

UDvorak's notebook (2017)

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```

memset( vi, 0, sizeof(dp));
for( int i = 1; i < 10; i++)
    cout << catalan( i ) <<endl;
return 0;
}

```

1.2 HornersRule

```

#include <iostream>
using namespace std;
/*
 * given the polynomial  $f(x) = 2x^3 - 6x^2 - 2x - 1$ 
 *  $f(8) = ?$ 
 *      |  $X^3$   $X^2$   $X^1$   $X^0$ 
 *      | 2   -6   -2   -1
 *      |      16   80   624
 *      -----
 *      2    10   78   623
 *  $f(8) = 623$ 
 * Complexity  $O(n)$ 
 */
typedef long long ll;
ll Horner( ll a[], ll n, ll x ){
    ll result = a[n];
    for(ll i=n-1; i >= 0 ; --i)
        result = result * x + a[i];
    return result;
}
int main(){
    ll grade = 3;
    // -1 -2x -6x^2 +2x^3
    ll a[] = {-1,-2,-6,2};
    ll x = 8;
    cout << Horner (a, grade, x);
    return 0;
}

```

1.3 Kadane

```

#include <bits/stdc++.h>
#define forn(i,j,k) for(int i=j; i<k; i++)
using namespace std;
typedef long long ll;
/*
 * Largest Sum Contiguous Subarray
 * Kadane Algorithm
 * Complexity:  $O(n)$ 
 */
inline ll kadane(ll data[8], int size){
    ll m1= data[0];
    ll m2 = data[0];
    forn(i, 1, size){
        m2 = max(data[i], data[i] + m2);
        m1 = max(m1, m2);
    }
    return m1;
}
int main(){
    int size = 8;
    ll data[8] = {-1,2,4,-3,5,2,-5,2};
    ll res = kadane(data, size);
    printf("The max sum that can be done with \n \
    Contiguous elements is: %lld \n", res);
    return 0;
}

```

```

}

```

1.4 PickTheorem

```

#include <stdio.h>
using namespace std;
/*
 * Pick's theorem is a useful method for determining the area
 * of any polygon whose vertices are points on a lattice,
 * a regularly spaced array of points
 *
 * b boundary point :
 *   a lattice point on the polygon including vertices
 * i interior point :
 *   a lattice points on the polygon's interior region
 *
 * Complexity:  $O(1)$ 
 */
double area_poligon(double b, double i){
    return (b/2) + i -1;
}
int main(){
    printf("%f",area_poligon(5,5));
    return 0;
}

```

2 data-structures

2.1 Fenwick

```

#include<bits/stdc++.h>
#define endl '\n'
using namespace std;
typedef long long ll;
typedef vector < ll> vll;
/*
 * Complexity Query  $O(n)$ 
 */
struct fw {
    int n; vll data;
    fw(int _n) : n(_n), data(vll(_n)) { }
    void update(int at, ll by) {
        while(at < n) {
            data[at] += by;
            at |= at + 1;
        }
    }
    void update_range( int l, int r, ll by){
        update(l, by);
        update(r+1, -by);
    }
    ll query(int at) {
        ll res = 0LL;
        while(at >= 0) {
            res += data[at];
            at = (at & (at + 1)) - 1;
        }
        return res;
    }
};
int main(){
#ifdef LOCAL
    freopen("in","r", stdin);

```

```

#endif
ios::sync_with_stdio(0);cin.tie(0);
int n, q, a, b;
char op;
cin >> n >> q;
fw *fen = new fw(n+1);
for( int i = 0; i < q; i++){
    cin >> op;
    if( '+' == op){
        cin >> a >> b;
        fen->update(a,b);
    }else{
        cin >>a; a--;
        cout << fen->query(a) << endl;
    }
}
}

```

2.2 MST

```

#include<bits/stdc++.h>
using namespace std;

/*
Complexity:  $n \log(n)$ 
*/
// from, to, weight
typedef tuple< int,int,int > edge;
typedef vector< int > vi;
bool customSort(const edge &a,const edge & b){
    return get<2>(a) < get<2>(b);
}
vector< edge > mst( vector< edge > &edges , int n ){
    union_find uf( n );
    vector< edge > res;
    sort( edges.begin(), edges.end(), customSort);
    int f, t , w;
    int tw =0;
    for( const edge &e: edges){
        tie(f, t, w) = e;
        if( uf.unite( f, t ) )res.push_back( e);
    }
    return res;
}
int main(){
#ifdef LOCAL
    freopen("in", "r", stdin);
#endif
    int n, m;
    int f, t , w;
    cin >> n >> m;
    vector< edge > edges( m );
    for( int i = 0 ; i < m; i++){
        cin >> f >> t >> w;
        edges[i] = make_tuple( f, t, w);
    }
    mst( edges, n );
    return 0;
}

```

2.3 SegmentTree

```

#include <iostream>

```

```

using namespace std;
const int N = 1e5 + 10;
int n, q;
int t[2 * N];

/*
Complexity Query  $O(\log(n))$ 
Create  $O(n^2)$ 
Update  $O(n^2)$ 
*/

int op( int a, int b){
    return min(a, b);
}

void update(int x, int y) {
    for (t[x += n] = y; x > 1; x >>= 1) {
        t[x >> 1] = op(t[x], t[x ^ 1]);
    }
}

int query(int l, int r) {
    int res = 1e8;
    for (l += n, r += n; l < r; l >>= 1, r >>= 1) {
        if (l & 1) res = op(res, t[l++]);
        if (r & 1) res = op(t[--r], res);
    }
    return res;
}

int main() {
    cin >> n >> q;
    for (int i = 0; i < n; i++) {
        cin >> t[i + n];
    }
    for (int i = n - 1; i > 0; i--) {
        t[i] = op(t[i << 1], t[i << 1 | 1]);
    }
    char qt;
    int l, r;
    while (q--) {
        cin >> qt;
        if (qt == 'q') {
            cin >> l >> r;
            cout << query(l - 1, r) << "\n";
        } else {
            cin >> l >> r;
            update(l - 1, r);
        }
    }
    return 0;
}

```

2.4 Trie

```

#include <bits/stdc++.h>
using namespace std;

/*
Struct for a trie
*/
struct node {
    node * son[26];
    bool is_end;
    int num_times;
    node(){
        memset(son, 0, sizeof(son));
        is_end = false;
        num_times = 0;
    }
}

```

```

};
/*
 * insert a word in the trie
 */
void insert(node* nd, char *s){
    if(*s){
        int pos = *s - 'a';
        if(!nd->son[pos]) nd->son[pos]=new node();
        insert(nd->son[pos], s+1);
    }else{
        nd->is_end = true;
    }
}
/*
 * Check if the word is in the trie
 */
int contains(node *nd, char *s){
    if(*s){
        int pos = *s - 'a';
        if(!nd->son[pos]) return false;
        return contains(nd->son[pos], s+1);
    }else{
        return nd->is_end;
    }
}
int main(){
    node * trie = new node();
    string a = "word";
    char *cstr = new char[a.length() + 1];
    strcpy(cstr, a.c_str());
    insert (trie, cstr);
    string b = "banani";
    strcpy(cstr, b.c_str());
    insert (trie, cstr);
    if (contains(trie, cstr)){
        cout << "ohh holly xx." << endl;
    }else{
        cout << "mother ..." << endl;
    }
    return 0;
}

```

2.5 UnionFind

```

#include <bits/stdc++.h>
using namespace std;
typedef vector<int> vi;
/*
 * Complexity O(log(n))
 */
struct union_find {
    vi p;
    union_find(int n) : p(n, -1) {}
    int find(int x) {
        return p[x] < 0 ? x : p[x] = find(p[x]);
    }
    bool unite(int x, int y) {
        int xp = find(x), yp = find(y);
        if (xp == yp) return false;
        if (p[xp] > p[yp]) swap(xp, yp);
        p[xp] += p[yp];
        p[yp] = xp; //add -1 if merge
        return true;
    }
    int size(int x) {

```

```

        return -p[find(x)];
    }
};

int main() {
    union_find uf(10);
    uf.unite(0, 2);
    cout << uf.find(0) << endl;
    cout << uf.find(2) << endl;
    assert(uf.find(0) == uf.find(2));
    assert(uf.find(0) != uf.find(1));
    return 0;
}

```

3 geometry

3.1 CenterCircle

```

#include <bits/stdc++.h>
using namespace std;
const double PI = acos(-1);
#define show(x) cout << #x << " = " << x << endl;
/*
 * Complexity O(1)
 */
struct pt {
    double x;
    double y;
    pt (){}
    pt (double _x, double _y){
        x = _x;
        y = _y;
    }
};
inline pt getCenter(pt p1, pt p2, pt p3){
    pt center;
    float m1 = (p2.y - p1.y)/(p2.x - p1.x);
    float m2 = (p3.y - p2.y)/(p3.x - p2.x);
    center.x = ( m1 * m2 * (p1.y - p3.y) + m2 * ( p1.x + p2.x)
                - m1 * (p2.x + p3.x) )
                / (2 * (m2 - m1) );
    center.y = -1 * (center.x - (p1.x + p2.x) / 2) / m1 + (p1.y +
        p2.y) / 2;
    return center;
}

int main(){
    pt p1(1,1), p2(2,4), p3(5,3);
    pt res = getCenter(p1, p2, p3);
    show(res.x)
    show(res.y)
    return 0;
}

```

3.2 PolygonArea

```

#include <bits/stdc++.h>
#define f first
#define s second
#define mp make_pair
#define pb push_back
using namespace std;
typedef long double ld;

```

```

typedef pair <ld, ld> point;
typedef vector < point > polygon;

/*
Complexity O(n)
*/
inline point diff(point o, point d){
    return mp(d.f-o.f, d.s - o.s);
}
inline ld crossProduct(point o, point d){
    ld cross = (o.f * d.s) - ( o.s * d.f);
    return cross > 0 ? cross : cross * -1;
}
inline ld area(polygon p){
    int num_points = p.size();
    ld area = 0;
    for (int i = 1; i < num_points -1 ; i++){
        point l1 = diff(p[0],p[i]);
        point l2 = diff(p[0],p[i+1]);
        area += crossProduct(l1,l2);
    }
    return abs(area/2.0);
}
int main(){
    polygon p;
    p.pb(mp(1,0)); p.pb(mp(2,1));
    p.pb(mp(1,2)); p.pb(mp(0,1));
    cout << area(p);
    return 0;
}

```

3.3 RayCasting

```

#include <bits/stdc++.h>
#define pb push_back
#define mp make_pair
using namespace std;
/*
This program implements the ray casting algorithm to check
if a point is inside or outside of a simple polygon
*/
typedef double ld;
struct point {
    ld x, y;
    point(){}
    point(ld x, ld y){
        this->x = x;
        this->y = y;
    }
};
struct vert {
    point o,d;
};
typedef vector < point > polygon;

inline ld cross(point o, point d){
    return(o.x * d.y) - ( o.y * d.x);
}
inline ld dot(point o, point d){
    return (o.x * d.x) + ( o.y * d.y);
}
inline point diff(point o, point d){
    return {d.x-o.x, d.y - o.y};
}
inline ld dist(point o, point d){
    return sqrt(dot(diff(o,d) , diff(o,d)));
}

inline bool segments_parallel(point a, point b, point c){
    return abs(cross(diff(c,a),diff(b,a))) == 0;
}

```

```

}
inline bool point_on_segment(polygon v, point c){
    int cant = v.size();
    for (int i=0;i<cant;i++){
        if (dist(v[i],c)==0) return true;
        if (dist(v[(i+1)%cant],c)==0) return true;
        if(segments_parallel(v[i], v[(i+1)%cant], c) &&
            dot(diff(c,v[i]), diff(c,v[(i+1)%cant])) < 0) {
            return true;
        }
    }
    return false;
}

/* Ray Casting algorithm
true inside
false outside
*/
bool point_in_polygon(point p, polygon a){
    bool inside = false;
    int cant = a.size();
    for (int i=0;i<cant;i++){
        int j = (i+1) % cant;
        point aux = a[i];
        point nxt = a[j];
        bool cond1 = (p.y < aux.y != p.y < nxt.y);
        bool cond2 = (p.x < aux.x + (nxt.x - aux.x) * (p.y - aux.y) /
            (nxt.y - aux.y));
        if ( cond1 && cond2 ){
            inside = !inside;
        }
    }
    return inside;
}
inline void test_point(polygon v, point pun){
    if(point_on_segment(v,pun)){
        cout << "on"<<endl;
    }else if (point_in_polygon(pun, v)){
        cout << "in"<<endl;
    }else{
        cout <<"out"<<endl;
    }
}
int main(){
    polygon p;
    p.pb(point(1,0)); p.pb(point(2,1));
    p.pb(point(1,2)); p.pb(point(0,1));
    test_point(p, point(0,0));
    test_point(p, point(1,1));
    test_point(p, point(1.5,0.5));
    return 0;
}

```

3.4 Struct

```

#include <bits/stdc++.h>
#define INF 1e9
#define EPS 1e-9
#define PI acos(-1.0)
#define debug(x) cout << #x << " " << x << endl;

using namespace std;

struct point {
    double x, y;
    point() {}
}

```

```

point(double _x, double _y){
    x = _x;
    y = _y;
}
point operator + (point p) const {
    return point(p.x + x, p.y + y); }
point operator - (point p) const {
    return point(x - p.x, y - p.y); }
point operator *(double d) const {
    return point(x*d, y*d); }
bool operator ==(point p) const {
    return p.x == x && p.y == y; }
double dot(point p) {
    return x*p.x + y*p.y;};
double cross2(point p) {
    return x*p.y - p.x*y;};
double mag () {
    return sqrt(x*x + y*y);};
double norm() {
    return x*x + y*y;};
double dist(point p2){
    return hypot(x - p2.x, y - p2.y); };
void show(){ printf("x= %lf, y=%lf\n", x, y);}
};

struct line {
    point o; //origin
    point d; //destiny
    double m;
    line (){}
    line( point _o, point _d){
        o = _o;
        d = _d;
    }
    double slope(){
        if (o.x != d.x){
            m = (double)(d.y - o.y) / (double)(d.x - o.x);
            return m;
        }
        m = INF;
        return INF;
    }
};

double cross(point &o, point &a, point &b) {
    return (a.x - o.x)*(b.y - o.y) - (a.y - o.y)*(b.x - o.x);
}
bool areParallel(line l1, line l2) {
    return fabs(l1.slope()-l2.slope())<EPS ;
}
double distToLine(point p, line l1) {
    // formula: c = a + u * ab
    point a = l1.o, b = l1.d, c;
    point ap = p-a, ab = b-a;
    double u = ap.dot(ab) / ab.norm();
    c = a + ab*u;
    return c.dist(p);
}

double distToSegment(point p, line l1) {
    point a = l1.o, b = l1.d, c;
    point ap = p-a, ab = b-a;
    double u = ap.dot(ab) / ab.norm();
    if (u < 0.0) {
        c = point(a.x, a.y); // closer to a
        return p.dist(a);
    }
    if (u > 1.0) {

```

```

        c = point(b.x, b.y); // closer to b
        return p.dist(b);
    }
    return distToLine(p, line(a, b));
}

int main(){
    point a(0,4);
    point b(5,0);
    point c(7,0);
    a.show();
    b.show();
    c.show();
    line l1(a,b), l2(a,c);
    cout << "m1= " << l1.slope() << endl;
    cout << "m2= " << l2.slope() << endl;
    cout << "parallel l1 || l2? = " << (areParallel(l1, l2)?"true":
        "false") << endl;
    cout << "dist from point to line= " << distToLine(c, l1) << endl;
    ;
    cout << "dist from point to segment= " << distToSegment(c, l1)
        << endl;
    return 0;
}

```

4 graph

4.1 Dijkstra

```

#include <bits/stdc++.h>
#define V 9
int minDis(int dist[], bool is_set[]){
    int min = INT_MAX, min_index;
    for (int v = 0; v < V; v++){
        if (is_set[v] == false && dist[v] <= min){
            min = dist[v], min_index = v;
        }
    }
    return min_index;
}

inline void dijkstra(int graph[V][V], int src){
    int dist[V];
    bool is_set[V];
    for (int i = 0; i < V; i++){
        dist[i] = INT_MAX, is_set[i] = false;
    }
    dist[src] = 0;
    for (int count = 0; count < V-1; count++){
        int u = minDis(dist, is_set);
        is_set[u] = true;
        for (int v = 0; v < V; v++){
            if (!is_set[v] && graph[u][v]
                && dist[u] != INT_MAX
                && dist[u]+graph[u][v] < dist[v])
                dist[v] = dist[u] + graph[u][v];
        }
    }
    for( int i= 0; i < V; i++)
        cout << i << " " << dist[i] <<endl;
}

int main(){
    int graph[V][V] =
        {{0, 4, 0, 0, 0, 0, 0, 0, 8, 0},

```

```

{4, 0, 8, 0, 0, 0, 0, 11, 0},
{0, 8, 0, 7, 0, 4, 0, 0, 2},
{0, 0, 7, 0, 9, 14, 0, 0, 0},
{0, 0, 0, 9, 0, 10, 0, 0, 0},
{0, 0, 4, 14, 10, 0, 2, 0, 0},
{0, 0, 0, 0, 0, 2, 0, 1, 6},
{8, 11, 0, 0, 0, 0, 1, 0, 7},
{0, 0, 2, 0, 0, 0, 6, 7, 0}
};
//distances from all points to 1
dijkstra(graph, 1);
return 0;
}

```

4.2 DijkstraHeap

```

#include <bits/stdc++.h>
#define pb push_back
using namespace std;
#define forn(i,a) for (int i=0; i<a ; i++)
#define INF 2e7
struct edge{
    int to, weight;
    edge(){}
    edge(int _to, int _weight){
        to = _to;
        weight = _weight;
    }
    bool operator < (edge e) const {
        return weight > e.weight;
    }
};
typedef vector < edge > ve;
typedef vector < ve > vve;
typedef vector < int > vi;
typedef priority_queue< edge> pq;
inline void dijkstra(vve &adj, int src, int num_nodes){
    vi dist = vi(num_nodes+1, INF);
    pq q;
    //by default
    q.push(edge(src,0));
    dist[src] = 0;
    //apply bfs
    while(!q.empty()){
        edge top = q.top();
        q.pop();
        int u = top.to;
        for(int i=0; i<adj[u].size(); i++){
            int v = adj[u][i].to;
            if(dist[u] + adj[u][i].weight < dist[v]){
                dist[v] = dist[u] + adj[u][i].weight;
                q.push(edge(v, dist[v]));
            }
        }
    }
    //Show results of distances
    cout << "Distancias desde el origen ";
    cout << src << endl;
    forn(i, num_nodes){
        cout << "Costo al nodo: " << i;
        cout << " = " << dist[i] << endl;
    }
}

int main(){
    int nodes =5;

```

```

vve adj(nodes);
//from to - weight
adj[0].pb(edge(1, 6));
adj[0].pb(edge(2, 2));
adj[1].pb(edge(3, 5));
adj[1].pb(edge(4, 7));
int src = 1;
dijkstra(adj, src, nodes);
return 0;
}

```

4.3 FloydWarshal

```

#include<iostream>
#include<stdio.h>
using namespace std;
/*
 * Floyd-Warshall gives us the shortest paths
 * from all sources to all target nodes.
 */
#define V 4 //number of vertex
#define INF 9999999

void floyd (int graph[][V]){
    int dist[V][V], i, j, k;
    for (i = 0; i < V; i++)
        for (j = 0; j < V; j++)
            dist[i][j] = graph[i][j];
    for (k = 0; k < V; k++){
        for (i = 0; i < V; i++){
            for (j = 0; j < V; j++){
                if (dist[i][k] + dist[k][j] < dist[i][j])
                    dist[i][j] = dist[i][k] + dist[k][j];
            }
        }
    }
    show(dist);
}

int main(){
    int graph[V][V] =
    { {0, 5, INF, 10},
      {INF, 0, 3, INF},
      {INF, INF, 0, 1},
      {INF, INF, INF, 0}
    };
    floyd(graph);
    return 0;
}

```

4.4 RecoveryTree

```

#include <iostream>
using namespace std;
/**Build a binary tree form a inorder and preorder string **/
int preIndex = 0;
struct node {
    char key;
    node *left, *right;
    node(int k) {
        key = k;
        left = NULL;
        right = NULL;
    }
}

```

```

    }
};
int search(string word, int b, int e, char c) {
    for(int i=b; i<=e; i++) {
        if(word[i] == c) return i;
    }
    return -1;
}
//Set preIndex to 0 to build another tree
node* build(string in, string pre, int b, int e) {
    if(b > e) return NULL;
    node *root = new node(pre[preIndex++]);
    if(b == e) return root;
    int inIndex = search(in, b, e, root->key);
    root->left = build(in, pre, b, inIndex - 1);
    root->right = build(in, pre, inIndex + 1, e);
    return root;
}

int main() {
    string pre, in;
    node *tree;
    while(cin >> pre >> in) {
        tree = build(in, pre, 0, pre.size() - 1);
        preIndex = 0;
    }
    return 0;
}

```

4.5 Tsort

```

#include<bits/stdc++.h>
#define debug(x) cout << #x << " = " << x << endl;
#define PB push_back
using namespace std;

typedef vector< bool > vb;
typedef vector< int > vi;

enum { NV, SV, V};
vb vis;
int N;
vector< vi > G;

void dfs( int src, stack< int > &S ){
    for( int son: G[src]){
        if( vis[ son ] == NV)
            dfs( son, S );
    }
    vis[src] = V;
    S.push( src );
}

void tsort( ){
    stack< int > S;
    vis.resize( N );
    vis.assign( N, NV);
    for( int i = 0; i < N; i++){
        if( vis[i] == NV)    dfs( i, S);
    }
    while(!S.empty()){
        cout << S.top() << endl;
        S.pop();
    }
}

int main(){

```

```

N = 6;
G.resize(N);
G[0].PB( 1 );
G[0].PB( 2 );
G[0].PB( 3 );
G[1].PB( 4 );
G[4].PB( 3 );
G[5].PB( 2 );
G[3].PB( 2 );

tsort( );
return 0;
}

```

5 mathematics

5.1 Binomial

```

#include <iostream>
using namespace std;
const int MAXN = 66;
unsigned long long ch[MAXN+5][MAXN+5];

int Cnk( ll n, ll k){
    ll res =1;
    // since C(n,k) == C(n, n-k)
    if( k > n-k) k = n-k;
    for( ll i = 0; i < k; i++){
        res = res*1LL*(n-i);
        res /= (i+1);
    }
    return res;
}

void binomial(int N){
    for (int n = 0; n <= N; ++n)
        ch[n][0] = ch[n][n] = 1;
    for (int n = 1; n <= N; ++n){
        for (int k = 1; k < n; ++k){
            ch[n][k] = ch[n-1][k-1] + ch[n-1][k];
        }
    }
}

int main(){
    binomial(10);
    cout << ch[10][2] << endl;
}

```

5.2 Binomial

```

import math, sys
MAXN = 431
choose = []
for i in range(0, MAXN+5):
    choose.append([0]*(MAXN+5))
def binomial(N):
    for n in range(0, N+1):
        choose[n][0] = choose[n][n] = 1
    for n in range(1, N+1):
        for k in range(1, n):
            choose[n][k] = choose[n-1][k-1] + choose[n-1][k]

```



```

if __name__ == "__main__":
    N = 431
    binomial(N)
    n, k = 10, 4
    print(choose[n][k])

```

5.3 ChangeBases

```

#include<bits/stdc++.h>
#define endl '\n'
#define show(x) cout <<#x << " = " <<x <<endl;
using namespace std;
typedef long long ll;
string chars = "0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ";

ll to10(ll n , ll b, ll mul){
    if (n ==0 ) return 0;
    return (n % 10)*mul + to10(n / 10, b, mul*1LL*b);
}

string tob(ll n, ll b){
    if (n == 0) return "";
    return tob(n / b, b) + chars[n % b];
}

/*
 * ob -> origin base
 * db -> destiny base
 */
string changeBase(ll num, ll ob, ll db){
    if (ob == 10) return tob(num, db);
    return tob(to10(num, ob, 1LL), db);
}

int main(){
    cout << changeBase(1000,2,10) <<endl;
}

```

5.4 CoinChange

```

#include <bits/stdc++.h>
#define MAXCOINS (10005)
#define MAXVALUE (105)
using namespace std;
typedef vector < int > vi;
int dp[MAXVALUE][MAXCOINS];
vi coins;
//recursive
int ways(int tg, int n){
    if ( 0 == tg) return 1;
    if ( 0 > tg) return 0;
    if ( n <= 0 && tg >0) return 0;
    return ways(tg, n-1) +
           ways(tg - coins[n -1], n);
}

//by dp
int waysdp(int tg, int n){
    for( int i=0; i< coins.size(); i++) dp[0][i] = 1;
    for(int i = 1 ; i<= tg; i++){
        for (int c = 0; c < n; c++){
            int x =0 , y = 0;
            if(i-coins[c] >= 0) x = dp[i - coins[c]][c];
            if( c >=1) y = dp[i][c-1];
            dp[i][c] = x + y;
        }
    }
}

```

```

    }
    return dp[tg][n-1];
}

int main(){
    coins.insert(coins.end(), {1,3,9,27});
    cout << ways(47, coins.size()) <<endl;
    cout << waysdp(47, coins.size()) <<endl;
    return 0;
}

```

5.5 Combination

```

#include<bits/stdc++.h>
using namespace std;

vector< int > com;
int k, n ;

void comb( int off, int ki){
    if( ki == 0 ){
        for( int &c: com) cout << c << " ";
        cout <<endl;
        return;
    }
    for( int i = off; i <= n - ki ; i++){
        com.push_back( i );
        comb( i+1, ki-1);
        com.pop_back();
    }
}

int main(){
    n = 5; k = 3;
    comb( 0, k );

    return 0;
}

```

5.6 CompareDoubles

```

#include <stdio.h>
using namespace std;
const double EPS = 1e-15;
/*
 * Return
 * -1 if x < y
 * 0 if x == y
 * 1 if x > y
 */
int cmp (double x, double y){
    return (x <= y + EPS) ? (x + EPS < y) ? -1 : 0 : 1;
}

int main(){
    double d1 = 0.0000000000000212;
    double d2 = 0.0000000000000213;
    int res = cmp(d1,d2);
    if (res == 0){
        printf("Equal \n");
    }else if(res == 1){
        printf("Greater\n");
    }else {
        printf("Less \n");
    }
}

```

5.7 Exponentiation

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
// (a^b)%c
ll expo(ll a, ll b, ll c){
    if (b == 0) return 1;
    if (b % 2 == 0) {
        ll temp = expo(a, b/2, c);
        return (temp * temp) % c;
    } else {
        ll temp = expo(a, b-1, c);
        return (temp * a) % c;
    }
}
int main(){
    cout << expo(2, 100, 1025);
    return 0;
}
```

5.8 ExtendedEuclides

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
typedef vector < ll > vl;

vl arr(3);
/*
    returns gcd(a,b) and find the coeficcients of bezout
    such that d = ax + by
    arr[0] gcd
    arr[1] x
    arr[2] y
*/
void extended(ll a, ll b){
    ll y = 0;
    ll x = 1;
    ll xx = 0;
    ll yy = 1;
    while(b){
        ll q = a / b;
        ll t = b;
        b = a%b;
        a = t;

        t = xx;
        xx = x-q*xx;
        x = t;

        t = yy;
        yy = y-q*yy;
        y = t;
    }
    arr[0] = a;
    arr[1] = x;
    arr[2] = y;
}
/*
    ax + by = c
    mcd(a,b) = d
    ax0 + by0 = d
    c = d * c'
*/
```

```
Bezouts identity
X = x0 * c' - (b/d) * k
Y = y0 * c' + (a/d) * k
*/
int main(){
    ll a = 20, b = 50;
    extended(a,b);
    printf("gcd(%lld, %lld) = %lld = %lld * %lld + %lld * %lld\n",
        a, b, arr[0], a, arr[1], b, arr[2]);
    return 0;
}
```

5.9 ExtendEuclidesSample

```
#include<bits/stdc++.h>
#define F first
#define S second
using namespace std;
typedef long long ll;
typedef pair<ll, ll> ii;

ll gcd;

ii extended(ll a, ll b) {
    ll y = 0, x = 1, xx = 0, yy = 1;
    while (b){
        ll q = a / b;
        ll t = b;

        b = a%b;
        a = t;
        t = xx;
        xx = x-q*xx;

        x = t;
        t = yy;
        yy = y-q*yy;

        y = t;
    }
    gcd = a;
    // a becomes gcd(a,b);
    return {x,y};
}

int main(){
#ifdef LOCAL
    freopen("in","r", stdin);
#endif
    int a, b, c;

    // ax + by = c
    while( cin >> a >> b >> c ){
        ii res = extended( a, b );
        if( c % gcd == 0 ){
            ll x = (c/gcd)*res.F, y = (c/gcd)*res.S;
            cout << x << " " << y << endl;
        }else{
            // no solution
        }
    }
    return 0;
}
```

5.10 Factorize

```
#include <bits/stdc++.h>
#define pb push_back
#define show(x) cout << #x << " = " << x << endl;
using namespace std;
const int MAXN = 1000000;
bool sieve[MAXN + 5];
typedef long long ll;
vector <ll> pri; //primes

void build_sieve(){
    memset(sieve, false, sizeof(sieve));
    sieve[0] = sieve[1] = true;
    for (ll i = 2LL; i * i <= MAXN; i++){
        if (!sieve[i]){
            for (ll j = i * i; j <= MAXN; j += i){
                sieve[j] = true;
            }
        }
    }
    for (ll i = 2; i <= MAXN; ++i){
        if (!sieve[i]) pri.pb(i);
    }
}

//before call this call build_sieve
vector <ll> fact(long long a){
    vector <ll> ans;
    ll b = a;
    for (int i = 0; 1LL * pri[i] * pri[i] <= a; ++i){
        int p = pri[i];
        while (b % p == 0){
            ans.push_back(p);
            b /= p;
        }
    }
    if (b != 1) ans.push_back(b);
    return ans;
}

int main(){
    build_sieve();
    ll num_to_fact= 128234234LL;
    vector < ll > vll = fact(num_to_fact);
    for (int x=0; x< vll.size(); x++){
        cout << vll[x] << " ";
    }
    cout << endl;
}
```

5.11 FastPow

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
inline ll add ( ll x, ll y){
    return (x%MOD + y%MOD)%MOD;
}
inline ll mul( ll x , ll y){
    return (x%MOD*1LL*y%MOD)%MOD;
}

inline ll fpow( ll x, ll p){ // (x^p)%MOD
    ll res=1LL;
    while( p ){
```

```
        if( p & 1){
            res = mul(res,x);
        }
        p >>= 1LL;
        x = mul(x,x);
    }
    return res;
}
```

5.12 GcdLcm

```
#include<cstdio>
using namespace std;
typedef long long ll;
ll mod( ll a, ll b){
    return (b + (a %b )) %b;
}
ll gcd ( ll a, ll b){
    if (b == 0 ) return a;
    return gcd( b, mod( a , b) );
}
ll lcm(ll n1, ll n2){
    return (n1 *1LL* n2) / gcd(n1,n2);
}

int main(){
    ll n1=2366, n2=273;
    printf("gcd(%ld, %ld) = %ld\n",
           n1, n2, gcd(n1,n2));
    return 0;
}
```

5.13 IsFibo

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
bool isPerfectSquare(long long x){
    ll s = sqrt(x);
    return (s*1LL*s == x);
}
bool isFibonacci(int n){
    // n is Fibinacci if one of 5*n*n + 4 or 5*n*n - 4 or both
    // is a perferct square, this is deduced of the discriminant
    //of binnets formule
    return isPerfectSquare(5*n*1LL*n + 4) || isPerfectSquare(5*1LL*n
        *n - 4);
}

// A utility function to test above functions
int main() {
    for (int i = 1; i <= 10; i++)
        isFibonacci(i)? cout << i << " is a Fibonacci Number \n":
            cout << i << " is a not Fibonacci Number \n"
                ;
    return 0;
}
```

5.14 IsPrime

```
import java.math.BigInteger;
import java.util.Scanner;
public class prime {
    public static void main(String[] args) {
```

```

BigInteger a = new BigInteger("1299827");
//User miller rabin & Lucas Lehmer
boolean res = a.isProbablePrime(10);
System.out.println(res? "It's prime":"It's not prime");
}
}

```

5.15 knapsack

```

#include<bits/stdc++.h>
#define MAX (int) 1e3
using namespace std;
int v[5] = {60, 100, 120, 30, 5};
int w[5] = {10, 20, 30, 30, 5};

int memo[MAX][MAX];

int knapsack( int n , int W){
    if( n == 0 || W == 0 ) return 0;
    int &ans = memo[n][W];
    if( ans != -1) return ans;
    if( w[n] > W ) { //not include too heavy
        ans = knapsack(n-1, W);
    }else{
        //Include
        int a1 = v[n]+ knapsack( n-1, W-w[n] );
        //Not include
        int a2 = knapsack( n -1, W);
        ans = max(a1, a2);
    }
    return ans;
}

int main() {
    for( int i = 0; i < MAX; i++)
        for( int j = 0; j < MAX; j++)
            memo[i][j] = -1;

    cout << knapsack ( 5, 50) << endl;
    return 0;
}

```

5.16 MatrixFibo

```

#include <bits/stdc++.h>
using namespace std;

const int MAX = 1000;
int f[MAX] = {0};
// Returns n'th fibonacci number using table f[]
int fib(int n){
    // Base cases
    if (n == 0) return 0;
    if (n == 1 || n == 2) return (f[n] = 1);
    // If fib(n) is already computed
    if (f[n]) return f[n];
    int k = (n & 1)? (n+1)/2 : n/2;
    // Applying above formula [Note value n&1 is 1
    // if n is odd, else 0.
    f[n] = (n & 1)? (fib(k)*fib(k) + fib(k-1)*fib(k-1))
        : (2*fib(k-1) + fib(k))*fib(k);

    return f[n];
}

```

```

}

/* Driver program to test above function */
int main(){
    int n = 9;
    printf("%d ", fib(n));
    return 0;
}

```

5.17 MillerTest

```

#include <bits/stdc++.h>
using namespace std;
typedef unsigned long long ll;
ll power(ll x, ll y, ll p){
    ll res = 1;
    x = x % p;
    while (y > 0){
        if (y & 1) res = (res*1LL*x) % p;
        y = y >> 1;
        x = (x * x) % p;
    }
    return res;
}

bool millerTest(ll d, ll n){
    ll a = 2 + rand() % (n - 4);
    ll x = (1LL)power(a, d, n);
    if (x == 1 || x == n-1)
        return true;
    while (d != n-1){
        x = (x *1LL* x) % n;
        d *= 2;
        if (x == 1) return false;
        if (x == n-1) return true;
    }
    return false;
}

bool isPrime(ll n, ll k){
    if (n <= 1 || n == 4) return false;
    if (n <= 3) return true;
    ll d = n - 1;
    while (d % 2 == 0) d /= 2;
    // Iterate given nber of 'k' times
    for (ll i = 0; i < k; i++)
        if (millerTest(d, n) == false)
            return false;
    return true;
}

int main(){
    ll k = 4; // Number of iterations
    ll n = 982451653;
    cout << (isPrime(n, k)? "True": "False") << endl;
    return 0;
}

```

5.18 NaiveFind

```

#include <bits/stdc++.h>
using namespace std;
int main(){
    string needle = "CD", haystack = "MANICD";
    if(haystack.find(needle) != string::npos) cout << "Gotcha!!!";
    else cout << "Not Gotcha";
    cout << endl;
}

```

```
    return 0;
}
```

5.19 PollarRho

```
#include <bits/stdc++.h>
using namespace std;

typedef long long ll;
ll num;

int modular_pow(ll base, int exponent, ll modulus){
    ll result = 1;
    while (exponent > 0){
        if (exponent & 1)
            result = (result * base) % modulus;
        exponent = exponent >> 1;
        base = (base * base) % modulus;
    }
    return result;
}
//take care if its' prime infinite loop
ll PollardRho(ll n){
    srand (time(NULL));
    if (n==1) return n;
    if (n % 2 == 0) return 2;
    ll x = (rand()%(n-2))+2;
    ll y = x;
    ll c = (rand()%(n-1))+1;
    ll d = 1;
    cout << n << endl;
    while (d==1){
        cout << d<<endl;
        x = (modular_pow(x, 2, n) + c + n)%n;
        y = (modular_pow(y, 2, n) + c + n)%n;
        y = (modular_pow(y, 2, n) + c + n)%n;
        d = __gcd(abs(x-y), n);
        if (d==n) return PollardRho(n);
    }
    return d;
}

int main(){
    num = 982451653;
    printf("One of the divisors for %lld is %lld.", num,
        PollardRho(num));
    return 0;
}
```

5.20 PollarRho

```
import random as r
def gcd( a, b):
    if(b == 0): return a;
    return gcd(b, a % b);
def pollardRho(N):
    if N%2==0: return 2
    x = r.randint(1, N-1)
    y = x
    c = r.randint(1, N-1)
    g = 1
    while g==1:
        x = ((x*x)%N+c)%N
        y = ((y*y)%N+c)%N
        y = ((y*y)%N+c)%N
```

```
        g = gcd(abs(x-y),N)
    return g
if(__name__=="__main__"):
    print(pollardRho(10967535067))
    print(pollardRho(113))
```

5.21 PrimalityTest

```
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
bool isPrime(ll n){
    if (n < 2) return false;
    if (n < 4) return true;
    if (n % 2 == 0 || n % 3 == 0) return false;
    if (n < 25) return true;
    for(int i = 5; i*i <= n; i += 6){
        if(n % i == 0 || n % (i + 2) == 0)
            return false;
    }
    return true;
}

int main(){
    cout << isPrime(23234) << endl;
    cout << isPrime(2) << endl;
    cout << isPrime(7454) << endl;
    cout << isPrime(976) << endl;
    cout << isPrime(1973) << endl;
    return 0;
}
```

5.22 RotateMatrix

```
#include <bits/stdc++.h>
using namespace std;
#define R 4
#define C 4
int arr[R][C];

void reverseColumns(){
    for (int i=0; i<C; i++)
        for (int j=0, k=C-1; j<k; j++,k--)
            swap(arr[j][i], arr[k][i]);
}

void transpose() {
    for (int i=0; i<R; i++)
        for (int j=i; j<C; j++)
            swap(arr[i][j], arr[j][i]);
}

/* anticlockwise rotate matrix by 90 degree*/
void rotate90(){
    transpose();
    reverseColumns();
}

int main() {
    int aux [R][C]=
    { {1, 2, 3, 4},
      {5, 6, 7, 8},
      {9, 10, 11, 12},
      {13, 14, 15, 16}
    };
    rotate90();
```

```
    return 0;
}
```

5.23 Sieve

```
#include <bits/stdc++.h>
#define tam 1000
using namespace std;
typedef long long ll;
typedef vector< bool > vbool;
void show (vbool primes){
    ll cap = primes.size();
    for(ll i = 0; i < cap; i++){
        cout << i << " : " << primes[i] << endl;
    }
}
vbool sieve(ll n){
    vbool sieve (tam);
    for (ll i = 0; i < tam; i++)
        sieve[i] = true;
    sieve [0] = sieve[1] = false;
    ll root = sqrt(n);
    for (ll i = 2; i < root; i++){ //find primes
        if(sieve[i]){
            //removes all the multiples
            //of the current prime
            for (ll k = i*1LL*i; k<= n; k+=i){
                sieve[k] = false;
            }
        }
    }
    return sieve;
}
int main(){
    vbool primes = sieve(1000);
    show(primes);;
    primes.clear();
    return 0;
}
```

5.24 Sum

```
/*
    Summatories
*/
int main(){
    sum(i) from 1 to n = n(n+1)/2
    sum(i^2) from 1 to n = n(n+1)(2n+1)/6
    sum(i^3) from 1 to n = (n^2(n+1)^2)/4

    //Geometric serie
    a * sum(r^k) from 0 to n = a * (1-r ^ (n+1)) / (1 -r)
    // ar + ar^2 + ar^3 ...
}
```

5.25 toBin

```
#include <bits/stdc++.h>
using namespace std;
void toBin(int x){
    for (int i =31; i>=0; --i)
```

```
        cout << ((x&(1LL<<i))!=0);
    }
    int main (){
        toBin(10);
        return 0;
    }
```

6 other

6.1 MergeSortPY

```
def merge_sort(arr):
    if (len(arr)>1):
        mid = len(arr) // 2
        lefthalf, righthalf = arr[:mid] , arr[mid:]
        merge_sort(lefthalf)
        merge_sort(righthalf)

        merge(lefthalf, righthalf, arr)

def merge(lh, rh, arr):
    il = 0
    ir = 0
    k = 0
    while il < len(lh) and ir < len(rh):
        if (lh[il] < rh[ir]):
            arr[k] = lh[il]
            il = il+1
        else:
            arr[k] = rh[ir]
            ir = ir+1
        k = k+1

    while il < len (lh):
        arr[k]= lh[il]
        il = il +1
        k = k+1

    while ir < len(rh):
        arr[k] = rh[ir]
        ir = ir +1
        k = k+1

def main():
    array = [-10, 37, 98 , 0 ,12, 192, 5]
    print("Original Array")
    print(array)
    merge_sort(array)

    print("Sorted Array")
    print(array)
    main()
```

6.2 Partitions

```
#include<iostream>
using namespace std;
/*
    Generate all unique
    partitions of a given integer
*/
void partitions(int n){
```

```

int p[n];
int k = 0;
p[k] = n;

while (true){
    for( int i =0; i <=k ; i++) cout <<p[i] << " ";
    cout <<endl;
    int rem_val = 0;
    while (k >= 0 && p[k] == 1){
        rem_val += p[k];
        k--;
    }
    if (k < 0) return;
    p[k]--;
    rem_val++;
    // If rem_val is more, then the sorted order is violated.
    // Divide
    // rem_val in different values of size p[k] and copy these
    // values at
    // different positions after p[k]
    while (rem_val > p[k]){
        p[k+1] = p[k];
        rem_val = rem_val - p[k];
        k++;
    }
    // Copy rem_val to next position and increment position
    p[k+1] = rem_val;
    k++;
}
}

int main(){
    cout << "All Unique Partitions of 7 \n";
    partitions(7);
    return 0;
}

```

6.3 TemplateC

```

#include <bits/stdc++.h>
using namespace std;

// INT_MAX -> limits.h
typedef long long ll;
typedef long double ld;
typedef vector < int > vi;
typedef vector < vi > vii;
struct point {int x, y;};

#define show(x) cout << #x << " = " << x << endl;
#define isOdd(x) (x & 0x01)
#define mod(a,b) (b + (a % b)) % b

const double PI = acos(-1);
const ld INF = 1e18;
const double EPS = 1e-15;

void input(){
    /*
    scanf("%ld",&value); //long y long int
    scanf("%c",&value); //char
    scanf("%f",&value); //float
    scanf("%lf",&value); //double
    scanf("%s",&value); //char*
    scanf("%lld",&value); //long long int
    scanf("%x",&value); //int hexadecimal
    scanf("%o",&value); //int octal
    */
}

```

```

}

void tricks(){
    int a=21,b=16,c=8;
    //if the numbers are long and long long end with and l or two l
    /*ie
    int
    __builtin_popcount
    long
    __builtin_popcountl
    long long
    __builtin_popcountll
    */
    //log2 floor
    show(__lg(21));
    show(__lg(16));
    show(__lg(8));
    cout << endl;
    //count the number of ones
    show(__builtin_popcount(16));
    show(__builtin_popcount(15));
    show(__builtin_popcount(0));
    cout << endl;

    //count the trailing zeros zer
    show(__builtin_ctz(16));
    show(__builtin_ctz(5));
    cout << endl;

    //count the leading zeros
    show(__builtin_clz(32));
    show(__builtin_clz(1024));
    cout << endl;
    //Returns one plus the index of the least significant
    //1-bit of x, or if x is zero, returns zero.
    show(__builtin_ffs(5));
    cout << endl;
    //Is a number x power of 2?
    show(((a & (a-1))==0));
    show(((b & (b-1))==0));
    cout << endl;

    //turn on the first n bits of a mask
    show(((1LL<<10)-1));
}

//Main
int main(){
    ios::sync_with_stdio(false);
    cin.tie(0);

    tricks();
    #ifdef LOCAL
        freopen("in.txt", "r", stdin);
        freopen("out.txt", "w", stdout);
    #endif
}

```

6.4 TemplateP

```

from sys import stdin
lines = stdin.read().splitlines()
for line in lines:
    a, b = [int(y) for y in line.split()]

```

6.5 UpperLowerBound

```
#include <bits/stdc++.h>
using namespace std;
int main () {
    int myints[] = {10,20,30,30,20,10,10,20};
    vector<int> v(myints,myints+8);           // 10 20 30 30 20 10
    sort (v.begin(), v.end());                // 10 10 10 20 20 20
    vector<int>::iterator low,up;
    low=lower_bound (v.begin(), v.end(), 20); //
    up= upper_bound (v.begin(), v.end(), 20); //
    cout << "lower_bound at position " << (low- v.begin()) << '\n';
    cout << "upper_bound at position " << (up - v.begin()) << '\n';
    return 0;
}
```

6.6 XIncludes

```
#include <vector>          vector<
#include <queue>           queue< priority_queue<
#include <set>             set< multiset<
#include <map>             map< multimap<
#include <bitset>         bitset<
#include <list>           list<
#include <deque>          deque<
#include <stack>          stack<
#include <complex>        complex<
#include <hash_map.h>     hash_map<
#include <hash_set.h>     hash_set<
#include <string>         string
#include <algorithm>      sort( stable_sort( make_heap( push_heap(
    pop_heap(
        lower_bound( upper_bound( equal_range(
            binary_search(
find( find_first_of( count( min( max( swap(
    fill( copy(
next_permutation( prev_permutation(
remove( replace( reverse( rotate(
    random_shuffle(
min_element( max_element( nth_element(
mismatch(
set_difference( set_intersection( set_union(
set_symmetric_difference( merge( unique(
    adjacent_find(
lexicographical_compare(
    lexicographical_compare_3way(
equal( includes(
accumulate( partial_sum( adjacent_difference

#include <numeric>
(
#include <iostream>       cin cout cerr istream ostream
#include <fstream>       ifstream ofstream ifstream( ofstream(
#include <sstream>       istringstream ostringstream
#include <cassert>       assert(
#include <cmath>         sin( cos( tan( asin( acos( atan( atan2( sinh
    ( cosh( tanh(
    sqrt( hypot( abs( exp( pow( ceil( floor(
        fmod( log( log10(
    fabs( M_PI
printf( scanf( fprintf( fscanf( sprintf(
sscanf(
```

```
getc( fgetc( putc( fputc( getchar( putchar(
    ungetc(
FILE stdin stdout stderr feof( fclose(
    fflush(
#include <cstdlib>       rand( srand(
#include <cstring>       memcpy( memmove( memchr( memset(
    strcpy( strncpy( strcat( strncat( strcmp(
    strncmp(
    strchr( strchr( strstr( strtok( strlen(
#include <ctime>       time( clock( CLOCKS_PER_SEC
```

6.7 YGenerator

```
#include <bits/stdc++.h>
using namespace std;
int main(){
    #ifdef LOCAL
        freopen("new.c", "w", stdout);
    #endif
    srand (time(NULL));

    int numRandom = 1000;
    cout << numRandom << endl;
    for( int i=1 ; i<=numRandom ; i++)
        int cant= rand() % 100 +2;
    return 0;
}
```

7 strings

7.1 Kmp

```
#include<bits/stdc++.h>
#define debug(x) cout <<#x << " = " << x << endl
#define rep(i, a, b) for( __typeof(a) i = a; i < b ; i++)

using namespace std;

int* compute(const string &t) {
    int m = t.size();
    int *p = new int[m];
    p[0]= 0;
    rep( i , 1 , m){
        p[i] = p[ i - 1 ];
        while( p[i] > 0 && t[i] != t[ p[i] ] ){
            p[i] = p[ p[i] - 1 ];
        }
        if( t[i] == t[ p[i] ] ) p[i]++;
    }
    return p;
}

int match( const string &ne, const string &ha ){
    debug( ne ); debug( ha );
    int m = ne.size(), n = ha.size();
    int *p = compute( ne );

    int s = 0;
    rep( i, 0, n){
        while( s > 0 && ha[ i ] != ne[ s ] )
            s = p[ s - 1 ];
    }
}
```



```

    if( ha[i] == ne[s] ) s++;
    if( s == m) return i - m + 1;
}
delete[] p;
return -1;
}

int main(){
#ifdef LOCAL
    freopen("in", "r" , stdin);
#endif

    string needle = "abcaby";
    string haystack = "abcabcabyid";

    cout << match ( needle , haystack ) <<endl;

    return 0;
}

```

7.2 LIS

```

#include<bits/stdc++.h>
using namespace std;
/*
 * Complexity Nlog(N)
 */
vector< int > getLis( const vector < int > A){
    int n = A.size();
    if( n == 0) return {};
    vector < int > tail ( n, 0);
    vector < int > lis ( n, 1);
    int ans = 1;
    tail[0] = A[0];
    for( int i = 1; i < n ; i++){
        if( A[i] < tail[0] ) {
            tail[0] = A[i];
            lis[i] = 1;
        }else if( A[i] > tail[ ans - 1] ) {
            tail[ ans++ ] = A[i];
            lis[ i ] = ans;
        }else{
            int cp = upper_bound( tail.begin(),
                                tail.begin()+ans, A[i]) - tail.begin();

            tail[ cp ] = A[i];
            lis[ i ] = cp+1;
        }
    }
    return lis;
}

int main(){
    vector < int > A = { 1, 3, 32 ,2 ,78, 9,2};
    getLis( A );
    // 1 2 3 2 4 3 3
    return 0;
}

```

7.3 LRSubs

```

#include<bits/stdc++.h>
using namespace std;

```

```

// Returns the longest repeating non-overlapping substring
string longestRepeatedSubstring(string str){
    int n = str.length();
    int LCSRe[n+1][n+1];
    // Setting all to 0
    memset(LCSRe, 0, sizeof(LCSRe));
    string res; // To store result
    int res_length = 0; // To store length of result

    // building table in bottom-up manner
    int i, index = 0;
    for (i=1; i<=n; i++){
        for (int j=i+1; j<=n; j++){
            // (j-i) > LCSRe[i-1][j-1] to remove
            if (str[i-1] == str[j-1] &&
                LCSRe[i-1][j-1] < (j - i)){
                LCSRe[i][j] = LCSRe[i-1][j-1] + 1;
                if (LCSRe[i][j] > res_length){
                    res_length = LCSRe[i][j];
                    index = max(i, index);
                }
            }
            else
                LCSRe[i][j] = 0;
        }
    }
    if (res_length > 0){
        cout << (index - res_length + 1)<<endl;
        for (i = index - res_length + 1; i <= index; i++)
            res.push_back(str[i-1]);
    }
    return res;
}

// Driver program to test the above function
int main(){
    string str = "hello,p23puoeouhello,oues";
    cout << longestRepeatedSubstring(str); //hello,
    return 0;
}

```

7.4 StringUtil

```

#include <bits/stdc++.h>
#define pb push_back
using namespace std;
typedef vector <string> vs;
int toNum(string a){
    stringstream toNum(a);
    int num;
    toNum >> num;
    return num;
}

string toString(double d){
    stringstream ss;
    ss << fixed << setprecision(10) << d;
    string num = ss.str();
    return num;
}

void toLowers(string &data){
    transform(data.begin(), data.end(), data.begin(), ::tolower);
}

void replace(string &a, string &from, string &to){
    int pos=0;
    while((pos = a.find(from,pos)) != string::npos){
        a.replace(pos, to.size(), to);
    }
}

```

```

        pos+=to.size();
    }
}
vs split(string line, char d){
    vector < string > elements;
    stringstream ss(line);
    string item;
    while(getline(ss, item, d))    elements.pb(item);
    return elements;
}

int main(){
    vs d1 = split("1990/10/5", '/');
    for (string s: d1){
        cout << toNum(s) << endl;
    }

    char a = 'a';
    cout << (isalnum(a)?"true":"false") << endl;
    cout << (isalpha(a)?"true":"false") << endl;
    cout << (isblank(a)?"true":"false") << endl;
    cout << (isdigit(a)?"true":"false") << endl;
    cout << (islower(a)?"true":"false") << endl;
    cout << (ispunct(a)?"true":"false") << endl;
    cout << (isupper(a)?"true":"false") << endl;
    cout << (isxdigit(a)?"true":"false") << endl;
    cout << (char)tolower(a) << endl;
    cout << (char)toupper(a) << endl;
    string hay = "hellohowareyouhow", ned = "whatare", from = "how";
    replace(hay, from, ned);
    cout << hay << endl;
    return 0;
}

```

7.5 SubstrK

```

#include <bits/stdc++.h>
#define debug(x) cout << #x << " = " << x << endl
#define pb push_back
/*
    Algorithm to find all possible
    substrings of size k given a set of values
*/
using namespace std;
set<string> subs;
//print all possible substrings of size k
void substringSizek(char set[], string prefix, int n, int k){
    //Base case
    if( 0 == k){
        cout << prefix << endl;
        subs.insert(prefix);
        return;
    }
    for( int i=0; i < n ; ++i){
        string newprefix = prefix + set[i];
        //k is decreased because we add a new character
        substringSizek(set, newprefix, n, k-1);
    }
}

```

```

    }
}
void init(char set[], int k){
    int n = strlen(set);
    substringSizek(set, "", n, k);
}
int main(){
    char set[3] ={'a', 'b'};
    int k = 3;
    init(set, k);
}

```

7.6 Zalgorithm

```

#include <bits/stdc++.h>
#define pb push_back
using namespace std;
typedef vector<int> vi;

/*
    * Complexity: O(N + M)
    */
vi z_val(string s){
    int n = s.size(), L = 0, R = 0;
    vi z(n);
    for( int i = 1; i < n ; i++){
        if( i > R){ // not prefix-substr
            L = R = i;
            while( R < n && s[R-L] == s[R]) R++;
            z[i] = R - L; R--;
        }else {
            int k = i - L;
            //there is no longer prefix start at s[i]
            if( z[k] < R-i+1){
                z[i] = z[k];
            }else{
                L = i;
                while( R < n && s[R-L] == s[R]) R++;
                z[i] = R-L; R--;
            }
        }
    }
    return z;
}

int main() {
    string haystack = "abcbabca", needle = "abc";
    int n = haystack.size(), m = needle.size();
    vi z = z_val(needle + "#" + haystack);
    for( int i = 0; i < z.size(); i ++){
        cout << i << " " << z[i] << endl;
    }
    return 0;
}

```