

First to Penalty



Contents

1	Template	2
2	Data structures	2
2.1	Simplified DSU (Stolen from GGDem)	2
2.2	Disjoint Set Union	2
2.3	Segment tree	2
2.4	Segment tree Lazy	3
2.5	Trie	4
3	Graphs	4
3.1	Graph Transversal	4
3.1.1	BFS	4
3.1.2	DFS	4
3.2	Topological Sort	4
3.3	APSP: Floyd Warshall	5
3.4	SSSP	5
3.4.1	Lazy Dijkstra	5
3.4.2	Bellman-Ford	5
3.5	Strongly Connected Components: Kosaraju	6
3.6	Articulation Points and Bridges: ModTarjan	7
4	Math	8
4.1	Identities	8
4.2	Binary Exponentiation and modArith	8
4.3	Modular Inverse (dividir mod)	8
4.4	Modular Binomial Coefficient and Permutations	8
4.5	Non-Mod Binomial Coefficient and Permutations	8
4.6	Modular Catalan Numbers	9
4.7	Ceil Fraccionario	9
4.8	Numeros de Fibonacci	9
4.9	Sieve Of Eratosthenes	9
4.10	Sieve-based Factorization	9
4.11	Berlekamp Massey	9
4.12	Modular Berlekamp Massey	10
4.13	Matrix exponentiation	10
5	Geometry	11
6	Strings	11
6.1	Explode by token	11
6.2	Multiple Hashings DS	11
6.3	Permute chars of string	11
6.4	Longest common subsequence	12
6.5	KMP	12
7	Clasicos	12
7.1	Job scheduling	12
7.1.1	One machine, linear penalty	12
7.1.2	One machine, deadlines	12
7.1.3	One machine, profit	13
7.1.4	Two machines, min time	13
8	Flow	14
8.1	Dinic, thx GGDem	14
9	Miscellaneous	15
9.1	Bit Manipulation	15
10	Testing	16

1 Template

```

1 #include "bits/stdc++.h"
2 //assert(x>0) si falla da RTE
3 using namespace std;
4 #define endl '\n'
5 #define DBG(x) cerr<<#x<< "=" << (x) << endl;
6 #define RAYA cerr<<"===== "<<endl;
7 #define RAYAS cerr<<"..... "<<endl;
8 // #define DBG(x) ;
9 // #define RAYA ;
10 // #define RAYAS ;
11
12 //-----SOLBEGIN-----
13 int main() {
14     ios_base::sync_with_stdio(false); cout.tie(NULL); cin.tie(NULL);
15     int tC;
16
17     cin >> tC;
18     while (tC--) {
19
20     }
21 }
22
23 //-----EOSOLUTION-----

```

2 Data structures

2.1 Simplified DSU (Stolen from GGDem)

```

1 int uf[MAXN];
2 void uf_init(){memset(uf,-1,sizeof(uf));}
3 int uf_find(int x){return uf[x]<0?x:uf[x]=uf_find(uf[x]);}
4 bool uf_join(int x, int y){
5     x=uf_find(x);y=uf_find(y);
6     if(x==y)return false;
7     if(uf[x]>uf[y])swap(x,y);
8     uf[x]+=uf[y];uf[y]=x;
9     return true;
10 }

```

2.2 Disjoint Set Union

```

1 class disjSet {
2     int* sz;
3     int* par;
4 public:
5     int len;
6     disjSet(int tam){
7         sz = new int[tam + 4]();
8         par = new int[tam + 4]();
9         len = 0;
10        for(int i = 0; i<=tam; i++){
11            par[i] = i;
12            sz[i] = 1;
13            len++;
14        }
15    }
16    int finds(int el){
17        if (el == par[el]) return el;
18        return par[el] = finds(par[el]);
19    }
20    void unions(int a, int b){
21        a = finds(a);
22        b = finds(b);
23        if (a == b) return;
24        len--;
25        //se hace que el gde sea padre del pequeno
26        if (sz[a] > sz[b]) swap(a,b);
27        par[a] = b;
28        sz[b] += sz[a];
29    }
30    ~disjSet(){
31        delete[] size;
32        size = nullptr;
33        delete[] parent;
34        parent = nullptr;
35    }
36 };

```

2.3 Segment tree

```

1 //MAXN = 2^k, n = tam arreglo inicial
2 int stsize; long long int neut;int n;
3 long long int* st = new long long int[2*MAXN-1]();
4 long long int fst(long long int a, long long int b);

```

```

5 long long int build(int sti,int csize){
6     if(csize == 1) return st[sti];
7     return st[sti] = fst(build(sti*2+1,csize/2),build(sti*2+2,csize/2));
8 }
9 void innit(){
10     for(int i = 0; i<stsize; i++) st[i] = neut;
11     /*int d = 0;
12     for(int i = stsize-n; i<stsize && d<n; i++){
13         st[i] = arr[d];d++;
14     }*/
15     build(0,n);
16 }
17 void upd(int ind, long long int val){
18     ind = stsize-n+ind;
19     st[ind] = val;ind--;ind/=2;
20     while(true){
21         st[ind] = fst(st[ind*2+1],st[ind*2+2]);
22         ind--;
23         if(ind<0) break;
24         ind/=2;
25     }
26 }
27 long long int rqu(int l, int r,int sti, int ls, int rs){
28     if(l<=ls && rs<= r) return st[sti];
29     if(r<ls || l>rs) return neut;
30     int m = (rs+ls)/2;
31     return fst(rqu(l,r,sti*2+1,ls,m),rqu(l,r,sti*2+2,m+1,rs));
32 }
33 long long int query(int l, int r){
34     return rqu(l,r,0,0,n-1);
35 }
36 //uso, inicializa neut, determina n (asegurate que sea una potencia de
37 //2), define fst para determinar
38 //la opracion del segment tree

```

2.4 Segment tree Lazy

```

1 //MAXN = 2^k, n = tam arreglo inicial
2 #define MAXN 524288
3 vector<int> arr;
4 int stsize; long long int neut;int n;
5 long long int* st = new long long int[2*MAXN-1]();
6 long long int* pendientes = new long long int[2*MAXN-1]();

```

```

7 long long int fst(long long int a, long long int b){return a+b;}
8 long long int build(int sti,int csize){
9     if(csize == 1) return st[sti];
10    return st[sti] = fst(build(sti*2+1,csize/2),build(sti*2+2,csize/2));
11 }
12 bool hasChildren(int sti){sti*=2;sti++;sti++;return sti<stsize;}
13 void innit(){
14     for(int i = 0; i<stsize; i++) st[i] = neut;
15     int d = 0;
16     for(int i = stsize-n-1; i<stsize && d<n; i++) {st[i] = arr[d];d++;}
17     build(0,n);
18 }
19 void updrec(int l,int r, int sl, int sr,int sti, long long int val){
20     if(sr<l || r< sl) return;
21     if(l<= sl && sr <=r){
22         st[sti] += val*(sr-sl+1);
23         if(hasChildren(sti)){pendientes[sti*2+1]+=val;pendientes[sti
24             *2+2]+=val;}
25         return;
26     }
27     int sm = (sl+sr)/2;
28     updrec(l,r,sl,sm,sti*2+1,val);
29     updrec(l,r,sm+1,sr,sti*2+2,val);
30     st[sti] = fst(st[sti*2+1],st[sti*2+2]);
31 }
32 void upd(int l, int r, long long int val){updrec(l,r,0,n-1,0,val);}
33
34 long long int rqu(int l, int r,int sti, int ls, int rs){
35     if(r<ls || l>rs) return neut;
36     if(l<=ls && rs<= r){
37         return st[sti]+pendientes[sti]*(rs-ls+1);
38     }
39
40     st[sti] += pendientes[sti]*(rs-ls+1);
41     if(hasChildren(sti)){pendientes[sti*2+1]+=pendientes[sti];pendientes
42         [sti*2+2]+=pendientes[sti];}
43     pendientes[sti] = 0;
44
45     int m = (rs+ls)/2;
46     return fst(rqu(l,r,sti*2+1,ls,m),rqu(l,r,sti*2+2,m+1,rs));
47 }
48 long long int query(int l, int r){

```

```

48     return rqu(l,r,0,0,n-1);
49 }
50 //uso, inicializa neut, lee n y arr, iguala n a la potencia de dos mas
    cercana y mayor
51 //determina stsize = 2*n (asegurate que sea una potencia de 2), define
    fst para determinar
52 //la opracion del segment tree
    
```

2.5 Trie

```

1 struct triver {
2     char alphabet;
3     bool ter;
4     vector<triver*> child;
5     triver(char a): alphabet(a) { child.assign(26, NULL); ter = false; }
6 };
7 class trie{
8 private:
9     triver* root;
10 public:
11     trie() { root = new triver('!');}
12     void insert(string s){
13         triver* curr = root;
14         for(char l: s){
15             if(curr->child[l-'A'] == NULL) curr->child[l-'A'] = new
                triver(l);
16             curr = curr->child[l-'A'];
17         }
18         curr->ter = true;
19     }
20     bool search(string s){
21         triver* curr = root;
22         for(char l: s){
23             if(curr == NULL) break;
24             curr = curr->child[l-'A'];
25         }
26         if(curr == NULL) return false;
27         return curr->ter;
28     }
29 };
    
```

3 Graphs

3.1 Graph Transversal

3.1.1 BFS

```

1 #define GS 400040
2 vector<int> graph[GS];
3 bitset <GS> vis;
4 //anchura O(V+E)
5 void dfs(int curr) {
6     queue<int> fringe;
7     fringe.push(curr);
8     while (fringe.size()) {
9         curr = fringe.front(); fringe.pop();
10        if (!vis[curr]) {
11            vis[curr] = 1;
12            for (int h : graph[curr]) fringe.push(h);
13        }
14    }
15 }
    
```

3.1.2 DFS

```

1 #define GS 400040
2 vector<int> graph[GS];
3 bitset <GS> vis;
4 //profundidad O(V+E)
5 void dfs(int curr) {
6     stack<int> fringe;
7     fringe.push(curr);
8     while (fringe.size()){
9         curr = fringe.top(); fringe.pop();
10        if (!vis[curr]) {
11            vis[curr] = 1;
12            for (int h : graph[curr]) fringe.push(h);
13        }
14    }
15 }
    
```

3.2 Topological Sort

```

1 #define GS 400040
2 vector<int> graph[GS];
    
```

```

3 bitset <GS> vis;
4 vector<int> topsort;
5 int e,n;
6 //profundidad
7 //O(N+E)
8 //Solo funciona con DAG's, no existe un top sort de un grafo Non-DAG
9 void todfs(int pa) {
10     vis[pa]=1;
11     for(int h: graph[pa]){if(!vis[h]){todfs(h);}}
12     topsort.push_back(pa);
13 }
14 void topologicalSort(){
15     vis.reset();
16     topsort.clear();
17     for(int i = 0; i<n; i++){if(!vis[i]){dfs(i);}}
18     reverse(topsort.begin(),topsort.end());
19 }
    
```

3.3 APSP: Floyd Warshall

```

1 #define GS 1000
2 #define INF 100000000
3 //destino, costo
4 int graph[GS][GS];
5 //All Pairs Dist
6 int dist[GS][GS];
7 //Toma en cuenta nodos [0-tam] inclusivo, modificar de acuerdo a las
8 //necesidades
9 //Ten cuidado con el valor que le pones a INF, puede provocar overflows
10 //o puede no ser lo suficientemente grande.
11 void Floyd_Warshall(int tam){
12     for(int i = 0; i<=tam; i++)
13         for(int f = 0; f<=tam; f++)
14             dist[i][f] = INF;
15
16     for(int i = 0; i<=tam; i++)
17         for(int f = 0; f<=tam; f++)
18             dist[i][f] = graph[i][f];
19
20     //para reconstruir el camino solo basta con guardar intermedio como
21     //el padre de ini si el cambio se hizo, -1 otherwise
22     for(int intermedio = 0; intermedio<=tam; intermedio++)
23         for(int ini = 0; ini<=tam; ini++)
    
```

```

21         for(int fin = 0; fin<=tam; fin++)
22             dist[ini][fin] = min(dist[ini][fin],dist[ini][intermedio]
23             ]+dist[intermedio][fin]);
    
```

3.4 SSSP

3.4.1 Lazy Dijkstra

```

1 #define GS 1000
2 #define INF 100000000
3 //destino, costo
4 vector<pair<int,int>> graph[GS];
5 int dist[GS];
6 void dijkstra(int origen,int tam){
7     for(int i = 0; i<=tam; i++){
8         dist[i] = INF;
9     }
10     priority_queue<pair<int,int>,vector<pair<int,int>>, greater<pair<int
11     ,int>>> pq;
12     pair<int,int> curr;
13
14     pq.push(make_pair(0,origen));
15
16     while(pq.size()){
17         curr = pq.top();pq.pop();
18         if(curr.first >= dist[curr.second]) continue;
19
20         dist[curr.second] = curr.first;
21         for(pair<int,int> h: graph[curr.second]){
22             if((h.second+curr.first)<dist[h.first]) pq.push({h.second+
23             curr.first,h.first});
24         }
25     }
26
27     //Esta es la implementacion huevona
28     //Resuelve Single Source Shortest Paths con aristas positivas
29     //Como es la lazy implementation, si funciona con edges negativos
30     //siempre y cuando no hayan ciclos negativos
31     //Si hay ciclos negativos se va atascar en un ciclo infinito
32     //Si no los hay puede que funcione en O((V+E)log(V)) o puede que se
33     //exponencial, si no jala prueba BellmanFord
    
```

3.4.2 Bellman-Ford

```

1 //esta es la implementacion huevona
2 #define GS 1000
3 //cuidado con overflows!!
4 #define INF 100000000
5 #define NINF -100000000
6 //destino, costo
7 vector<pair<int,int>> graph[GS];
8 int dist[GS];
9 struct edge{
10     int from,to,cost;
11 };
12 //Corre en O(VE)
13 void bellmanFord(int origen,int tam){
14     for(int i = 0; i<=tam; i++){
15         dist[i] = INF;
16     }
17     dist[origen] = 0;
18     edge aux;
19     vector<edge> aristas;
20     bool optimal;
21
22     for(int i = 0; i<=tam; i++){
23         for(pair<int,int> h: graph[i]){
24             aux.from = i; aux.to = h.first;aux.cost = h.second;
25             aristas.push_back(aux);
26         }
27     }
28
29     //Si se relajan todos las aristas V-1 veces en un orden arbitrario
30     //Se asegura que la distancia optima para cada vertice sera
31     //alcanzada
32     for(int i = 0; i<tam && !optimal; i++){
33         optimal = true;
34         for(edge elem: aristas){
35             if(dist[elem.from] + elem.cost < dist[elem.to]){
36                 dist[elem.to] = dist[elem.from] + elem.cost;
37                 //si algun vertice fue actualizado significa que puede
38                 //que
39                 //las distancias aun no sean optimas
40                 optimal = false;
41             }
42         }
43     }
44 }

```

```

42
43 //Se corre de nuevo para asegurar encontrar todos los ciclos
44 //negativos
45 for(int i = 0; i<tam && !optimal; i++){
46     optimal = true;
47     for(edge elem: aristas){
48         if(dist[elem.from] + elem.cost < dist[elem.to]){
49             //Si aun despues de correr V-1 veces se puede actualizar
50             //Significa que esta en un ciclo negativo
51             dist[elem.to] = NINF;
52             //si algun vertice fue actualizado significa que puede
53             //que
54             //las distancias aun no sean optimas
55             optimal = false;
56         }
57     }
58 }

```

3.5 Strongly Connected Components: Kosaraju

```

1 #define GS 2010
2 vector<int> graph[GS];
3 vector<int> graphI[GS];
4 vector<int> orden;
5 bitset<GS> vis;
6
7 void invertirGrafo(int n){
8     for(int p = 1;p<= n; p++)
9         for(int h: graph[p])graphI[h].push_back(p);
10 }
11 void obtOrd(int p,int n){
12     vis[p] = 1;
13     for(int h: graph[p]){
14         if(!vis[h] && h<=n) obtOrd(h,n);
15     }
16     orden.push_back(p);
17 }
18 int findSCC(int n){
19     int res = 0;
20     invertirGrafo(n);
21     orden.clear();

```

```

22     for(int i = 1; i<=n; i++) vis[i] =0;
23     for(int i = 1; i<=n; i++) if(!vis[i]) obtOrd(i,n);
24     reverse(orden.begin(),orden.end());
25     //cuenta los connected components
26     //vector<int> lsc;
27     stack<int> fringe;
28     int curr;
29     for(int i = 1; i<=n; i++) vis[i] =0;
30     for(int i: orden){
31         //lsc.clear();
32         if(!vis[i]){
33             fringe.push(i);
34             while (fringe.size()){
35                 curr = fringe.top();fringe.pop();
36                 //lsc.push_back(curr);
37                 if (!vis[curr]) {
38                     vis[curr] = 1;
39                     for (int h : graphI[curr]) fringe.push(h);
40                 }
41             }
42             res++;
43         }
44         //hacer lo que sea con lcsc
45     }
46     return res;
47 }
48
49 //OJO esto solo jala con directed graphs
50 //por definicion todas las undirected graphs tienen un solo SCC
51 //NOTAR QUE LOS GRAFOS QUE USA CUMPLEN CON: 0<=VERTICE<=n

```

3.6 Articulation Points and Bridges: ModTarjan

```

1 #define GS 50
2 vector<int> graph[GS];
3 bitset<GS> vis, isArtic;
4 vector<int> padre;
5 //id por tiempo, menor id accesible
6 //ya sea por descendientes o por back edges
7 vector<int> tId,lId;
8 //cantidad de hijos que tiene en el bfs spanning tree
9 int rootChildren;
10 int cnt;

```

```

11 int dfsRoot;
12 void findAP_B(int p){
13     cnt++;vis[p] = 1;tId[p] = cnt;lId[p] = tId[p];
14
15     for(int hijo: graph[p]){
16         if(!vis[hijo]){
17             padre[hijo] = p;
18             if(p == dfsRoot) rootChildren++;
19
20             findAP_B(hijo);
21
22             //esto significa que ni por un back edge el hijo accede al
23             //padre
24             //por lo que si el padre fuese eliminado el hijo quedaria
25             //aislado
26             if(lId[hijo] >= tId[p]) isArtic[p] = 1;
27             if(lId[hijo] > tId[p]){
28                 //esto significa que si se eliminase el camino de padre
29                 //se lograria desconectar el grafo, aka bridge
30             }
31             lId[p] = min(lId[p],lId[hijo]);
32         }else{
33             //si hay un ciclo indirecto, actualiza el valor para el
34             //padre
35             if(hijo != padre[p]) lId[p] = min(lId[p],tId[hijo]);
36         }
37     }
38 }
39 //OJO esto solo jala con Undirected graphs
40 /*
41 MAIN
42 for(int i = 0; i<n; i++){
43     if(!vis[i]){
44         rootChildren = 0;
45         dfsRoot = i;
46         findAP_B(i);
47         //el algoritmo no puede detectar si el nodo que lo origino
48         //es un articulation point, por lo que queda checar si
49         //en el spanning tree que genero tiene mas de un solo hijo
50         isArtic[i] = (rootChildren>1?1:0);
51     }
52 }

```

50 `*/`

4 Math

4.1 Identities

$$C_n = \frac{2(2n-1)}{n+1} C_{n-1}$$

$$C_n = \frac{1}{n+1} \binom{2n}{n}$$

$$C_n \sim \frac{4^n}{n^{3/2}\sqrt{\pi}}$$

$$\sigma(n) = O(\log(\log(n))) \text{ (number of divisors of } n)$$

$$F_{2n+1} = F_n^2 + F_{n+1}^2$$

$$F_{2n} = F_{n+1}^2 - F_{n-1}^2$$

$$\sum_{i=1}^n F_i = F_{n+2} - 1$$

$$F_{n+i}F_{n+j} - F_nF_{n+i+j} = (-1)^n F_i F_j$$

$$\text{(Möbius Inv. Formula) Let } g(n) = \sum_{d|n} f(d), \text{ then } f(n) = \sum_{d|n} d \cdot ng(d) \mu\left(\frac{n}{d}\right).$$

$$\text{Permutaciones objetos repetidos } P(n, k) = \frac{P(n, k)}{n_1! n_2! \dots}$$

$$\text{Separadores, Ecuaciones lineares } a \text{ variables} = b \left(\binom{a}{b} \right) = \binom{a+b-1}{b} = \binom{a+b-1}{a-1}$$

4.2 Binary Exponentiation and modArith

```

1 long long int inf = 100000000007;
2 //suma (a+b)%m
3 //resta ((a-b)%m+m)%m
4 //mult (a*b)%m
5 long long binpow(long long b, long long e) {
6     long long res = 1; b%=inf;
7     while (e > 0) {
8         if (e & 1) res = (res * b)%inf;
9         b = (b * b)%inf;
10        e >>= 1;
11    }
12    return res;
13 }
```

4.3 Modular Inverse (dividir mod)

```

1 long long int inf = 100000000007;
2 long long int gcd(long long int a, long long int b, long long int& x,
3     long long int& y) {
4     x = 1, y = 0;
5     long long int x1 = 0, y1 = 1, a1 = a, b1 = b;
6     while (b1) {
```

```

6         long long int q = a1 / b1;
7         tie(x, x1) = make_tuple(x1, x - q * x1);
8         tie(y, y1) = make_tuple(y1, y - q * y1);
9         tie(a1, b1) = make_tuple(b1, a1 - q * b1);
10    }
11    return a1;
12 }
13 long long int modinverse(long long int b, long long int m){
14     long long int x,y;
15     long long int d = gcd(b,inf,x,y);
16     if(d!=1) return -1;
17     return ((x%inf)+inf)%inf;
18 }
```

4.4 Modular Binomial Coefficient and Permutations

```

1 long long int inf = 100000000007;
2 //cat[n] = bincoef(2*n,n)/(n+1), cat[0] = 1
3 class binCoef{
4     long long int lim;
5     long long int* fact;
6 public:
7     binCoef(long long int l){
8         lim = l; fact = new long long int[l+1];fact[0]= 1;
9         for(long long int i = 1; i<=l; i++) fact[i] = (fact[i-1]*i)%inf;
10    }
11    //perm = (fact[n] * modinverse(fac[n-k],inf)%inf;
12    long long int query(long long int n, long long int k){
13        if(n<k) return 0;
14        return (fact[n] * modinverse((fac[n-k]*fact[k])%inf,inf))%inf;
15    }
16 };
```

4.5 Non-Mod Binomial Coefficient and Permutations

```

1 //Solo usar con n<=20
2 //cat[n] = bincoef(2*n,n)/(n+1), cat[0] = 1
3 unsigned long long int bincoef(unsigned long long int n, unsigned long
4     long int k){
5     if(n<k) return 0;
6     unsigned long long int num = 1, den= 1;
7     for(unsigned long long int i = (n-k)+1; i<=n; i++) num*=i;
8     for(unsigned long long int i = 2; i<=k; i++) den*=i;
9     //perm = return num;
```



```

9     return num/den;
10 }
    
```

4.6 Modular Catalan Numbers

```

1 long long int inf = 10000000007;
2 class catalan{
3     long long int* cat; long long int lim
4 public:
5     catalan(long long int l){
6         lim = l; cat = new long long int[l+10]; cat[0] = 1;
7         for(long long int i = 0; i<=l; i++) cat[i+1] = (((((4LL*i+2)%inf)
8             *cat[i])%inf) *modinverse(n+2))%inf;
9     }
10    long long int query(long long int n){ return cat[n];}
    
```

4.7 Ceil Fraccionario

```

1 long long int techo(long long int num, long long int den){ return (num+
    den-1)/den;}
    
```

4.8 Numeros de Fibonacci

```

1 //en caso de ser usados mod un m pequeno
2 //recordar que los numeros de fibonacci se repiten por lo menos cada m^2
3 //0(n)
4 unsigned long long int fib(int n){
5     unsigned long long int a = 1, b = 1, aux;
6     if(n<=2){
7         return 1;
8     }
9     for(int i = 3; i<=n; i++){
10        aux = a+b;
11        a = b;
12        b = aux;
13    }
14    return b;
15 }
    
```

```

1 const long long int inf = 10000000007;
2 unordered_map<long long int, long long int> Fib;
3 //0(log n) :DD
4 long long int fib(long long int n)
    
```

```

5 {
6     if(n<2) return 1;
7     if(Fib.find(n) != Fib.end()) return Fib[n];
8     Fib[n] = (fib((n+1) / 2)*fib(n/2) + fib((n-1) / 2)*fib((n-2) / 2)) %
9         inf;
10    return Fib[n];
    }
    
```

4.9 Sieve Of Eratosthenes

```

1 #define MAXN 10e6
2 class soe{
3 public:
4     bitset<MAXN> isPrime;
5     soe(){
6         for(int i = 3; i<MAXN; i++) isPrime[i] = (i%2);
7         isPrime[2] = 1;
8         for(int i = 3; i*i<MAXN; i+=2)
9             if(isPrime[i])
10                for(int j = i*i; j<MAXN; j+=i)
11                    isPrime[j] = 0;
12    }
13 };
    
```

4.10 Sieve-based Factorization

```

1 #define MAXN 10e6
2 class soe{
3 public:
4     int smolf[MAXN];
5     soe(){
6         for(int i = 2; i<MAXN; i++) smolf[i] = (i%2==0?2:i);
7
8         for(int i = 3; i*i<MAXN; i+=2)
9             if(smolf[i]==i)
10                for(int j = i*i; j<MAXN; j+=i)
11                    smolf[j] = min(smolf[j], smolf[i]);
12    }
13 };
    
```

4.11 Berlekamp Massey

```

1 typedef long long int ll;
2 //Obtiene recurrencia lineal dados los primeros elementos en O(n^2)
    
```

```

3 vector<ll> berlekampMassey(const vector<ll> &s) {
4     vector<ll> c;
5     vector<ll> oldC;
6     int f = -1;
7     for (int i=0; i<(int)s.size(); i++) {
8         ll delta = s[i];
9         for (int j=1; j<=(int)c.size(); j++) delta -= c[j-1] * s[i-j];
10        if (delta == 0) continue;
11        if (f == -1) {
12            c.resize(i + 1);
13            mt19937 rng(chrono::steady_clock::now().time_since_epoch().
14                count());
15            for (ll &x : c) x = rng();
16            f = i;
17        } else {
18            vector<ll> d = oldC;
19            for (ll &x : d) x = -x;
20            d.insert(d.begin(), 1);
21            ll df1 = 0;
22            for (int j=1; j<=(int)d.size(); j++) df1 += d[j-1] * s[f+1-j];
23            assert(df1 != 0);
24            ll coef = delta / df1;
25            for (ll &x : d) x *= coef;
26            vector<ll> zeros(i - f - 1);
27            zeros.insert(zeros.end(), d.begin(), d.end());
28            d = zeros;
29            vector<ll> temp = c;
30            c.resize(max(c.size(), d.size()));
31            for (int j=0; j<(int)d.size(); j++) c[j] += d[j];
32            if (i - (int) temp.size() > f - (int) oldC.size()) {oldC =
33                temp;f = i;}
34        }
35    }
36    return c;
37 }

```

4.12 Modular Berlekamp Massey

```

1 typedef long long int ll;
2 long long int inf = 1000000007;
3 vector<ll> bermas(vector<ll> x){
4     vector<ll> ls,cur;

```

```

5     int lf,ld;
6     for(int i = 0; i<x.size(); i++){
7         long long int t = 0;
8         for(int j = 0; j<cur.size(); j++) t=(t+x[i-j-1]*(long long int)
9             cur[j])%inf;
10        if((t-x[i])%inf==0)continue;
11        if(cur.size()==0){cur.resize(i+1);lf=i;ld=(t-x[i])%inf;continue;
12        };
13        long long int k = (x[i]-t)*powermod(ld,inf-2)%inf;
14        vector<ll>c(i-lf-1);c.push_back(k);
15        for(int j = 0; j<ls.size(); j++) c.push_back(-ls[j]*k%inf);
16        if(c.size()<cur.size()) c.resize(cur.size());
17        for(int j = 0; j<cur.size();j++) c[j]=(c[j]+cur[j])%inf;
18        if(i-lf+ls.size()>cur.size())ls=cur,lf=i,ld=(t-x[i])%inf;
19        cur=c;
20    }
21    for(int i =0; i<cur.size(); i++) cur[i]=(cur[i]%inf+inf)%inf;
22    return cur;
23 }

```

4.13 Matrix exponentiation

```

1 typedef vector<vector<long long int>> Matrix;
2 long long int inf = 1000000007;
3 Matrix ones(int n) {
4     Matrix r(n,vector<long long int>(n));
5     for(int i= 0; i<n; i++){
6         r[i][i]=1;
7     }
8     return r;
9 }
10 Matrix operator*(Matrix &a, Matrix &b) {
11     int n=a.size(),m=b[0].size(),z=a[0].size();
12     Matrix r(n,vector<long long int>(m));
13     for(int i=0; i<n; i++){
14         for(int j=0; j<m; j++){
15             for(int k=0;k<z; k++){
16                 r[i][j]+=((a[i][k]%inf)*(b[k][j]%inf))%inf;
17                 r[i][j]%=inf;}}}
18     return r;
19 }
20 Matrix be(Matrix b, long long int e) {
21     Matrix r=ones(b.size());

```

```

22 while(e){if(e&1LL)r=r*b;b=b*b;e/=2;}
23 return r;
24 }
25
26 //Matrix mat(n,vector<long long int>(n));

```

5 Geometry

6 Strings

6.1 Explode by token

```

1 // #include <sstream>
2
3 vector<string> explode(string const& s, char delim) {
4     vector<string> result;
5     istringstream iss(s);
6     for (string token; getline(iss, token, delim); )
7     {
8         result.push_back(move(token));
9     }
10    return result;
11 }

```

6.2 Multiple Hashings DS

```

1 struct multhash{
2     unsigned long long int h1,h2;
3     unsigned long long int alf[257];
4     bool operator < (multhash b) const {
5         if (h1 != b.h1) return h1 < b.h1;
6         return h2 < b.h2;
7     }
8     bool operator == (multhash b) const { return (h1== b.h1 && h2== b.h2)
9         ;}
10    bool operator != (multhash b) const { return !(h1== b.h1 && h2== b.h2)
11        ;}
12 public:
13     string s;
14     multhash(){
15         h1 = 0; h2 = 0; s = "";
16         for(char l = 'a'; l<='z'; l++) alf[l] = l-'a'+1;
17     }

```

```

16 void innit(){
17     unsigned long long int inf,p,op;
18
19     inf = 999727999;
20     p = 325255434;op = 325255434;
21     for(char l: s){
22         h1+=(p*alf[l])%inf;
23         p*=op;
24         p%=inf;
25     }
26
27     inf = 1070777777;
28     p = 10018302;op = 10018302;
29     for(char l: s){
30         h2+=(p*alf[l])%inf;
31         p*=op;
32         p%=inf;
33     }
34 }
35 };
36 //VALORES ALTERNATIVOS DE INF, LOG 17
37 //6666665555777777
38 //986143414027351997
39 //974383618913296759
40 //973006384792642181
41 //953947941937929919
42 //9090909090909091
43 //VALORES PARA P, USAR PRIMOS MAYORES A |Alfabeto|
44 //31,47,53,61,79

```

6.3 Permute chars of string

```

1 void permute(string str){
2     // Sort the string in lexicographically
3     // ascennding order
4     sort(str.begin(), str.end());
5
6     // Keep printing next permutation while there
7     // is next permutation
8     do {
9         cout<<str<<endl;
10    } while (next_permutation(str.begin(), str.end()));
11 }

```

6.4 Longest common subsequence

```

1 //0(|te|*|pa|)
2 //cambiar score para otros problemas, str all match = +2, miss/ins/del =
   -1
3 //usar char que no este en el alfabeto para denotar del/ins
4 string te,pa;
5 long long int ninf = -10e13;
6 long long int score(char a, char b){
7     if(a=='*' || b=='*') return 0;
8     if(a==b) return 1;
9     return ninf;
10 }
11 long long int lcs(){
12     long long int** dp;te = "*" + te; pa = "*" + pa;
13     long long int res = 0;
14
15     dp = new long long int*[te.size()];
16     for(int i = 0; i<te.size(); i++) dp[i] = new long long int[pa.size()
17         ]();
18
19     for(int r = 1; r<te.size(); r++){
20         for(int c = 1; c<pa.size(); c++){
21             dp[r][c] = dp[r-1][c-1] + score(te[r], pa[c]);
22             dp[r][c] = max(dp[r][c-1] + score(te[r], '*'), dp[r][c]);
23             dp[r][c] = max(dp[r-1][c] + score('*', pa[c]), dp[r][c]);
24         }
25     }
26     return dp[te.size()-1][pa.size()-1];
27 }

```

6.5 KMP

```

1 string T,P;
2 int bt[MAXN];
3 //0(|Text|+|Pattern|)
4 void KMPpre(){
5     int i = 0,j = -1; bt[0] = -1;
6     while(i<P.size()){
7         while(j>=0 && P[i]!=P[(j>=0?j:0)]) j = bt[j];
8         i++;j++; bt[i] = j;
9     }

```

```

10 }
11 int kmp(){
12     int res =0, i = 0, j = 0;
13     while(i<T.size()){
14         while(j>=0 && T[i] != P[(j>=0?j:0)]) j = bt[j];
15         i++; j++;
16         if(j==P.size()){//match, do anything
17             res++;j = bt[j];
18         }
19     }
20     return res;
21 }

```

7 Clasicos

7.1 Job scheduling

7.1.1 One machine, linear penalty

```

1 //cuando se tiene que encontrar un orden optimo
2 //para trabajos con una funcion lineal de penalty, basta con hacer un
   sort en O(n log n)
3 struct trabajo{
4     long long int penalty,tiempo;
5     int ind;
6 };
7 bool comp(const trabajo a, const trabajo b){
8     if (a.tiempo * b.penalty == a.penalty * b.tiempo) return a.ind<b.ind
9         ;
10    return a.tiempo * b.penalty < a.penalty * b.tiempo;

```

7.1.2 One machine, deadlines

```

1 //calcula la maxima cantidad de jobs que se pueden hacer dados sus
   deadlines y duraciones en O(n log n)
2 struct Job {
3     int deadline, duration, idx;
4
5     bool operator<(Job o) const {
6         return deadline < o.deadline;
7     }
8 };
9 vector<int> compute_schedule(vector<Job> jobs) {

```

```

10     sort(jobs.begin(), jobs.end());
11
12     set<pair<int,int>> s;
13     vector<int> schedule;
14     for (int i = jobs.size()-1; i >= 0; i--) {
15         int t = jobs[i].deadline - (i ? jobs[i-1].deadline : 0);
16         s.insert(make_pair(jobs[i].duration, jobs[i].idx));
17         while (t && !s.empty()) {
18             auto it = s.begin();
19             if (it->first <= t) {
20                 t -= it->first;
21                 schedule.push_back(it->second);
22             } else {
23                 s.insert(make_pair(it->first - t, it->second));
24                 t = 0;
25             }
26             s.erase(it);
27         }
28     }
29     return schedule;
30 }

```

7.1.3 One machine, profit

```

1 // Dado n Jobs y su profit, calcula cual es el mayor profit que se puede
  // obtener en O(n^2)
2 struct Job{int start, finish, profit;};
3 bool jobComparataor(Job s1, Job s2){return (s1.finish < s2.finish);}
4 // Find the latest job (in sorted array) that doesn't
5 // conflict with the job[i]. If there is no compatible job,
6 // then it returns -1.
7 vector <Job> arr;
8 int* memo;
9 int latestNonConflict( int i){
10     for (int j = i - 1; j >= 0; j--)
11         if (arr[j].finish <= arr[i - 1].start)
12             return j;
13     return -1;
14 }
15 // A recursive function that returns the maximum possible
16 // profit from given array of jobs. The array of jobs must
17 // be sorted according to finish time.
18 int findMaxProfitRec( int n){

```

```

19 // Base case
20 if (n == 1) return arr[n - 1].profit;
21 if (memo[n]>=0) return memo[n];
22 // Find profit when current job is included
23 int inclProf = arr[n - 1].profit;
24 int i = latestNonConflict(n);
25 if (i != -1) inclProf += findMaxProfitRec( i + 1);
26
27 // Find profit when current job is excluded
28 int exclProf = findMaxProfitRec( n - 1);
29
30 return memo[n]=max(inclProf, exclProf);
31 }
32
33 // The main function that returns the maximum possible
34 // profit from given array of jobs
35 int findMaxProfit( int n){
36     sort(arr.begin(),arr.end(), jobComparataor);
37     return findMaxProfitRec(n);
38 }

```

7.1.4 Two machines, min time

```

1 //Obtiene el ordenamiento optimo de Jobs en dos maquinas en O(n log n)
2 struct Job {
3     int a, b, idx;
4     bool operator<(Job o) const {return min(a, b) < min(o.a, o.b);}
5 };
6 vector<Job> johnsons_rule(vector<Job> jobs) {
7     sort(jobs.begin(), jobs.end());
8     vector<Job> a, b;
9     for (Job j : jobs) {
10         if (j.a < j.b)
11             a.push_back(j);
12         else
13             b.push_back(j);
14     }
15     a.insert(a.end(), b.rbegin(), b.rend());
16     return a;
17 }
18
19 pair<int, int> finish_times(vector<Job> const& jobs) {
20     int t1 = 0, t2 = 0;

```

```

21     for (Job j : jobs) {
22         t1 += j.a;
23         t2 = max(t2, t1) + j.b;
24     }
25     return make_pair(t1, t2);
26 }

```

8 Flow

8.1 Dinic, thx GGDem

```

1  #define pb push_back
2  #define mp make_pair
3  #define fst first
4  #define snd second
5  #define ALL(s) s.begin(),s.end()
6  #define SZ(x) int((x).size())
7  #define fore(i,a,b) for(int i=a,to=b;i<to;++i)
8  using namespace std;
9  typedef long ll;
10
11 #define INF (1LL<<62)
12 // Min cut: nodes with dist>=0 vs nodes with dist<0
13 // Matching MVC: left nodes with dist<0 + right nodes with dist>0
14 struct Dinic{
15     int nodes,src,dst;
16     vector<int> dist,q,work;
17     struct edge {int to,rev;ll f,cap;};
18     vector<vector<edge>> g;
19     Dinic(int x):nodes(x),g(x),dist(x),q(x),work(x){}
20     void add_edge(int s, int t, ll cap){
21         g[s].pb((edge){t,SZ(g[t]),0,cap});
22         g[t].pb((edge){s,SZ(g[s])-1,0,0});
23     }
24     bool dinic_bfs(){
25         fill(ALL(dist),-1);dist[src]=0;
26         int qt=0;q[qt++]=src;
27         for(int qh=0;qh<qt;qh++){
28             int u=q[qh];
29             fore(i,0,SZ(g[u])){
30                 edge &e=g[u][i];int v=e.to;
31                 if(dist[v]<0&&e.f<e.cap)dist[v]=dist[u]+1,q[qt++]=v;
32             }

```

```

33     }
34     return dist[dst]>=0;
35 }
36 ll dinic_dfs(int u, ll f){
37     if(u==dst)return f;
38     for(int &i=work[u];i<SZ(g[u]);i++){
39         edge &e=g[u][i];
40         if(e.cap<=e.f)continue;
41         int v=e.to;
42         if(dist[v]==dist[u]+1){
43             ll df=dinic_dfs(v,min(f,e.cap-e.f));
44             if(df>0){e.f+=df;g[v][e.rev].f-=df;return df;}
45         }
46     }
47     return 0;
48 }
49 ll max_flow(int _src, int _dst){
50     src=_src;dst=_dst;
51     ll result=0;
52     while(dinic_bfs()){
53         fill(ALL(work),0);
54         while(ll delta=dinic_dfs(src,INF))result+=delta;
55     }
56     return result;
57 }
58 };
59
60 //-----SOLBEGIN-----
61 int main() {
62     ios_base::sync_with_stdio(false); cout.tie(NULL); cin.tie(NULL);
63     //l set,r set
64     int n,m;
65     cin>>n>>m;
66     m+=n;
67     Dinic d(n+m+2);
68     for(int i = 1; i<=n; i++) d.add_edge(0,i,1);
69     for(int i = n+1; i<=m; i++) d.add_edge(i,m+1,1);
70
71     int fin,q;
72     for(int i = 1; i<=n; i++){
73         cin>>q;
74         while(q--){
75             cin>>fin;

```

```

76         d.add_edge(i,n+fin,1);
77     }
78 }
79 int res =d.max_flow(0,m+1);
80 m-=n;
81 //how many were left unmatched
82 cout<<m-res<<endl;
83 }
84 //-----EOSOLUTION-----

```

9 Miscellaneous

9.1 Bit Manipulation

```

1  #include "bits/stdc++.h"
2  using namespace std;
3  #define endl '\n'
4
5
6  int main() {
7      ios_base::sync_with_stdio(false); cout.tie(NULL); cin.tie(NULL);
8      //Se representan bitmasks de 30 a 62 bits
9      //usando signed int y signed long long int
10     //para evitar problemas con el complemento de dos
11     signed int a, b;
12     //para multiplicar un numero por dos solo es necesario aplicar un
13     //shifteo de sus bits a la izquierda
14     a = 1;
15     a= a << 3;
16     cout << a << endl;
17     //para dividir un numero entre dos es necesario aplicar un
18     //shifteo a la derecha
19     a = 32;
20     a = a >> 3;
21     cout << a << endl;
22     //para encender el bit n de a, solo hay que igualar a = a | pow(2,n-1)
23     //prende el tercer bit
24     a = 1;
25     b = 1 << 2;
26     a = a | b;
27     cout << a << endl;
28     //para apagar el bit n de a, solo hay que a &= ~pow(2,n-1)
29     //prende el tercer bit

```

```

30     a = 5;
31     b = 1 << 2;
32     a &= ~b;
33     cout << a << endl;
34     //para revisar si el bit n de a esta encendido
35     //revisa si el tercer bit esta encendido
36     a = 5;
37     b = 1 << 2;
38     a = a & b;
39     cout << (a?"SI":"NO") << endl;
40     //para volter el bit n de a, solo hay que igualar a = a ^ pow(2,n-1)
41     //apaga el tercer bit
42     a = 5;
43     b = 1 << 2;
44     a = a ^ b;
45     cout << a << endl;
46     //para obtener el bit menos significativo que esta encendido a& -a
47     a = 12;
48     cout << log2(a & ((-1) * a))+1 << endl;
49     //para prender todos los bits hasta n
50     a = (1<<4)-1;
51     cout << a << endl;
52 }
53 //-----EOSOLUTION-----

```

```

1  #include "bits/stdc++.h"
2  using namespace std;
3  #define endl '\n'
4  #pragma GCC optimize("O3")
5  #pragma GCC target("popcnt")
6
7  //no usar con visual c++
8  //solo con g++ like compilers
9  int main() {
10     ios_base::sync_with_stdio(false); cout.tie(NULL); cin.tie(NULL);
11     signed long long int a, b, n;
12     //Obtain the remainder (modulo) of a when it is divided by n (n is a
13     //power of 2)
14     a = 15; n = 8-1;
15     a &= n;
16     cout << "a%n, a%15, a%2^3" << endl;
17     cout << a << endl;
18     //Apaga el bit menos significativo de a

```

```
18  a = 14;
19  b = (a & ((-1) * a));
20  a &= ~b;
21  cout << a << endl;
22  //enciende el ultimo cero de a
23  a = 9;
24  b = ~a;
25  b = (b & ((-1) * b));
26  a = a | b;
27  cout << a<<endl;
28  //contar bits encendidos en a
29  cout << __builtin_popcount(a)<<endl;
30  //chechar la paridad de a
31  cout << (__builtin_parity(a) ? "IMPAR" : "PAR") << endl;
32  //contar leading zeroes en a
33  cout << __builtin_clz(a)<<endl;
34  //contar 9,trailling zeroes en a
35  cout << __builtin_ctz(a)<<endl;
36  }
37  //-----EOSOLUTION-----
```

10 Testing