost/tuple/tuple.hpp>
6  #include <boost/graph/push_relabel_max_flow.hpp>
7
8  using namespace std;
9  using namespace boost;
10
11  // #define DEBUG
12
13  #ifdef DEBUG
14  #define D(x) x
15  #else
16  #define D(x)
17  #endif
18
19  typedef adjacency_list_traits<vecS,vecS,directedS> Traits;
20  typedef adjacency_list<vecS, vecS, directedS, no_property,
21      property<edge_capacity_t, long,
22      property<edge_residual_capacity_t, long,
23      property<edge_reverse_t, Traits::edge_descriptor> > > > Graph;
24
25  typedef graph_traits<Graph> GraphTraits;
26  typedef GraphTraits::vertex_descriptor Vertex;
27  typedef GraphTraits::edge_descriptor Edge;
28  typedef property_map<Graph,vertex_index_t>::type IndexMap;
29  typedef property_map<Graph,edge_capacity_t>::type EdgeCapacityMap;
30  typedef property_map<Graph,edge_residual_capacity_t>::type ResidualCapacityMap;
31  typedef property_map<Graph,edge_reverse_t>::type ReverseEdgeMap;
32
33  void addFlowEdge(Graph &g, EdgeCapacityMap &capacity, ReverseEdgeMap &rev_edge, int u, int v, int c) {
34      Edge e, reverseE;
35      tie(e,tuples::ignore) = add_edge(u,v,g);
36      tie(reverseE,tuples::ignore) = add_edge(v,u,g);
37      capacity[e] = c;
38      capacity[reverseE] = 0;
39      rev_edge[e] = reverseE;
40      rev_edge[reverseE] = e;
41  }
42
43  void testCase() {
44      // graph is given as a grid
45      int gridX, gridY, numSources;
46      cin>>gridX>>gridY>>numSources;
47
48      Graph g;
49      EdgeCapacityMap capacity = get(edge_capacity, g);
50      ReverseEdgeMap rev_edge = get(edge_reverse, g);
51      ResidualCapacityMap res_capacity = get(edge_residual_capacity, g);
52
53      //need two "layers" one for in-vertices, the other for out-vertices because
54      //the "vertex"-capacity is 1
55      //the in-vertex is on the first layer, meaning its index <= numVerticesOnOneLayer
56      int numVerticesOnLayer = gridX*gridY;
57
58      const int SOURCE = numVerticesOnLayer*2;
59      const int SINK = numVerticesOnLayer*2+1;
60
61      for(int i=0; i<gridX; i++) {
62          for(int j=0; j<gridY; j++) {
63              int curVertex = numVerticesOnLayer + i*gridY+j;
64              // upper row
65              if(j>0) {
66                  addFlowEdge(g, capacity, rev_edge, curVertex, i*gridY+j-1,1);
67              } else {
68                  addFlowEdge(g, capacity, rev_edge, curVertex, SINK,1);
69              }
70              // right column
71              if(i<gridX-1) {
72                  addFlowEdge(g, capacity, rev_edge, curVertex, (i+1)*gridY+j,1);
73              } else {
```

```

74         addFlowEdge(g, capacity, rev_edge, curVertex, SINK,1);
75     }
76     // lower row
77     if(j<gridY-1) {
78         addFlowEdge(g, capacity, rev_edge, curVertex, i*gridY+j+1,1);
79     } else {
80         addFlowEdge(g, capacity, rev_edge, curVertex, SINK,1);
81     }
82     // left column
83     if(i>0) {
84         addFlowEdge(g, capacity, rev_edge, curVertex, (i-1)*gridY+j,1);
85     } else {
86         addFlowEdge(g, capacity, rev_edge, curVertex, SINK,1);
87     }
88
89     //connect out-vertex to its in-counterpart
90     addFlowEdge(g, capacity, rev_edge, curVertex-numVerticesOnLayer, curVertex,1);
91 }
92 }
93
94 for(int i=0; i<numSources; i++) {
95     int x,y;
96     cin>>x>>y;
97     addFlowEdge(g, capacity, rev_edge, SOURCE, x*gridY+y,1);
98 }
99
100 D(cout<<"num_vertices_<u></u>"<<num_vertices(g)<<endl;)
101
102 long flow = push_relabel_max_flow(g, SOURCE, SINK);
103
104 cout<<flow<<endl;
105
106 }
107
108 int main() {
109     int numCases;
110     cin >> numCases;
111     while(numCases--) testCase();
112     return 0;
113 }

```


Next Path

Missing.

Odd Route

Missing.

```
1  #include <iostream>
2  #include <vector>
3  #include <queue>
4  #include <limits>
5  #include <boost/config.hpp>
6  #include <boost/graph/adjacency_list.hpp>
7  #include <boost/graph/dijkstra_shortest_paths.hpp>
8
9  using namespace std;
10 using namespace boost;
11
12 typedef adjacency_list<vecS, vecS, directedS, no_property,
13 property<edge_weight_t, int> > Graph;
14 typedef graph_traits<Graph>::vertex_descriptor Vertex;
15 typedef graph_traits<Graph>::edge_descriptor Edge;
16
17 void testCase() {
18     int numVertices, numEdges;
19     cin>>numVertices>>numEdges;
20     Graph g(numVertices*4);
21
22     int source,target;
23     cin>>source>>target;
24
25     target = numVertices*3 + target;
26
27     property_map<Graph, edge_weight_t>::type weightMap = get(edge_weight, g);
28     for(int i = 0; i < numEdges; ++i)
29     {
30         int u,v,w;
31         cin>>u>>v>>w;
32         bool success;
33
34         Edge e;
35         if(w%2==1) {
36             tie(e, success) = add_edge(u, v+3*numVertices, g);
37             weightMap[e] = w;
38             tie(e, success) = add_edge(u+numVertices, v+2*numVertices, g);
39             weightMap[e] = w;
40             tie(e, success) = add_edge(u+2*numVertices, v+numVertices, g);
41             weightMap[e] = w;
42             tie(e, success) = add_edge(u+3*numVertices, v, g);
43             weightMap[e] = w;
44
45         } else {
46             tie(e, success) = add_edge(u, v+2*numVertices, g);
47             weightMap[e] = w;
48             tie(e, success) = add_edge(u+numVertices, v+3*numVertices, g);
49             weightMap[e] = w;
50             tie(e, success) = add_edge(u+2*numVertices, v, g);
51             weightMap[e] = w;
52             tie(e, success) = add_edge(u+3*numVertices, v+numVertices, g);
53             weightMap[e] = w;
54
55         }
56     }
57 }
58
59 std::vector<Vertex> predecessors(num_vertices(g));
60 std::vector<int> distancesFromSource(num_vertices(g));
61
62 dijkstra_shortest_paths(g, source,
63     predecessor_map(&predecessors[0]).distance_map(&distancesFromSource[0]));
64
65 if(distancesFromSource[target] < numeric_limits<int>::max()) {
66     cout<<distancesFromSource[target]<<endl;
67 } else {
68     cout<<"no"<<endl;
69 }
70
71 }
```

```
73
74  int main()
75  {
76      int testCases;
77      cin>>testCases;
78
79      while(testCases-->0) testCase();
80  }
```

Radiation 2

Missing.

Missing Roads

Standard maximum matching in Linear Programming formulation:

For each edge between u and v introduce variable x_{uv} . If the variable is set to 1 the edge is part of the matching, and if it set to 0, the edge is not in the matching. $\max \sum x_{uv}$ Subject to the constraint that no for every vertex u $x_{uv_1} + x_{uv_2} + \dots \leq 1$